WHO/EHE/92.2
ENGLISH ONLY
DISTR: GENERAL

WHO COMMISSION ON HEALTH AND ENVIRONMENT

REPORT OF THE PANEL ON FOOD AND AGRICULTURE

WORLD HEALTH ORGANIZATION

Geneva
1992

CONTENTS

PREFACE

The WHO Commission on Health and the Environment was charged with assessing the impacts of environmental change on human health, indicating where further research is needed, and with laying the foundation for the development of strategies to tackle the problems of health and the environment already being encountered, and those expected to arise in the future. Four technical Panels were established to assist the Commission, on Energy, Food and Agriculture, Industry, and Urbanization, respectively, these topics being recognized as major driving forces in development and as the principal causes of environmental change affecting health.

The Panel on Food and Agriculture (Annex I) met in June and December 1990 and, on the basis of working papers, made a comprehensive review of the environmental changes to be expected as a consequence of expanding and intensifying food, agricultural and fisheries production to meet the needs of the increasing world population. This review included the various beneficial and harmful effects on human health of present practices and developments in these sectors, anticipated future trends, and the measures needed to match food production to population growth, while reducing associated adverse effects on the environment and health to a minimum and securing an overall improvement of dietary quality.

The main conclusions and recommendations of the Panel arising from this review are presented in the Summary (Part I). The Summary is followed by sections, based on the individual working papers, that give a broad overview of the aspects of the subject considered by the Panel to be of principal importance in deciding and implementing national and international policies in the sectors concerned.

ACKNOWLEDGEMENTS

The Panel wishes to acknowledge the valuable assistance given by:

Dr J. Copplestone (formerly Chief, Pesticide Development and Safe Use, WHO, Geneva), Ivybridge, Devon, United Kingdom.

Professor C.E. Pray, Rutgers University, New Brunswick, New Jersey, USA.

Professor P. Rieder and Dr N. Gotsch, Swiss Federal Institute of Technology, Zürich, Switzerland.

Dr R.W. Stephany and Dr I.S. Notermans, National Institute of Public Health and Environmental Protection, Bilthoven, Netherlands.

Dr Swart and Dr H. van Keulen, Agricultural University, Centre of Agribiological Research, Wageningen, Netherlands.

This Report was prepared by Dr G.J. Stott, Consultant (formerly of WHO, Geneva), Saint Paul en Chablais, France, on the basis of material provided by Panel Members, external advisers and the WHO Secretariat.

1. SUMMARY

Introduction

Current and emerging food production and preservation capabilities provide the potential to produce an adequate global supply of safe, nutritious food. However, drastic changes in the agriculture, fisheries and food sectors will be required to prevent negative health and environmental effects in achieving an adequate food supply for the seven billion or more people that will inhabit the world in the year 2010. The management of the food, agriculture and fisheries sectors must be refocused to encompass sustainable production objectives and to ensure their application in a regionally sensitive manner, particularly in regions with limited land and water resources and burgeoning populations. Hunger and malnutrition continue largely because of poverty, political and distribution problems and lack of knowledge and capacity to use existing technology.

The interactions of environment, food, water and health are complex. The production of food affects health by way of nutritional status and by diseases related to agriculture, fishing and the contamination of food and water. Changes in food production and those in the environment resulting from them may influence human health directly, or indirectly when they affect the disposable income of members of the community.

Although both the environment and agriculture may directly affect health in the short run, increasing food demands on agriculture may produce cumulative and long-term environmental changes that may themselves endanger food supplies and human health. This review concentrates on the direct and specific effects on health, but often the indirect and non-specific consequences may be of comparable or greater importance and must not be forgotten.

In view of the trends in population growth, the demands likely to be placed upon the food and agriculture sectors in the future, and the associated potential for adverse environmental change such as deforestation, soil degradation and water pollution, there is an urgent need to address the problems identified in this report, especially those associated with the risk to human health, notably the spread of foodborne disease. If these problems are not addressed in an adequate and timely manner, serious environmental and associated health consequences will result.

Major forces affecting food and agriculture

A number of forces will exert a profound influence on food and agriculture over the coming years. The continuation of global trends in economics, trade and communications, and the adoption of common policies, will make the interdependence between countries increasingly important.

Rapid population growth continues in some regions of the world. As compared with the situation in 1990, by the year 2010 there will be an extra 1900 million people to be fed, a rise of 36% from 5300 to 7200 million people. This assumes substantial efforts by people to limit their rate of numerical increase. Ninety per cent of the entire projected growth over the next 20 years is expected to take place in the countries which are currently classified as developing nations. Progressive urbanization of society is taking place, including significant change in family structure and function. The urban population of the world will reach 3600 million, a rise of 62% from the 2200 million city dwellers in 1990. Moreover the urban population of developing countries will increase by 92% (from 1400 million to 2600 million) in the twenty years from 1990, a four-fold increase since 1970. By the year 2000, 24 cities will each have a population exceeding 10 million and 16 of these will be in developing countries. Even if family planning receives the urgent attention that it desperately requires from all rapidly growing populations, population growth and urbanization will continue to dominate the scene for the next two decades. While urbanization will be difficult to restrain, the pattern of urbanization may be more open to planning.

A 36% increase in food, other agricultural products and potable water will be required over the next twenty years simply to match the rise in population; the need for half a billion people to be properly fed instead of remaining undernourished, and the greater demand from populations with a rising income will all lead to a vast increase in total food production. An excessive demand for food of animal origin will continue to characterize people in the higher income groups, leading to increases in animal feed production.

The pressure on agriculture and food production, as both population and per capita demand increase, will lead to a greater burden on the environment. This burden will be unevenly generated and have uneven environmental effects. Globally, these will be adverse and will require concerted action. Although per capita demands may be greatest from the more affluent populations, these usually have more resources with which to avert harmful effects. Poor rural communities and rapidly increasing urban populations, however, have lower per capita demands but a large aggregate need for food and water. Such peoples are more immediately vulnerable to the effects of any further environmental deterioration, which may result in increased poverty, poor health, lower environmental health standards, and in certain circumstances, mass migration of people.

This increased demand will fall on resources of land and water which are finite, where the most productive areas have already been used, and where the cost of bringing marginal land into production, and of using less readily available water, will be high. Much of this marginal land may have only temporary fertility unless specific measures are taken to maintain it, while the productivity of natural fisheries is also sharply limited. The area of arable land will decrease due to soil erosion from over-grazing; laterization of clear-felled areas; soil salinization and other types of land degradation; and the expansion of urban, industrial and other developments.

Rapid population growth may lead to fragmentation of land ownership, inability to maintain a suitable mixture of crops, unviable farm units, loss of food security, and the acceleration of shifting cultivation or, in the absence of new lands or fertilizers, over-cultivation. Such changes in land tenure and the means of food production, and the growing number of landless families, will further marginalize the very poor.

Water availability and quality, already totally inadequate in much of the world, will remain major problems for rural areas of developing countries and also for many urban populations, who may face the additional problem of high utilization charges. Needs for water will increase greatly, and for several large cities the meeting of water demands will become increasingly costly as supplies will have to be brought from far away. Reuse of water implies more stringent standards for treatment. The increasing production of wastewater and sewage will require more extensive treatment facilities, as well as large outlays of capital.

The continuing long-term need for industrial development to produce goods, services and employment will lead to more intensive food production, which will itself become more industrialized. Consequently, and especially because of urbanization, the demand for, and the resources employed in, packaging, processing, storage and distribution of food, will increase in volume and importance.

The public is becoming much more aware of the need to produce, protect and market food in ways which minimize adverse change in our environment and is more demanding in this respect. The emergence of revolutionary scientific tools (e.g., biotechnological advances) offers the possibility of significantly increasing food production, reducing waste and enhancing safety. Regrettably, however, the great potential benefit to humanity may be limited by the widening gap between scientific knowledge and public understanding, due in part to misinformation but also to sensational reporting by the media.

Health and environmental problem areas

Analysis of the present situation, current trends, and projections for the future permit the identification of certain problem areas that need to be addressed if a sizeable but sustainable expansion of food and agricultural production is to be assured and associated adverse effects averted.

Food production and supplies

The principal challenge is to meet the increasing demands for food, other agricultural products and water in ways that foster long-term improvements in health, and which are also sustainable, economical and competitive.

Despite the fact that globally there is at present sufficient food for all, great difficulties have to be overcome to ensure the availability and equitable distribution of safe, nutritious and affordable food supplies to meet health needs in many parts of the world, and notably in areas of rapid population growth.

Policies and planning

Some current international and national policies cause distortions in world trade and patterns of production, have harmful effects on agriculture, fisheries and food production and adverse consequences for the environment and health, and may contribute to poverty and malnutrition.

There is often a failure to take the possible health consequences fully into account in the design and implementation of agricultural and fisheries policies and programmes. An example is the production of tobacco which has very serious and negative impacts on human health and on scarce land and fuelwood resources. Moreover, the lack of an integrated approach to development of the agriculture and forestry sectors results in failure to recognize the important relationship of both sectors to the protection of wildlife habitats, biological diversity and genetic resources.

Increasing difficulties are being faced by regulatory agencies in keeping up with rapid advances in scientific capability and in responding to changing political perceptions and their societal implications.

Food and water safety

Diminishing water resources and deteriorating water quality, associated with contamination by pathogens, human and animal wastes, and agricultural and industrial chemicals and the breeding of vectors of disease, are also consequent risks to health through the biological and chemical contamination of food and water supplies.

Occupational hazards

Farm, fisheries and manufacturing workers continue to be exposed to occupational diseases and unsafe working conditions (dust, chemicals, heavy machinery, exhausts, etc.).

Natural resources

The scarcity of arable land and its over-cultivation are causing an increase in soil degradation and erosion, in some areas leading to desertification.

Pre-harvest and post-harvest losses are massive problems especially in developing countries, and food wastage is likely to continue at a substantial level, especially in more affluent societies.

There is an increasing demand for water and energy in agricultural production, food processing, distribution and marketing.

Health consequences

If timely and appropriate action is not taken to mitigate the environmental impacts of agriculture, fisheries, food production and water use, then the following situations will prevail.

- As the urban population increases, the dependence on an efficient food distribution system will become greater. This may increase the prevalence of household food insecurity, associated malnutrition and health risks among the growing masses of urban poor.

- Microbial, viral and parasitic diseases from contaminated food and water will continue to be serious health problems. New agents of public health importance will continue to emerge. The diarrhoeal diseases related to food and water, causing high infant mortality and universal morbidity, will increase.

- Vector-borne diseases from irrigation, other water resource developments, and uncontrolled wastewater will increase substantially. Malaria, schistosomiasis, filariasis and arbovirus fevers will continue to be major problems.

- The problems outlined above will be reflected in static or rising levels of infant and young child malnutrition and mortality, as well as morbidity at all ages, but predominantly among the poor, the very young, the aged and the sick.

- Chronic diseases linked to inappropriate life-styles, smoking and diet (for example, obesity, diabetes or coronary heart disease), which are characteristic of the more affluent countries, are now emerging and becoming significant problems also in developing countries. The increasing urbanization will accelerate this trend.

- As the intensity of food production increases, the risk of occupational diseases and accidents among those working in this and related sectors will increase substantially unless sufficient efforts for safety and prevention are made.

Principal objectives

Improving human health

With the overall purpose of improving human health and well-being over the next two decades, through action on environmental factors linked to socioeconomic development, the following principal objectives need to be pursued by the food, agriculture and fisheries sectors throughout the world.

Meeting national nutrient goals

These sectors should produce a wide variety of good quality, safe and nutritious food that meets national population nutrient goals, and should provide food and other agricultural products at reasonable cost to consumers, and adequate returns to producers, processors and marketers. They should be energy-efficient, less dependent on non-renewable energy resources, and should neither create nor aggravate environmental problems.

Increasing agricultural production

The agriculture sector should seek to obtain a significant increase in arable land by appropriate restoration and enhancement practices, including planned integration with forest and water management, so as to secure a well-managed soil base to ensure long-term productivity. Both food and agriculture sectors should contribute actively to the improvement of surface and ground water quality by proper management, on a sustainable basis, of the water available to them. Special emphasis is required on sustainable fisheries and aquaculture production to maximize returns and benefits from this important sector.

Liberalizing trade and increasing aid

A more innovative and generous approach should be taken to trade and aid which recognizes the impact of income disparities on the ability of governments and people to alleviate or control their priority environmental health problems.

Improving public understanding of the issues at stake

An improved and scientifically correct public appreciation is needed of the risks and the benefits associated with agricultural production methods, food preservation and distribution, and food consumption (e.g., diets), as compared with other risks in everyday life.

Promoting health and protecting the environment

As in many other fields of human endeavour, the intelligent and imaginative application of what is already known could solve the great majority of the current and anticipated problems related to health and the environment that are or will be associated with the food, agriculture and fisheries sectors - given the necessary national and international political will and economic and scientific support.

To avert the potentially serious and harmful consequences for health and the environment of the great increases in food and agricultural production that will occur over the next two decades, effective national and international action is required on three main fronts - the adoption of general policies, their implementation, and research.

General policies

While current efforts to make the agriculture, fisheries and food sectors more environmentally sustainable are encouraging, there is a need for a more integrated approach to development to promote and protect human health and avoid undesirable environmental change from expanded food production, processing and marketing.

Explicit consideration should be given to the effects on health of policies and programmes for population, agriculture, food, nutrition, fisheries, water and the environment, as well as to the coordination and inter-linking of these policies to ensure good health and avoid harmful environmental effects.

Priority should be given to environmental health problems related to sustainable agriculture, food and fisheries production in the following programme areas:

- In food safety, the priority problem is the elimination or reduction of contamination by foodborne pathogens (such as *Salmonella, Campylobacter, Listeria,* etc.). Chemicals in food are a lesser risk, but improved regulation and management of chemicals (e.g., integrated pest control) is required in agriculture and fisheries production, and food storage and preservation.

- A further priority is the need to increase food supply by raising production and at the same time reducing losses, using all available and appropriate technologies which assure sustainability.

- Governments should formulate and implement comprehensive and sustainable water policies that include domestic, irrigation and industrial water supplies and the management of surface water and wastewater.

- Health promotion and disease control considerations should be incorporated into the planning, construction, management and operation of water resource and land developments for agriculture and aquaculture.

Each country should formulate and implement policies and programmes to ensure that all households have access to an adequate and affordable diet which will alleviate energy and nutrient deficiencies while promoting long-term sustainability in food production. At the same time, excessive consumption of certain dietary components, such as fats, oils and sugars, which contribute to overweight and some chronic diseases, should be discouraged. Moreover, it must be stressed that any substantial increase in the production of grain-fed animals to match the increase in world population and demand would have serious environmental effects in many parts of the world.

Particular attention should be paid to the potential health and environmental effects of the high rates of population growth and low rates of growth in food and agricultural production forecast for many countries of the world, and notably in sub-Saharan Africa. Effective action is urgently needed in these countries to facilitate family planning and increase productivity in agriculture.

In view of the grave environmental impacts and health effects associated with the production, processing and consumption of tobacco, present efforts to reduce public demand for tobacco products and to identify and introduce suitable replacement crops need to be more vigorously pursued.

Research

Substantial resources are already employed in the development of new technologies to enhance the productivity of resources used in food and agricultural production, processing and distribution, and such research should continue. Increasing productivity in food and agriculture, often through biotechnological research, is however a means to an end rather than an end in itself. The choice of methods to obtain and exploit such gains should always take full account of their expected effect on the well-being of people and animals, their health and nutritional status.

An important but insufficiently recognized area for research is that of behaviour and motivation in relation to food and agriculture, and their effects on health, nutrition and the environment. Research is therefore needed on:

- how to guide the food and agriculture sectors, communities and households towards practices which promote good health without adverse environmental and agricultural effects;
- how governments can take effective action to improve health and nutrition and ensure safety and sustainability in food and agricultural production; and
- how to get new technologies with their benefits and risks better understood and accepted by the public and used to best effect.

Also falling under the heading of research is the systematic collection, analysis and monitoring of information on the health and environmental effects of:

- current trends related to food consumption and agricultural production; and
- modifications in these trends brought about by government policies, the application of new technology, and behavioural changes in the public.

Since both problems and opportunities vary according to cultural, regional, climatic, economic and other circumstances, it is important that research and development priorities be established in the light of local or national needs. Developing countries should be encouraged to concentrate on their own practical problems rather than to copy patterns of research of the industrialized countries. What is needed is a new and complementary approach to research to explore areas hitherto neglected and which should include:

- the review of relevant research findings from industrialized countries and their application through appropriate technologies to the needs and conditions of developing countries;

- the development of simple low-cost, yet effective, methods of protecting water quality, improving food storage and preservation, increasing agricultural yields, minimizing pollution, and reducing the prevalence of foodborne and water-borne disease; and

- the compilation and evaluation of traditional practices in these fields and, where suitable, their adaptation to present-day conditions.

International collaboration and aid

The international organizations and development banks, the various governmental agencies for international technical collaboration and aid, and nongovernmental organizations all have important roles to play: in improving health through action on the food and agriculture sectors and the environment; and in securing international consensus on the approaches needed and commitment to their implementation. In addition, general agreement and concerted action are required in:

- strengthening international collaboration and coordination concerning all environmental issues affecting health, food, and nutrition, and ensuring that the implications for health are taken fully into account in all development programmes and projects;

- improving the collection, analysis and dissemination of relevant information, among countries and within them; and

- enhancing collaboration among United Nations agencies and development banks in managing the future development of food and agriculture in relation to environment and health.

At national level, technical and financial assistance would be required by many countries in:

- formulating and implementing suitable national food and agricultural policies for the protection of health and the environment;

- promoting and coordinating relevant research on these topics, setting suitable priorities that respond to national needs, and strengthening their capability to undertake such research;

- incorporating "health and the environment" in the curricula of educational institutions;

- implementing international standards for food and in agriculture; and

- strengthening national capabilities to manage the health and environmental aspects of agriculture, fisheries and food development.

2. WILL THERE BE ENOUGH FOOD FOR ALL IN THE YEAR 2010 ?

In 1990, the estimated world population was 5300 million. Although in global terms there was sufficient food for all, over 1000 million or about one-fifth of all people were living in a state of absolute poverty with insufficient means to meet their daily needs. Moreover, almost every year many millions face hunger or starvation as a result of natural catastrophes, crop failures, and the effects of conflict and civil strife.

Globally, food grain production has been rising faster than population, and current and emerging food production and preservation capabilities provide the potential to produce an adequate supply of safe, nutritious food for all the peoples of the world, both now and up to the year 2010 at projected rates of population growth, and even beyond.

The potential of developing countries to increase their own food production through increases in yield, arable land and cropping intensity is considerable (see Fig. 2.1). But in many countries distribution is likely to remain a major problem and one that will have to be addressed as a priority.

Over the period 1961-63 to 1981-83, there was substantial progress in improving food supplies in developing countries (Table 2.1).

However, even during this period, which included the relatively prosperous 1970s, the improvement in Africa was much less than that obtained in other developing regions. For example, over the 12-year period 1972-74 to 1984-86, in sub-Saharan Africa (excluding South Africa) 27 countries showed an increase in dietary energy supplies but in 18 the situation deteriorated. By contrast, in the Americas (excluding Canada and the USA) dietary energy supplies improved in 30 countries and declined in only 8 countries (Table 2.2).

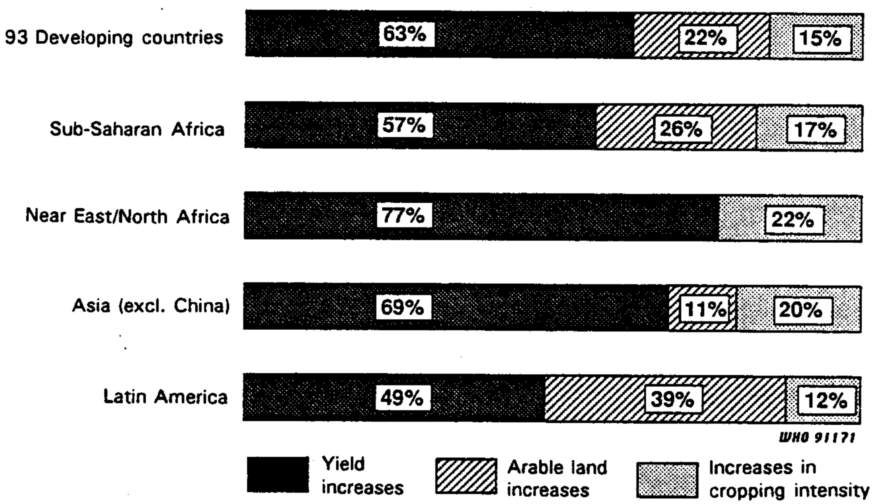

Fig. 2.1. Possibilities of increased food production: 1982/84-2000. From: Ref. 1.

Since then, the economic climate has changed - for the worse - and in planning for the future the possibility must be considered that, for some countries at least, the coming years may bring a deteriorating food situation, in spite of global sufficiency. In every country, different worlds live side by side, rich and poor, urban and rural, industrialized and agrarian, so that even where national food supplies are adequate large sections of the population may still not have sufficient food for their needs.

Over the next 20 years, food production will have to keep pace with the growth of the world population from 5300 million to a projected 7200 million, an increase of 36%, just to maintain the present situation. The great challenge for governments and the food, agriculture and fisheries sectors is to ensure food and nutrition security and sustainable growth in a way that does not place undue pressure on the environment, and leaves the world a place still fit to live in.

Table 2.1. Trends in dietary energy supplies (calories/person per day), by region and economic group[a]

Region	Period A 1961-63	Period B 1981-83	% increase A-B
Developed countries	3110	3390	9
Developing countries	1980	2400	21
Developing market economies	2060	2340	14
- Africa	2120	2230	5
- "Far East"[a]	1940	2190	13
- Latin America	2370	2620	11
- "Near East"[a]	2230	2900	30
Asian centrally planned economies	1830	2540	39
World	2340	2660	14

[a] As defined by FAO.

From: Ref. 2.

Table 2.2. Dietary energy supplies (calories/person per day) in selected developing countries

Region	Period 1972-74	Period 1982-4	Number of countries: change over 12 years	
			Decrease	Increase
Africa 45 sub-Saharan countries[a]	2102	2187	18	27
Americas 38 countries[b]	2383	2577	8	30

[a] Excluding South Africa
[b] Excluding Canada and the United States

From: Ref. 3.

For some parts of the world, solutions will lie in advanced technology; for others, in the application of what is known, through the development of technologies adapted to their situations. For still others, food self-sufficiency may not be a sustainable goal, and the only solution for such countries is to increase foreign currency earnings through industrial activity.

The environmental impacts that all these changes will undoubtedly create should not be allowed to cause deterioration in the health situation nor in environmental carrying capacity.

Wise national and international policies will be needed, which address priorities effectively. Despite extremely difficult economic circumstances, some sub-Saharan African countries have achieved significant reductions in infant and child mortality while others, economically better-off, have not done as well. Greater wealth, therefore, is not by itself sufficient to ensure better health. The point is important since for many countries financial stringency is unfortunately likely to continue.

References

1. Data supplied by FAO.

2. FAO, The fifth world food survey, Rome, Food and Agriculture Organization of the United Nations, 1987.

3. FAO, The state of food and agriculture 1989, Rome, Food and Agriculture Organization of the United Nations, 1989.

3. FACTORS INFLUENCING DEMAND FOR FOOD, AGRICULTURAL AND FISHERIES PRODUCTS

Although various policy options are available for increasing agricultural production and reducing losses to meet future needs for edible energy, nutrients, and agricultural products, the three key considerations are population growth, consumption patterns, and food losses. Continuation of high rates of population growth, rapid substitution of livestock products for vegetable products, and large food losses, will in the long run, place severe stress on the agricultural sector, with potential negative environmental effects. On the other hand, rapid reduction in the population growth rate, reduced losses, and maintenance of an overwhelmingly vegetarian diet, along with appropriate changes in agricultural production, including technological change and improved rural infrastructure, would make it possible to meet the needs for food and agricultural products without such stress for the foreseeable future. There is no foregone conclusion: humanity has a choice.

Population growth

Most of the change in the consumption of food and agricultural products is due to growth in population and incomes. Overall, the population growth rate during the 1980s was about 1.8%, down from 1.9% during the 1970s and 2.2% during the 1960s [1]. Most of the decrease in the rate of growth since the mid-1960s has originated in East Asia, Latin America, and Western Europe. The growth rate in South Asia has been virtually constant at 2.2% and sub-Saharan Africa has shown an increase from 2.6% to the current 3.2%. A projected decrease in the overall growth rate from 1.8 to 1.7% during the 1990s is due primarily to relatively large expected decreases in South Asia and smaller decreases in Latin America.

Thus, at constant *per capita* incomes, the demand for food and agricultural products is expected to increase at about 1.7% annually during the 1990s. The greater part of this increase will occur in the developing countries, with sub-Saharan Africa showing the largest percentage increase.

Patterns of consumption and demand

Agricultural production and associated resource utilization are determined primarily by the demand for food and other agricultural products. Therefore, expected future demand is an important consideration in efforts to predict future environmental effects of agriculture.

The most important factors which influence consumption and demand patterns of food and agricultural products are population growth, changes in incomes, income distribution, relative prices, and the rate of urbanization. These have contributed to significant changes in the past and will continue to do so in the foreseeable future. Changes in the opportunity cost of women's time, intra-household budget control, and tastes and preferences may also be important.

The change in the consumption of food and agricultural products during the last 20-30 years differs among regions. However the shift from foods of vegetable origin to animal products is widespread [2]. The rate of change is highest in Eastern Europe and the USSR. With about two-thirds of all energy coming from vegetable sources and one-third from foods of animal origin, the developed market economies appear to have reached a level where no further substitution between the two groups is desired. The developing countries as a whole are just entering the phase of rapid substitution and are still in the phase of relatively large increases in the consumption of both categories of food.

Regional averages cover large differences among countries. A very clear relationship emerges between *per capita* income levels and consumption patterns as well as changes in these patterns. Low-income developing countries rely heavily on cereals, roots and tubers, and the importance of these foods increased during the 1970s. Higher-income developing countries, on the other hand, obtain a smaller and decreasing proportion of their energy from these foods. The opposite change occurred for sugar and animal products - their relative importance has decreased for the poor and increased for the higher-income developing countries. Thus, an increasing discrepancy in the dietary patterns between low-income and high-income developing countries has been evident during the last 20 years [3].

Countries with low growth rates during the 1970s and 1980s tended to increase reliance on cereals while reducing the relative importance of animal products. High-growth countries, on the other hand, showed large increases in the consumption of animal products and sugar while reducing the relative importance of cereals and root crops.

Average figures for cereals cover large differences among the various cereal types. Thus, while the annual growth rate for cereals used for food in developing countries during the period 1961-83 was 3.3%, wheat consumption grew at an annual rate of 5.2%. Similarly, in developed countries, maize consumption for food grew at 2.2% annually as compared to an average growth rate of 0.5% for all cereals for food. Consumption of cereals by animals grew at very high rates, reaching 11.5% per year for maize in Asia [3]. Considerable changes also occurred within the animal products. Beef and pork each accounted for 30-40% of total meat consumption in both developed and developing countries. However, the relative importance of beef fell significantly in developing countries from the early 1960s to the mid-1970s while pork gained. The most significant development, though, was a rapid increase in the importance of poultry meat in all regions, with annual rates of increase close to 10% in North Africa and the Middle East, and close to 8% for developing countries as a whole.

Income growth

There is a strong relationship between incomes and the patterns of consumption of food and agricultural products. Income increases among the poor generally result in large increases in the demand for basic food staples such as root crops and cereals, and income increases among the better-off tend to be reflected in rapid increases in the demand for animal products.

The strong effect of income on meat consumption is reflected in very large differences in meat consumption, not only between developing and developed countries but also among developing countries at different income levels. Developing countries with annual *per capita* incomes above US$ 1250 consume almost ten times the quantities consumed in countries with incomes below US$ 250. Thus, the distribution of income growth will greatly influence future demand. Because of the effect of rising income on the consumption of animal products, a much greater demand for feed grains is likely to be the most important source of change in future demand patterns in developing countries. Although still at a low level in many such countries, large future increases in demand may be expected, particularly in higher-income developing countries and Eastern Europe. Thus, it is projected that feed will account for about one-fourth of all cereals consumed in the developing countries by year 2000, compared to 16% in 1980 [3]. This is likely to put a significant burden on the supply capacity in higher-income developing countries and Eastern Europe. If domestic supply is unable to keep up, rapid increases in import demand are likely to occur, as indeed has already happened in many of the high-income developing countries in the Middle East and elsewhere.

As the demand for livestock products expands, production will become intensified and more concentrated on specialized production units. In addition to their direct environmental effects, such intensification and specialization will increasingly be based on cereals and concentrates which compete for agricultural resources. The conversion of cereals and concentrates to animal products involves large losses of edible energy and leads to corresponding increases in resource requirements and associated environmental risks.

Urbanization

The population growth rate in urban areas is very high in virtually all developing countries. It is expected that the proportion of the population of the developing countries living in urban areas will increase from 29% in 1980 to 45% by the years 2000 and 2010. For the world as a whole, the expected increase is from 39% in 1980 to 51% by the year 2000 and 52% by 2010.

Such rapid urbanization will place considerable stress on agricultural production and distribution. It also implies changing consumption patterns away from root crops, maize, millet, and sorghum towards wheat, rice and other foods requiring less preparation time, as well as animal products.

Although this substitution in consumption patterns is taking place as a result of urbanization in virtually all developing countries, recent developments in many African countries are illustrative. In these countries, rice and wheat consumption increases at a rapid rate while the consumption of coarse grains, roots and tubers - the traditional staples in Africa - decreases. In less than 20 years, the importance of rice in the diet increased from 6 to 9% while sorghum dropped from 16 to 12%. Annual growth rates in West Africa were about minus 2% for sorghum and millet, close to zero for maize, and 5-8% for rice and wheat, respectively.

Food imports and domestic production

Unfortunately, the natural environments in most African countries are not favourable for the production of wheat and rice and virtually all the wheat and a large share of the increases in rice consumption must be imported. Although efforts to expand rice production through irrigation and other technological change could accelerate the growth rate in rice production, the costs involved in expanding production at the rate of the current consumption increase are likely to be extremely high and the environmental effects may be severe. Thus, import requirements are likely to continue to increase, while demand for domestically produced foods will fall. It is possible that the current developments are creating long-term structural changes in the consumption patterns which will not easily be reversed in response to changes in relative prices. This also implies that the demand for sorghum, millet and maize is unlikely to respond greatly to reduced prices brought about by expansions in domestic production. An early indication of such a situation is presented by relatively large surpluses of maize in Kenya, Malawi and Zimbabwe at prices below export parity, and by attempts to barter these surpluses for imported wheat and rice.

If the cereal substitution is at least in part irreversible, rather than merely a response to changes in relative prices, opportunities for changes in the production patterns should be explored. Experience to date indicates that massive expansions of rice production in Africa, outside of those areas currently cultivating rice, generally require very high investments. Furthermore, efforts to develop and/or adapt high-yielding rice varieties have not been very successful and production costs are generally high. However, although prospects may not be bright, further exploration is needed on this matter with due consideration of the environmental implications.

Pre-harvest and post-harvest losses

According to the National Academy of Sciences [4] in the USA, more than 100 million tonnes of cereals and legumes are lost annually in the developing countries. This is sufficient to provide the minimum energy requirements of about 300 million people [5]. The magnitude of losses varies among products, locations, and over time. It is estimated that the average losses in cereals and legumes are above 10% while losses in starchy staples, vegetables, and other perishables exceed 20%. Losses are particularly high in fish, and may be of the order of 25% on the average. The losses are caused by biological, microbiological, chemical, biochemical, mechanical, physical, and physiological factors [6].

Improvements in processing, storage, transportation, and other marketing activities are the most promising opportunities for reducing these losses. Altering the characteristics of the products, including their resistance to pests through the application of biotechnology, offers considerable promise for reducing post-harvest as well as pre-harvest losses.

Food wastage

In addition to pre-harvest and post-harvest losses, a number of sources of food waste exist within the household, including table waste and spoilage. The poor seem to waste a smaller proportion of the food purchased than the better-off households. The largest percentage waste appears to occur with foods of animal origin, followed by vegetables, cereal products, and fruits. Separable fat in red meat is one of the items often discarded. This is of interest to this analysis for two reasons. Firstly, production of fat requires a large input of energy from feed sources including cereals, and secondly, increasing concern about excess fat consumption is likely to strengthen the trend to discard fat. The implication is a large and increasing waste of resources in feed production with its associated implications for the environment. Thus, while reduced fat consumption should be pursued for health reasons, discarding separable fat is clearly not the most appropriate approach.

About 34 million people are categorized as obese in the USA, with 12 million of them being severely obese [7]. Assuming an average overweight of 20 kg, the additional energy needed for body maintenance is approximately 350 calories daily. Assuming an average energy requirement for non-obese individuals of 2400 calories daily, the excess consumption due to obesity (not counting the energy needed to become obese) in the USA alone is equal to the energy requirements of five million people. But obesity is not limited to the USA; it is widespread in Europe, the Caribbean, the South Pacific, and parts of Africa and Latin America.

References

1. World Bank, World development report 1990, New York, Oxford University Press for the World Bank, 1990.

2. FAO, Production yearbook. Rome, Food and Agriculture Organization of the United Nations, 1989.

3. Paulino, Leonardo A., Food in the third world: past trends and projections to 2000, Washington, DC, International Food Policy Research Institute, 1986 (Research Report No. 52 (June)).

4. National Academy of Sciences, Postharvest food losses in developing countries, Washington, DC, National Academy of Sciences, 1978.

5. Bourne, M.C., Preharvest and postharvest losses of crops. In: Malnutrition: determinants and consequences, New York: Alan R. Liss, Inc., pp. 327-335, 1984.

6. Pariser, E.R., Post-harvest food losses in developing Countries. In: Price Gittinger, J., Leslie, J., & Hoisington, C., ed. Food policy: integrating supply, distribution and consumption. Baltimore, Johns Hopkins University Press 1987.

7. National Research Council, Designing foods: Animal product options in the marketplace, Washington, DC, National Academy Press, 1988.

4. NATURAL RESOURCES FOR FOOD, AGRICULTURAL AND FISHERIES PRODUCTION

Land-based ecosystems

For the continued supply of most staple foods and many other agricultural products, such as biomass fuels, fibres, resins, spices, medicinal products and other chemicals, human society relies on the natural productivity of several land-based ecosystems. Of these systems, the arable lands are exploited relatively intensively, mostly by settled agriculture. Other productive ecosystems such as forests, rangelands and wetlands may be subjected to varying degrees of management. Under appropriate cultivation practices, most of the productive land-based ecosystems will retain an adequate productive potential over a considerable length of time, although a slight fall in yields may ultimately occur even in the most favourable areas, due to erosion and loss of minerals in the soil.

Some land-based ecosystems are of profound, though indirect, importance to food growing and agricultural production, as they protect river basins from floods and erosion, regulate microclimate, provide bio-diversity or habitats for natural enemies of pests, or perform other functions of immediate importance to agriculture. Certain ecosystems are in this sense both productive and protective, the tropical rainforest being a typical example of this category.

In principle, all these ecosystems will degrade only slightly under reasonable management stress and will recover through the process of succession once this stress is lifted. They are therefore to be considered renewable natural resources. Unfortunately, a growing proportion of land-based productive and protective ecosystems is being irreversibly degraded, and subsequently lost, as a result of too much human-induced stress.

Tobacco is a case in point, its cultivation being harmful to the environment and the end product for human use being a major cause of morbidity and mortality. Compared with other crops, tobacco is very demanding of nutrients and if these are not replaced by adequate provision of costly and, in many cases, imported fertilizers, soil degradation may result. Moreover, the production of good-quality leaf requires the extensive use of herbicides, nematocides, fungicides, insecticides and other chemicals. The use of complex chemical compounds brings the possibility of contamination of crops, soil and water, and occupational hazards. Furthermore, tobacco contributes to forest depletion through clearing land for cultivation, and felling trees to provide wood for curing, construction of drying sheds, and packaging material. In a word, tobacco production is legal but lethal, and the search for suitable alternative crops is a matter of urgency.

Under the pressure of economic, political and demographic forces, many communities have adopted short-sighted and inadequate land use policies, or have failed to introduce environmentally sound practices. At the local level, people often fail to survive or to make the transition into the market economy without overtaxing the carrying capacity of their land. Some of these processes are briefly reviewed.

Deforestation

Although forests in all climatic zones are of great economic importance as providers of food and other products, they are indeed often of greater importance to agriculture through their protective functions, especially in the tropics. Another aspect of the agricultural importance of forests is their potential to provide new arable land, through felling and clearance. Proper forest management practices should attempt to reconcile these three functions in the best interests of agriculture, timber extraction, water quality control, wildlife conservation and maintaining their amenity value. However, under the pressure of economic, political and demographic forces, current management practices are increasingly failing to renew existing forest reserves, let alone restore those already lost.

Statistics on global forest reserves are hard to obtain and suffer from lack of standardization. As a result of the increased demand for agricultural land and accelerated timber extraction (both for fuel and industry), it has been estimated that approximately 100 million hectares of forest has been lost throughout the world since 1950 [1]. In their first assessment of tropical forest resources, FAO and UNEP estimated that in 1982 the rate of deforestation of tropical closed woodlands was 11.4 million hectares a year [1]. The deforestation is either large-scale, industrial and immediately devastating, unless accompanied by reforestation, which is seldom the case; or is small-scale and insidious, leading to slow but steady degradation and impoverishment.

If current trends continue, tropical forests will cover only 7% of the planet's land area by the year 2000, compared to 15% in 1950. Temperate forests may remain stable at around 20%, because of less population pressure and more successful reforestation [2].

The major effect of deforestation on agriculture is that the release of rainwater becomes more erratic and, therefore, irrigation water supplies are threatened. Massive deforestation in the water catchment areas of major rivers is widely accepted to be responsible for excessive flooding in fertile coast plains, giving rise to the loss of crops and human lives.

Desertification

About one-third of the planet's land surface is either semi-arid or arid, i.e., receives less than 250 mm of rain per year or hardly any rain at all. Because of the drought stress, these areas have a very low natural productivity, but some will support low-density herding or seasonal agriculture. With prudent irrigation, productivity may be increased in most semi-arid areas to levels where commercial agricultural exploitation is cost-effective, depending on soil and climate characteristics. For the most part, however, semi-arid lands tend to be vulnerable to further degradation. If vegetation cover is lost primarily because of natural climatic shifts, the resulting process of degradation is referred to as desertization. Desertification, on the other hand, is a process induced by human activities, such as the felling of trees (mostly for fuel), inappropriate agricultural practices or overgrazing by goats or cattle.

Reclamation

The process of converting economically unattractive land or bodies of water into a more useful resource base, for example by irrigation or drainage, or by landfill, is usually referred to as reclamation. For the present review, the main interest lies with those forms of reclamation which affect agricultural land use. However, reclamation of shallow waters or other areas for purposes of urban or industrial development may indirectly affect agriculture by relieving pressure on arable land already under exploitation for the production of food. Likewise, the creation of freshwater basins by the reclamation of inland seas may affect fishery resources.

Reclamation of wetlands by means of drainage, and turning them into arable land, has been applied in many parts of the world, most notably in Europe. In Asian countries, natural wetlands have been reclaimed on a large scale by hydrological works, mostly rendering them suitable for irrigated agriculture. The gains in agricultural potential may be accompanied by a change in the patterns of risk of vector-borne diseases, as some of these may be reduced and others aggravated by reclamation. From a fisheries and wildlife conservation point of view, wetlands have now been reduced to critically low levels in many countries. Another form of reclamation affecting agriculture is the transformation of semi-arid and arid lands to irrigated arable lands by the introduction of water. This practice has been well developed in several countries, particularly in the Middle East where (e.g., Pakistan) it has given rise to major problems with salinization. Most suitable applications are those demanding relatively low water inputs (e.g., by drip irrigation) for permanent crops, such as fruit trees. As the water demands may weigh heavily in countries with little rainfall, this practice may create conflicts with other interests (e.g., for drinking-water and sanitation, industry).

Competitive alternative energy sources

As non-renewable sources of energy become scarcer and the pressure to reduce toxic atmospheric emissions increases, traditional agricultural usage of arable land and potentially reclaimable land areas may need to compete more with the generation of solar energy and hydropower or the cultivation of alternative renewable energy crops, such as sugar cane, rape oil seed, oil palm, etc. Vast areas of fertile agricultural land have already been lost to the construction of hydroelectric dams, notably in Africa and Asia. As the most suitable sites are being used up, the trend is bound to slow down in the medium term. Semi-arid and arid areas with potential for solar energy generation have not yet been fully exploited, but if this should occur in the near future, there is obviously little danger of affecting agricultural potential. The only country where the utilization of alternative automotive fuels of vegetable origin (ethanol) has been national policy for many years, Brazil, has not experienced any untoward effects from the displacement of food crops so far.

Other competitive land uses

It is the broad objective of land-use planning to arrive at the most appropriate land resources allocation, taking into consideration the specific qualities of soils, topography, demographic factors and economic needs. Ideally, the process of decision-making involved is one of optimizing the benefits from limited resources. Unfortunately, the reality is that no land-use planning process can start from scratch and that many conflicting interests cannot be reconciled.

Where demographic or economic forces have caused a land scarcity, some of the land most suited for agriculture may be allocated to housing, industry or infrastructures. This is of special concern in countries where agriculture is already under pressure, as remaining arable land is likely to be of poor quality or in remote areas. Table 4.1 provides a striking example of the situation in two of the most densely populated countries of the world: Japan, which is mostly mountainous and consequently has little land available for agriculture, and the Netherlands, which is mostly flat and is blessed with soils that are very suitable for agriculture.

Table 4.1 Land-use patterns in two densely populated countries in 1985

Land-use type	Percentage of total area	
	Japan	Netherlands
Agriculture	14.5	64.2
Woodlands	67.0	8.0
Uncultivated lands	0.8	4.0
Water surfaces	3.5	9.2
Roads and railroads	2.8	3.4
Built environment	4.0	10.1
Other	7.4	1.1
Total (percentage)	100.0	100.0
Total (in 1000 sq. km)	377.8	37.3

Sources: **Japan** - Japan Institute for Social and Economic Affairs. "Japan 1988, an international comparison", Tokyo, 1987.
Netherlands - Central Bureau of Statistics, Department of Soil Statistics, The Hague, personal communication, Mr Bunschoten, 1990.

Despite competition from other forms of land use, FAO figures [3] indicate that total agricultural land (i.e., arable land, permanent crops and irrigated land) has expanded from 1 521 076 thousand hectares in 1965 to 1 701 112 thousand hectares in 1985, which amounts to an annual increase of 0.5% (at the same time, total production of cereals, root crops, pulses, oil crops, meat and milk increased by 2.8% per annum). In certain parts of the world, notably in Europe and North America, there is an excess of agricultural land as well as crops produced, while in some of the semi-arid and arid zones of Africa and elsewhere the available agricultural production systems cannot meet local demands at all times. As the need to increase food productivity will continue, land-use planning will come under increasing pressure to safeguard particularly those land areas with high agricultural potential from intrusion by other developments.

Management and exploitation of aquatic resources

Freshwater systems are primarily used for the extraction of drinking-water. Aquatic ecosystems of all kinds serve society as sources of food as well as sinks for wastes. As not all of these uses are mutually compatible, conflicts of interest may arise, unless tight planning mechanisms and strict regulations are in force.

Most food harvested from aquatic ecosystems consists of animal products (e.g., fish, shellfish, crustaceans, mammals). Because of economic factors, the general practice is to harvest natural stocks to levels below those where maximum sustainable yields can be produced, except where quota systems based on an understanding of the population dynamics of the species are in force. A major factor in the overexploitation of ocean fisheries is the growing scale of these operations and the increasing efficiency of tracking down the target species and bringing them on board. This not only leads to depletion of stocks of the target species themselves, but also upsets intricate balances in the marine food-web, with untoward consequences for other species. Overfishing of krill (a kind of zooplankton of mixed composition), for example, is threatening certain species of whales and marine birds.

Similar phenomena affect productivity in freshwater ecosystems. As rivers often serve as spawning grounds and nurseries for marine or brackish water species, the hydrological management of rivers through dams, sluices, water extraction or diversion, may interfere with marine productivity. Organic and inorganic pollution poses an additional hazard to the productivity of all aquatic ecosystems. A significant rise in the biological oxygen demand, caused by organic pollution, may be sufficient to kill all fish over a vast area. Toxic wastes and heavy metals, emitted with run-off water or industrial effluents, exert different effects on different aquatic species. Organisms may either show stunted growth and a diminished immunity to disease, and eventually a decline in the population, or manifest no apparent symptoms at all. If the latter category is used as food (shellfish), the substances accumulated in their tissues may present a serious risk for human health, as has been well documented.

The high demand for certain species such as salmon and trout has given rise to the development of intensive aquaculture methods, by which these species can be mass-produced under seminatural conditions (e.g., floating cages in estuaries or lakes, release of pond-bred fingerlings in natural waters). These systems are sensitive to chemical pollution and spills (oil), and are themselves sources of eutrophication (e.g., increased nutrient input from fish feed and excreta) and chemical pollution (e.g., pharmaceuticals used for the treatment of fish diseases) which, in turn, may affect natural food stocks.

Fish ponds and irrigated agricultural land form valuable sources of animal protein in many parts of the world. If properly managed, fish farming can assist rural communities in the recycling of organic waste (e.g., as practiced in China and other Asian countries) and in the control of water-related vectors of human diseases such as malaria, filariasis and Japanese encephalitis.

References

1. FAO/UNEP, The global assessment of tropical forest resources. Rome, Food and Agriculture Organization of the United Nations, 1982.

2. Myers N., ed., The GAIA atlas of planet management, Pan Books, 1985.

3. FAO, World agricultural statistics. Rome, Food and Agriculture Organization of the United Nations, 1987.

5. ENVIRONMENTAL EFFECTS OF INTENSIVE AGRICULTURAL PRODUCTION

From 1975 until the present, almost all of the growth in agriculture has been due to increases in land productivity, by increasing the output per unit of land in one season and also by increasing the number of crops harvested each year (i.e., multiple cropping). Animal production has been intensified by the shift from herding animals across large areas to find feed, to settled cultivation, and then to confinement management.

The growth in land productivity has been due to a combination of research efforts resulting in new varieties of plants, responsive to fertilizer and irrigation; modern fertilizers, pesticides and machinery; greater control over traditional measures, such as irrigation; and improved management by better educated farmers.

Increases in animal productivity have come from a combination of research, modern inputs and better management. Breeders introduced new breeds of animals which use improved rations of grain efficiently, better animal health measures, and confinement management. As with plants, improved breeds and modern inputs have some impact on animal productivity if added to traditional practices, but when they are combined they boost productivity more than the sum of the impact of individual inputs.

Rain-fed and irrigated agriculture

The great increase in the use of fertilizers was induced by the combination of low fertilizer prices and high land prices in Europe and Japan. The supply of relatively inexpensive fertilizers in turn induced the development of fertilizer-responsive varieties which increased the demand for fertilizers even further. Fertilizers were used most intensively in Europe, which on average used more than 200 kg/ha, and included some countries such as the Netherlands that used about 750 kg/ha. At the same time Japan, the country in Asia with highest levels of fertilizer use, used 431 kg/ha. Most developing countries even in Asia use far less - for example India uses 50 kg/ha and Indonesia 100 kg/ha. As a result, ground water contamination has been a problem in Europe, Japan and some areas of the USA, in which more concentrated levels of fertilizer were used than in developing countries.

A number of conditions favour the leaching of nutrients from rain-fed arable land. In areas with intensive crop production and high application rates of chemical fertilizers, with a surplus of annual precipitation over evapo-transpiration (i.e., a net annual downward flow of water), nutrients such as nitrate, and potassium ions can easily be leached, owing to their high mobility in water. Other substances, the most important being cadmium, phosphates, agricultural pesticides, fungicides and chemicals used to disinfect soils, are less mobile and move downwards more slowly. However, in the long run these compounds may also reach the ground water, and subsequently surface waters, especially where ground water is found at shallow depths. For example, in the Netherlands, agricultural chemicals are a continuing and growing threat to the quality of the drinking-water supply.

In dry regions with irrigated crop production, there may be leaching of chemicals towards the drainage systems. Where irrigation and drainage systems are not properly managed, salinization and alkalinization may make soils unproductive.

Wetland rice production is another case in point. Globally almost 10% of the harvested area in agriculture is occupied by wetland rice, which is grown in inundated fields. Percolation in these soils may be considerable, and in East Asia rates of 10-20 mm/day are considered optimal for good crop growth. Hence, leaching of nutrients and agricultural chemicals to ground and surface waters may be important in areas dominated by wetland rice production.

Leached phosphates and nitrate from heavily fertilized agricultural lands are the main causes of eutrophication of inland waters and coastal zones, and have important effects on aquatic ecosystems, such as depletion of oxygen and algal blooms. The algal blooms form organic sediments, and anaerobic decomposition of these sediments may be an important source of methane, a gas which contributes about 20% to the greenhouse warming effect. Emissions from wet rice fields contribute about 20% to the global atmospheric methane.

A small part of the ammonia in chemical nitrogenous fertilizers is lost to the atmosphere; and heavy applications of animal manures may give rise to high losses of ammonia which are of local importance in areas with an intensive livestock industry. The atmospheric concentration of nitrous oxide is increasing steadily, contributing about 5% to global warming and also causing depletion of ozone in the stratosphere. Major causes for this rise in nitrous oxide include: emissions from agricultural lands by denitrification of nitrite and nitrate; and denitrification of these substances leached from the cultivated soils in surface waters and aquifers.

With the growing world population, further expansion and intensification of agriculture is unavoidable. As the emission of pollutants to the ground water and atmosphere have long-lasting effects, the environmental impacts of this development should primarily be controlled by increasing the efficiency of the use of water and nutrients. Developing countries should aim at avoiding negative environmental effects resulting from the intensive agricultural practices in the industrialized countries. Reuse of water and agricultural wastes for irrigation or aquaculture, and sound application of agricultural wastes (directly or after processing) as fertilizers, could play a role in this respect, provided that the harmful side-effects for health and environment are avoided.

Livestock production

Intensive raising of livestock, with confined animals, may cause locally concentrated production of slurries and manures. The stables and feed-lots are highly concentrated sources of gaseous emissions of ammonia. The organic wastes may cause serious problems, when they are applied on surrounding agricultural land. These wastes contain large quantities of nitrogen compounds, phosphate, potassium, copper, zinc, cadmium and other heavy metals. Only a part of these compounds is taken up by the plants; the remainder accumulating in the subsoil, or leaching out to ground and surface waters. Ammonia volatilization from stables and feed-lots may be considerable and large amounts are lost during and after the spreading of manure on agricultural land. Part of the nitrate formed may leach out to the ground water, and part may be denitrified, whereby dinitrogen oxide and nitrous oxide are formed. Furthermore, the increasing world population of cattle is one of the major sources of methane in the atmosphere.

Many ground waters, aquifers and surface waters are heavily polluted as a consequence of the application of animal wastes on agricultural land in regions with livestock industry. In such regions much of the surface water is eutrophicated, and biological life in these waters has already dramatically changed. Drinking-water wells are often heavily polluted, containing nitrate levels of many hundreds of milligrams per litre. Even if the leaching from cultivated lands is drastically reduced, it will take many years or even centuries before the effects of present agricultural activities will be eliminated completely.

Pesticides

Pests and diseases have always been a problem for certain crops in certain seasons. The factors that have increased output per unit of land - increased use of fertilizer, higher plant population, increased intensity (less fallow land, continuous cultivation of the same crop, and more crops per season), and new varieties - have also increased disease and pest problems. Plant breeders have bred resistance to some pests in new varieties but have not kept ahead of all pests. Demand for insecticides grew with the Green Revolution in developing countries. Demand for fungicides has been highest in Europe. Demand for herbicides has been greatest in the USA.

Increases in the value of pesticides sold throughout the world are shown in Fig. 5.1 [1].

Worldwide crop production depends heavily on the continuous availability of effective pesticides. Resistance varies regionally, because of differences in the use of the chemicals, but it seems there is little reason to believe that worldwide production of any of the major crops is threatened in the foreseeable future [2]. Instead, a "build-up of a resistance problem to the point at which national and regional food production is threatened" is more likely [3]. Research and development on new pesticides are increasingly expensive. It has been estimated that US$ 80-120 million are spent on every new pesticide [2], and these costs will continue to increase in the future [4]. It takes 8-10 years to bring a new product to the market.

The effects of climatic change on pest, disease and weed development are complex. However, an increased pressure of existing and new pathogens and weeds on crops can be expected [5], which would require intensified chemical control with the danger of an upsurge in resistance and ecosystem pollution.

Data on pesticide use are not readily available and are not very reliable because they are expressed in quantities of active ingredient, which can vary widely in their effectiveness on pests. The greatest quantities are used by the USA and the USSR. However, on a per hectare basis, European countries use higher levels than these two countries. Developing countries have primarily used insecticides to control insect pests of rice, cotton, soya beans and tropical fruits. Most of the problems of pesticide residues in water have been found in developed countries, but high levels of chlorinated hydrocarbon pesticides have also been measured in water in Colombia, Malaysia, United Republic of Tanzania, and Thailand [6]. The problems of poisoning of agricultural workers may be more serious in developing countries because much of the spraying is done with hand-carried equipment and workers do not wear protective clothing, either because of ignorance or the high ambient temperature.

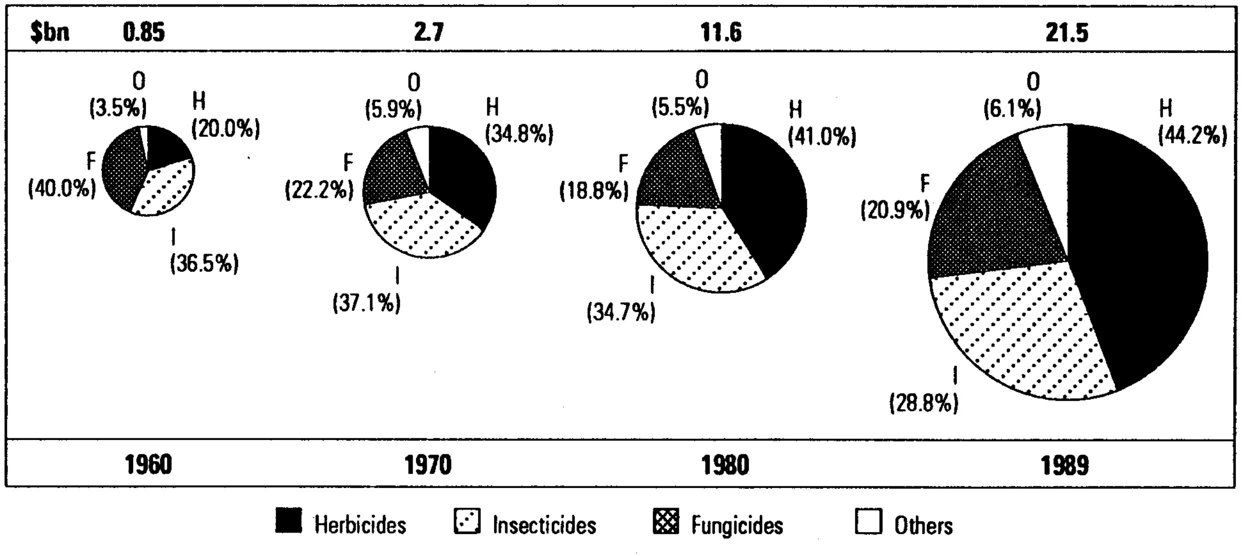

Fig. 5.1. World Pesticide Market. From: Ref. 1

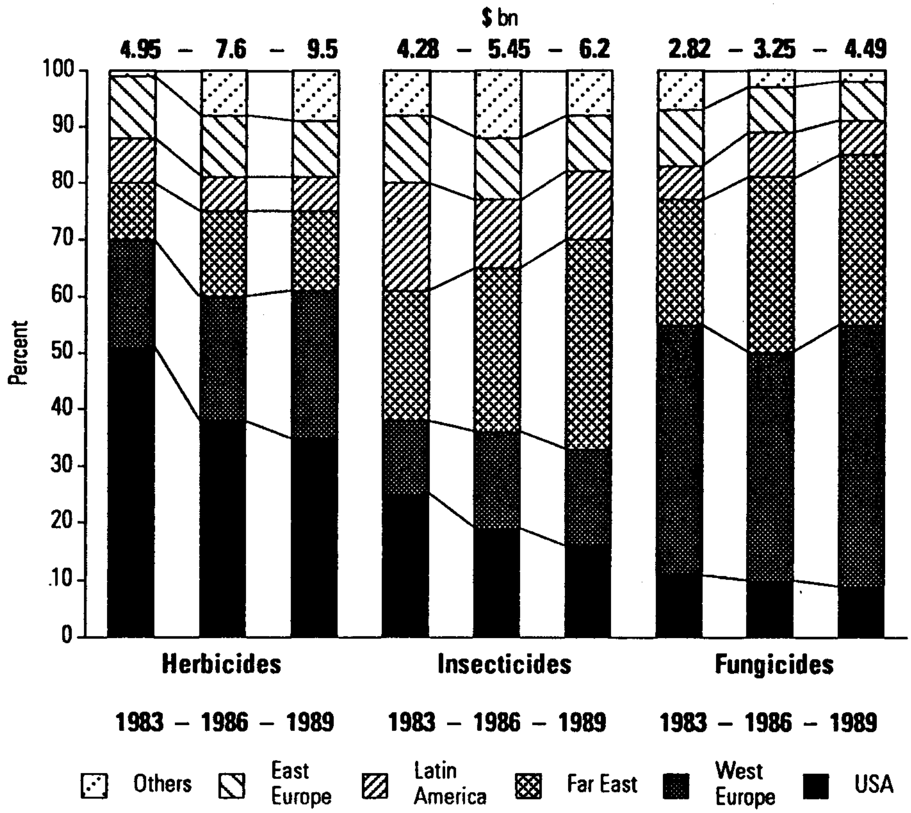

Fig. 5.1. World Pesticide Market *(continued)*

An important aspect of the safe use of pesticides is the possible occurrence of residues of these chemicals and their metabolites in food. Environmental criteria play an important role in the re-registration of older pesticides and the registration of new chemicals. Ecotoxicity criteria include:

- toxicity to fish,
- toxicity to bird life,
- toxicity to non-target insects,
- toxicity to small water crustaceae,
- toxicity to water plants, and
- toxicity to algae.

In recent times, some registration authorities have asked for studies on aquatic systems in addition to those on the usual test species. The research is done in ponds with varying levels of pesticide contamination. The shift in the balance between the different species is investigated, together with the potential of a pesticide to bioaccumulate in the food-chain.

New areas of concern include the environment itself, effects on non-target organisms and the exposure of man via other routes than the food-chain. The field of pesticide science is still a very dynamic one but some clear trends in product development and application patterns can be discerned in the pesticides on the market, their use and diversity. The number of pesticides is expected to grow less dramatically than it did in the past decades; even a decrease seems possible in the developed world, as older pesticides disappear while new pesticides enter the market more slowly. Pesticides disappear from the market because resistance develops, undesirable side-effects become apparent and more data are required for further registration, rendering the product economically unattractive. Replacement of older pesticides by new compounds is now slower than in the past since requirements for the registration of new compounds are becoming more stringent.

Nevertheless, on a worldwide basis, the use of pesticides will tend to increase rather than decrease, especially in the developing countries which have a growing demand for more food of better quality. Increase in use is to be understood here in terms of "hectares (or tonnes of food products) treated", rather than "kilograms of pesticides sprayed", for there is a clear tendency towards pesticides with higher biological activity and lower dosage rates. The increased use in the developing countries will probably outweigh the intended decrease in the developed countries, where there is a trend to reduce the use of pesticides, in particular for ecological reasons.

The chemical diversity of pesticides in use will continue to increase as science advances, for example:

- more polar compounds, which are generally more biodegradable, will enter the market;
- high molecular weight compounds with a more specific biological action will replace simple classical broad-spectrum pesticides, since biotechnology offers the possibility to produce these large molecules on a commercial basis; and
- optically-active enantiomers will replace racemic mixtures whenever possible.

However, this trend towards low-dosage, more active pesticides does not necessarily mean that they will be less toxic for non-target organisms.

National and international pesticide monitoring programmes cover foodstuffs and feed, human tissues, total diets and environmental samples. For risk assessment, foodstuffs for human consumption form the first category of concern. It can be expected that the diversity of foodstuffs treated with pesticides will increase with international trade and the demand for greater variety by consumers. There will and must be continued vigilance over the occurrence of pesticide residues in food and animal feed (since it is directly linked to the food-chain) to keep the pesticide situation under control.

Monitoring of human tissues will still be necessary for some time to follow the effect of banning the older persistent pesticides, but, since the trends are slow and the data difficult to evaluate toxicologically, a decrease in interest for this type of programme can be anticipated. Analysis of human blood can be useful for estimating professional or accidental exposure. Continued monitoring of human milk is justified, but, with the slow evolution of trends, economies in the frequency of such monitoring would be possible.

In the developed countries, total diet studies have been carried out and are valuable in estimating the (most often reassuringly low) actual daily intakes. Spotting problem areas is, however, only possible when the "market basket" approach has been followed. On the other hand, a duplicate diet study may be more accurate, as it should by definition represent the actual intake of the population. Guidance on the implementation of exposure studies has been provided by WHO [7] and results of food contamination monitoring and exposure studies have been published [8].

In addition to the monitoring of foodstuffs and feed for regulatory and registration purposes, there is growing economic interest in the certification of food and feed for low pesticide content as a positive quality characteristic. A special area of importance with respect to pesticides is the developing countries, as data with regard to behaviour of pesticides under tropical conditions are scarce. The use of pesticides can be expected to increase considerably in the developing countries, hence the need for development and maintenance of a proper surveillance system for foodstuffs, feed, and the environment. Unfortunately, in many of these countries strictly controlled application of pesticides and adequate monitoring are rarely feasible.

Subclinical infection of animals

After the Second World War, intensive breeding and fattening of animals became a major activity of agricultural production. Enormous quantities of animal feed had to be imported from tropical and subtropical countries into countries with a rapidly developing animal husbandry, i.e., Western and North-Western Europe and the North American continent. Animal feeds, composed partly of meals of animal origin (e.g., blood, bone and feather meal, fish meal) and largely of meals of vegetable origins, (e.g., palmpit-residues, cacao-bean shells, soya beans), have been shown to be contaminated with pathogens, especially *Salmonella* [9,10,11].

It seems that these imported feeds have been the primary source of animal infections in the postwar years. Owing to the often highly contaminated feedstuffs and probably also to intensive breeding and fattening procedures, especially of pigs, calves and poultry, a great number of animals became subclinically infected carriers. Unfortunately, these otherwise completely healthy animals could not be detected with the normal methods of "ante-mortem" and "post-mortem" meat inspection.

However, these clinically healthy animals continue to shed pathogens such as *Salmonella* and *Campylobacter* with their faeces, which results not only in contamination of the environment (surface water, soil), but also in contamination of wet surfaces during slaughtering, meat processing and distribution. Investigations in various countries have shown that very high percentages of food animals have become such carriers in recent decades [12,13,14]. Millions of carrier animals all over the world have contributed to this contamination of the environment and hence to the creation of infection cycles, which at present play an important role in the epidemiology of foodborne diseases.

So far, no significant success has been achieved in reducing the number of carrier animals. The original cause, namely animal feed, is probably no longer the main source of infection, due to effective pelletizing in many countries. The contaminated environment, however, including surface water, soil, birds, rodents and insects, seems now to be the main source of infection of clinically healthy animals.

Research with vaccination of animals to reduce the prevalence of subclinical infections has been carried out in recent years without, however, great success so far [16].

Increasing amounts of animal and plant wastes

In discussing the impact of agriculture on the environment, a clear distinction should be made between the developed and the developing worlds.

In the developed world, agricultural production has increased rapidly during the past decades, partly through genetic improvements in plant material, but mainly through the increasing use of external inputs such as fertilizers and pesticides. This has been made possible by technical innovations and the economically attractive terms of exchange between agricultural products and these external inputs (for instance, through the Common Agricultural Policy of the European Economic Community). As a result, very intensive arable production systems have developed, usually with a fairly narrow crop rotation, alongside intensive animal husbandry systems, in which large amounts of concentrates are used. This separation of animals and land has led in many cases to serious problems.

In arable farming systems, there has been increasing replacement of organic manures (animal manure, green manure) by chemical fertilizers, whose injudicious use has resulted in wasteful application, with pollution of water and air as a consequence. In recent years, however, there has been an insistent call for the development of integrated farming systems, with the reuse of organic crop residues as a source of plant nutrients [17]. Application of the recommendations worked out in this framework can lead to efficient recycling of crop residues, which can contribute to minimizing the use of chemical fertilizers, with its negative consequences, and to improvement of soil structure, with beneficial effects for water balance and resistance to wind and water erosion. At the same time, practically all crop residues ("plant wastes") can effectively be reused within the existing arable farming systems. Hence, within the intensive farming systems prevailing in the developing world, there is a need for reconsideration of the value of crop residues, but there does not appear to be any great need to look for alternative uses of the material outside the agricultural sector.

Intensive animal husbandry systems largely rely on the use of external feed resources, which leads to very unfavourable efficiencies of nutrient uptake, where, for instance, not more than about 15% of the input of nitrogen is exported in animal products [18]. Hence, a strong surplus exists, that accumulates in manure ("animal wastes"), with serious environmental effects: leaching of nutrients to the ground water; gaseous losses to the atmosphere from storage places or during application; and accumulation of less mobile elements in the soil.

A solution to this problem must basically be found in a better equilibrium between inputs and outputs in these systems. This will require lower use of external resources, mainly chemical fertilizer and concentrates, rather than suggestions for alternative uses of the animal waste. There are possibilities for a more efficient application of fertilizers that would lead to lower losses and create opportunities for the application of animal manure within the system as a source of plant nutrients. The input of concentrates can be reduced by partial replacement with high quality feed grown on-the-spot at the home farm (fodder beets, grain). This renewed combination of animal husbandry and arable farming within the present systems also leads to greater opportunities for the application of animal manure as an organic fertilizer. In combination with environmentally sound application methods (injection, ploughing-in), the environmental impact of animal manure can be minimized [19].

In most developing countries, the situation is completely different from that in the developed world. Their rapid population growth has led to an increasing demand for food. The terms of trade between agricultural commodities and external inputs are, in general, very unfavourable, hence the use of these inputs is not economically viable. To satisfy the food demand, therefore, the agricultural sector is forced to use exhaustive production techniques.

In arable farming this means that the balance of plant nutrients is negative, hence outputs exceed inputs. The result is that the organic matter content of the soil decreases steadily, and cannot be replaced by organic amendments (crop residues or animal manure). Inevitably, this also leads to physical degradation, with negative consequences for the water balance and eventually complete desertification [20]. An urgent need exists, therefore, for the application of more "conservative" production techniques, which include the reincorporation of a larger proportion of the crop residues ("plant wastes") into the soil system.

Because of the deteriorating situation with respect to fossil fuels (high prices), and the continuously decreasing availability of firewood, an increasing proportion of plant and animal wastes is used as fuel for cooking and heating. This affects their availability within the agricultural sector and leads to the conclusion that, in fact, in most developing countries a glaring "deficit" of plant and animal wastes exists [21].

A solution often proposed is the integration of arable farming and animal husbandry, which could lead to a more efficient use of the natural resources. The main benefit from such an integration would be the conservation of plant nutrients. However, as pointed out, the amount present in the system is already limited and since some losses are inevitable this could only be achieved through efficient "concentration" of the nutrients, i.e., transport from extensively used natural pastures to more intensively used arable fields. This would lead to accelerated exhaustion of the extensive areas, with a high risk of degradation.

On a worldwide scale, plant and animal wastes do not form a serious threat to sustainability of agricultural production systems, or to ecological values. In more intensive production systems, a surplus, particularly of animal wastes, apparently exists, but by developing integrated production systems this can be remedied relatively easily, although economic feasibility must be considered. In most extensive production systems, under which by far the largest part of agricultural production takes place, crop residues and animal manure are in "short supply", and all possible measures should be taken to encourage their increased production, including the use of external inputs through more favourable terms of trade.

References

1. County Nat West Wood Mac (CNWWMc), United Kingdom based bank, edition 1990, M.O.D.

2. Dover, M.J. & Croft, B.A., Pesticide resistance and public policy. BioScience, 36: 78-85 (1986).

3. Conway, G.R., The future. In: Conway, G.R., ed. Pesticide resistance and world food production, London, Imperial College, Centre for Environmental Technology, pp. 77-90, 1982.

4. Gotsch, N. & Rieder, P., Forecasting future developments in crop protection. Crop Protection, 9: 83-89 (1990).

5. Roberts, L., Is there life after climate change? Science, 242: 1010-1012 (1988).

6. World Resource Institute. World resources 1990-91. New York, Oxford University Press, 1990.

7. Guidelines for predicting dietary intake of pesticide residues. Joint UNEP/FAO/WHO Food Contamination Monitoring Programme in collaboration with the Codex Committee on Pesticide Residues, Geneva, World Health Organization, 1989.

8. Assessment of chemical contaminants in food. Report of the UNEP/FAO/WHO Programme on Health-related Environmental Monitoring, Geneva, UNEP/FAO/WHO, 1988.

9. Bischoff J. & R. Rhode, Salmonellen in Fisch- und Fleischmehlen ausländischer Herkunft. Berl. Münch. Tierärztl. Wisch. 68: 307 (1956).

10. Rutquist L., Vorkommen von *Salmonella* in Futtermitteln vegetablischen Ursprungs. Zblat.Vet.Med., 8: 1016 (1961).

11. Jacobs, J. et al., Studies on the incidence of *Salmonella* in imported fish meal, Zblat.Vet.Med., 6: 542 (1963).

12. Galton, M.M., *Salmonella* in swine, cattle and the environment of abattoirs, Journal of infectious diseases, 95: 236 (1954).

13. Edel, W. et al., Epidemiological studies on *Salmonella* in a certain area ("Walcheren Project") I. The Presence of *Salmonella* in man, pigs, insects, seagulls and in foods and effluents, Zblat. Bakt. Hyg., I. Abt. Orig. A, 325: 476-484 (1976).

14. Nottingham, P.M. & Urselmann, A.J., *Salmonella* infection in calves and other animals, New Zealand journal of agricultural research, 4: 233 (1961).

15. Oosterom, J. et al., Epidemiological studies on *Salmonella* in a certain area ("Walcheren Project"). IV. The incidence of *Salmonella* in the sewage system, in the faeces of man and pets as well as in shops, kitchens and lavatories in the village of Aagtekerbe. Zblat. Bakt. Hyg., I. Abt. Orig. A, 248: 190-201 (1980).

16. Report of the WHO Consultation on Specific Methods (immunization) of prevention and control of *Salmonella* in animals, Munich, 13-17 October, 1986.

17. Vereijken, P., From integrated control to integrated farming, an experimental approach. Agricultural systems, 26: 37-43 (1989).

18. Meer, H.G. van der & Uum-van Lohuyzen, M.G., The relationship between inputs and outputs of nitrogen in intensive grassland systems. In: Meer, H.G. van der, Ryden, J.C., & Ennik, G.C., ed. Nitrogen fluxes in intensive grassland systems. Dordrecht, Martinus Nijhoff Publishers, pp. 1-17, 1986.

19. Aarts, H.F.M. & van Keulen, H., De konsekwenties van stringente milieumaatregelen op de mogelijkheden voor weide- en voederbouw op de zandgronden: een theoretische benadering, 1991 (in preparation).

20. Keulen, H. van & Breman, H., Agricultural development in the West-African Sahelian region: a cure against land hunger? Agriculture, ecosystems and environment, 32: 177-192.

21. Ridder, N. de & van Keulen, H., Some aspects of the role of organic matter in sustainable intensified arable farming systems in the West-African semi-arid-tropics (SAT). Fertilizer research (in press).

6. INCREASING DEMANDS FOR WATER AND APPROPRIATE MANAGEMENT OF WATER RESOURCES FOR AGRICULTURE

Water demand for agriculture

Agriculture is dependent on water supplies to such an extent that food sustainability cannot be attained without appropriate water resources development and management. In contrast to the last two decades, increases in agricultural production can no longer occur through the expansion of cultivated land. With few exceptions, such as North-East Brazil, where large areas of land are now being reclaimed for agricultural uses, arable land is approaching limits to expansion. India has exploited practically 100% of its land resources for agriculture, while only 3% is left for further lateral expansion in Bangladesh. Pakistan, the Philippines and Thailand still have a potential for expansion of about 20% [1]. The global rate of increase of arable land and permanent crops has declined from 0.4% during the decade 1970-1979 to 0.2% during the period 1980-1987. In the developing countries as a whole, the rate of increase also declined from 0.7 to 0.4% [2,3].

Increased production must therefore rely on increases in crop yields to levels never reached in the past. Annual growth rates with an average yield of over 2% in agriculture as a whole in developing countries will be necessary to attain food sustainability by the year 2000. Irrigated agriculture itself should contribute about 3% to this yield increase to allow for the overall increase of 2%. The gross irrigated area in the world is estimated (1987) to be of the order of 230 million hectares, of which the developing countries account for 165 million.

Almost all of the increase in irrigation in recent years has been in Asia, where it was already intensively used, but increased dramatically after 1960, permitting the intensification of land use. In Asia, irrigation which supplements rainfall during the monsoons, produces higher yields of rainy season crops and permits the cultivation of a second or third crop during the dry season. The expansion of irrigated agriculture, due to a combination of government and donor enthusiasm for such investments, was in part stimulated by the food problems of the 1960s and in part by the potential of the Green Revolution. Irrigation construction projects have slowed considerably in recent years. The sites that were easiest to irrigate have now been used, and governments are short of money.

Assuming that the current trends of reducing rates of expansion of irrigated land both in developed and in developing countries are reversed, and rates of increases close to 1.5% in the world as a whole are attained, the total area irrigated could amount to some 280 million hectares in the year 2000, and to 320 million hectares in 2010. On the basis of an average global demand of 15 000 cubic metres per hectare per year, water demand for irrigation can be estimated at 4 200 billion cubic metres annually by the year 2000 and 4 800 billion cubic metres by the year 2010.

If irrigation represents the only prospect for food security, a worldwide commitment to the protection and management of water resources will be mandatory to maintain water quality and to cope with the extraordinary volumes needed in the near future.

Trends in the availability and quality of water resources

About 97.4% of the world's water is not suitable for consumption due to its salinity. Only the remaining 2.6% is freshwater but this is not all readily available since much of it is either locked in glacial ice (about 2%) or stored underground (about 0.6%). The relatively small volume which is potentially available from the total precipitation that falls on land, excluding evaporation, amounts to about 39 000 billion cubic metres per year [4]. Unfortunately this is not uniformly distributed over the earth's surface. About 6% of the land is classified as desert and 29% is subject to varying degrees of

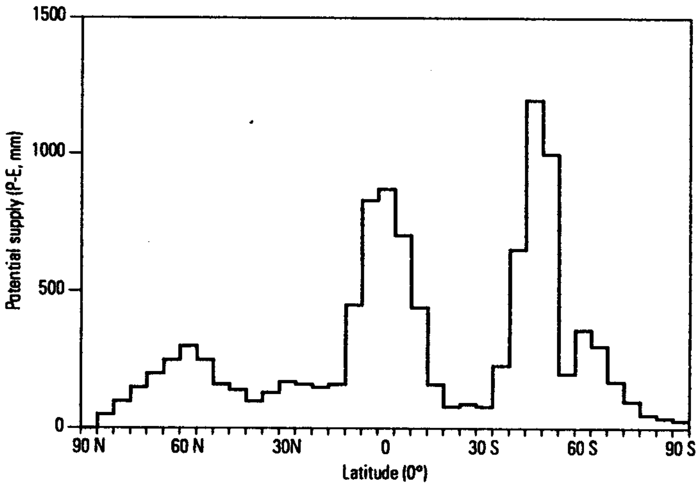

Fig. 6.1.Potential water supply (precipitation-evaporation) over the land surfaces of the globe [6].

desertification [5]. Figure 6.1 shows the potentially available water (precipitation less evaporation) as a function of latitude [6]. Maximum availability of water is around latitude 50 °S where the land area is small and population is sparse. Latitudes 40 °N to about 70 °N contain most of the water-rich countries of the world (in terms of total annual runoff), such as the USSR (4384 km^3/year), Canada (2901 km^3/year) and the USA (2478 km^3/year). Brazil (5190 km^3/year) and Indonesia (2530 km^3/year), situated in the belt between the equator and latitude 30 °S, can be considered as among the richest countries in terms of availability of water resources.

Most of the countries located in latitudes 10 °N to 50 °N are water-poor, such as Barbados (0.05 km^3/year), Egypt (1 km^3/year), Saudi Arabia (2.2 km^3/year) and Haiti (11 km^3/year). In most of these countries, the insufficiency of potential supply is aggravated by an inadequate distribution of rainfall leading to long dry seasons followed by heavy floods, both being detrimental to agriculture.

Food sustainability at country level seems to be very critical in several developing regions of the world where the low potential of water supply is exacerbated by high population growth rates.

Models for predicting global climatic changes due to an increase in the earth's temperature by atmospheric accumulation of infra-red absorbing gases are at a relatively early stage of development. However, while no reliable forecast can be made with respect to regional changes, there is no doubt that a major effect on the world's food system is likely to occur in a relatively short period of time [7]. The potential water supply will probably change widely in association with higher temperature increases at higher latitudes than in the lower ones, and with a slightly more pronounced warming during winter than in summer. It is expected that in latitudes ranging from 45 °S to 60 °S, where a higher potential water supply is available, precipitation could increase by about 5% in summer and by as much as 15% in winter. Precipitation may also increase in the equatorial region, but the semi-arid mediterranean climates (latitudes from 30 °N to 50 °N) will continue to have the same weather patterns during summer, and a winter rainfall reduction of 5-10%. Several regional studies have been made to forecast effects of temperature rise on runoff [8,9].

Other water-related negative effects such as increase of evapotranspiration rates (assumed to be about 2-3% per degree of temperature rise) may occur as a consequence of the earth's temperature increase.

Positive effects include warming at high altitudes, which will benefit agriculture where temperature now limits crops, and the fertilizing effects of increased carbon dioxide in the atmosphere (allowing for increasing rates of photosynthesis). However, these will not suffice to compensate for the global crop reduction caused by scarcity of water or its temporal and geographic distribution patterns.

Average agricultural production costs will almost certainly increase due to water scarcity and climatic changes. Adaptation to new conditions, especially through appropriate management of water resources and agricultural policies and practices, will be of fundamental importance to ensure food security.

The availability and distribution of freshwater resources are already unsatisfactory and the deterioration of quality is also becoming an important issue since contamination of water resources continues to increase in many parts of the world. Organic pollution, associated with domestic wastewater and the food and agriculture industry; pollution by synthetic organic compounds from major industries such as pulp and paper, chemicals, petrochemicals, refining and textiles; eutrophication of lakes and man-made reservoirs by the discharge of nutrients of domestic and industrial origin, increase of nitrates in ground waters, and salinization resulting from evaporation and waterlogging in irrigation systems; and acidification of surface waters through high atmospheric input of sulfuric and nitric acids are some of the causes of the degradation of natural water resources.

Pollution largely affects the water resources available for irrigation. Data on faecal coliform concentrations in rivers throughout the world have been gathered from 1979 to 1984 by the WHO/UNEP Global Environmental Monitoring System (GEMS) [10]. In about 45% of the rivers, faecal coliform concentrations were 1 000 per 100 ml or greater, while nearly 15% had levels of 10 000 or more per 100 ml. Water from such rivers is widely used for irrigation in most countries of the world, without any legislative restrictions on its use [11].

Bacterial concentrations in receiving waters would be substantially reduced if coliform concentrations could be included (in addition to biological oxygen demand and suspended solids) among the criteria utilized to establish the quality of effluents from secondary treatment plants treating domestic wastewater.

Agriculture itself has contributed to the deterioration of water resources. The clearing of land, the use of fertilizers and pesticides, and the practice of irrigation have had a major impact on water quality in many parts of the world. Drainage water with high salinity and excess of nutrients has contributed to increases in the concentration of total dissolved solids and eutrophication of lakes and reservoirs. Increasing concentrations of nitrates and pesticides in surface and ground waters have also been attributed to agricultural practices, making them unfit for domestic supply or other beneficial uses.

Data provided by GEMS/WATER indicate that 10% of the rivers monitored exceed the nitrate levels established by WHO for drinking-water (10 mg/litre as N). In Europe, over 90% of the rivers monitored have shown wide variations in nitrate levels, and 5% of them have nitrate concentrations over 200 times the background concentration found in unpolluted rivers. In South America, many lakes and man-made reservoirs are reaching hypereutrophic levels due to the discharge of nutrients (mainly nitrogen and phosphorous) from drainage water and untreated domestic wastewater.

The occurrence of agricultural pesticides in continental waters has been widely reported. A literature review made by Milde et al. reports the occurrence of 22 different pesticides in ground waters of 34 localities in the USA and Europe [12].

Data provided by the GEMS/WATER programme collected from 448 sampling stations in 59 countries, clearly show the impact of organic pollutants of agricultural origin, such as DDT, DDE, aldrin, dieldrin, endrin, mirex, lindane, and other isomers of hexachlorocyclohexane (HCH), on continental waters (rivers, lakes and ground water) [13,14].

As a consequence of such widespread contamination of aquatic resources, several pesticides - primarily herbicides - have been detected in drinking-water. These have the potential, even in very small concentrations, to cause chronic adverse effects in the human populations consuming contaminated water.

Furthermore, the presence of pesticides in water resources may lead to the emergence of some degree of resistance in vectors of water-borne and water-related diseases, making the application of routine vector control techniques inefficient if not useless.

Water management for sustainable agricultural development

The challenge of achieving sustainable water resources development and management, in a situation of increasing pollution and growing competition for the use of limited water resources, requires a global commitment and the joint efforts of all water-consuming sectors.

Domestic and municipal water needs now account for about 7% of total withdrawals. By the year 2000, with improved living standards and amenities, domestic use will account for 14-16% of withdrawals in Europe, South America, and Australia/Oceania, and 9-10% in Asia, Africa and North America [7].

On the other hand, water losses in urban distribution systems continue to be very high mainly in developing countries. A survey made in 1986 in 15 large Latin American cities provided figures of unaccounted-for water ranging from 39 to 67%, with an average of 55%, about half being associated with water losses [15].

Water authorities in both industrialized and developing countries should implement operational control programmes to reduce losses in water distribution systems. In the city of Sao Paulo, Brazil, an intensive programme of this nature was carried out by SABESP, the Water Authority for the State of Sao Paulo reducing the unaccounted-for water from 36.3% in 1977 to 27.1% in 1982. The savings allowed for an increase of about 46% in the number of house connections, without the need to increase water production.

Water withdrawal for industry and energy production is about 40-80% in the industrialized world and 3-5% in developing countries. The global average is today about 21%. However, it is expected that by the year 2000 this figure will rise to 24-28%, with increasing demand in developing countries where the industrial production will account for 25% of the global industrial output [16].

The industrial sector, especially in developing countries, can make substantial water savings if properly managed in terms of water consumption. Modern industrial systems are available that need less water for processing (and consequently produce less wastewater) and these should replace the traditional water consuming systems still operating in many industrialized or developing countries. Industrial pollution control should be enforced by replacing the commonly utilized "end of pipe treatment" by the "in-plant control" concept which provides better effluents and in most cases allows for water recycling as well as reclamation and reuse of by-products along the industrial lines of production.

Application of appropriate differential tariffs for different classes of users, as well as progressive tariffs throughout the full spectrum of consumption, will contribute substantially to the reduction of water demand on both domestic and industrial sectors.

Worldwide, water withdrawal for irrigation, now about 63% of total withdrawals, is expected to decline to 55% by the year 2000. Since the increase of growth rates in average crop yields has to be achieved through irrigation, it is almost certain that withdrawal for irrigation will continue to rise [7].

The three major water-demanding sectors (domestic and municipal, industrial, and irrigation) account today for about 91% of the total withdrawal, a figure which may increase to 95% by the year 2000. Irrigation will continue to be the largest demanding sector, and special consideration should be given to it to maintain food sustainability. A global effort is needed on issues related to appropriate policies, institutional structures, research, development, education and training, as well as socioeconomic, legal, financial and technical aspects.

A comprehensive approach is needed which should aim to improve the exploitation, conservation and management of water resources.

Increasing the availability of water

There are several potentially viable options for increasing access to water resources through the exploitation of some portion of the atmospheric water which does not become naturally available. Some of them are well established, and provide a sure input to the water balance in most countries. Others are highly speculative and still require substantial work to assess their real significance in terms of volumes provided as well as their technical and economical feasibility.

Use of wastewater for irrigation

In the last two decades, there has been an increase in the utilization of wastewater for crop irrigation, mainly in the arid and semi-arid regions of both developed and developing countries.

The shift to this traditional practice of reuse has several causes which include the increasing scarcity of alternative waters for irrigation; the high cost of artificial fertilizers; the demonstration that health risks and soil damage are minimal if the necessary precautions are taken; the high cost of advanced water treatment plants; the sociocultural acceptance of the practice; and the recognition by water resource planners of its value. Studies made in several countries have shown that crop yields can increase if wastewater irrigation is provided under appropriate management [17].

For example, in a city of one million inhabitants using an average of 200 litres of water per person per day of which 85% is returned to the sewerage system, the volume available would be of about 62 million m^3/year which would allow the irrigation of about 6 200 hectares, at an application rate of 10 000 m^3/hectare.

Well planned and properly managed agricultural reuse projects can improve environmental conditions by reducing damage to hydraulic resources and by developing the surroundings of large cities. The factors which may lead to improvement of the environment when wastewater is used rather than being disposed of in other ways are the following:

- The conservation of water resources for water supply and irrigation.

- Avoidance of discharge to surface waters with its unpleasant effects, and preventing the development of anaerobic conditions in rivers and eutrophication of lakes and reservoirs.

- Saving ground water resources in areas where over-utilization of these resources in agriculture causes problems of water level depletion and salt intrusion.

- Favouring soil conservation by the build-up of humus on agricultural land and prevention of land erosion.

- Helping to control dust storms and desertification in arid zones through the irrigation and fertilization of tree belts, thus reducing the environmental degradation caused by the search for fuel wood.

- Improvement of urban living conditions and recreational activities through irrigation and fertilization of green spaces such as gardens, parks and sports facilities.

On the other hand, there are some potentially negative environmental effects that should be carefully considered in reuse planning and system control.

- Ground water contamination. The main problem is associated with nitrate contamination when ground water is used as a source of water supply. This may occur when a highly porous unsaturated layer above the aquifer allows for deeper percolation of nitrates from the wastewater. However, when a deep homogeneous unsaturated layer capable of retaining nitrates lies above the aquifer, there is little chance of contamination. The uptake of nitrogen by crops may reduce the possibility of nitrate contamination of the underground water-table, depending on the rate of uptake by plants and the rate of wastewater application to crops.

- Build-up of chemical contaminants in the soil. Depending on the characteristics of the wastewater, long-term irrigation may lead to build-up of toxic materials (heavy metals, refractory organics, specific ions such as boron) and salinity in the unsaturated layers of agricultural soil. To avoid reaching toxic levels and the absorption of toxic substances by crops, wastewater used for irrigation should be of predominantly domestic origin. Adequate soil drainage is also of fundamental importance in minimizing soil salinization.

- Long-term irrigation schemes may create habitats for the development of disease vectors, such as mosquitos and snails. This possibility is minimized if appropriate design and maintenance prevents the occurrence of stagnant water in distribution canals and drains and/or if standard vector control techniques are used. Where partially-treated wastewater (having a high content of organic matter) is used, care should be taken to prevent the increased breeding of culicine mosquitos (with the risk of spread of lymphatic filariasis in endemic areas).

- Microbial and/or helminth infections may also be transmitted through wastewater reuse schemes, where appropriate health protective measures have not been enforced.

WHO has published guidelines for the safe use of wastewater in agriculture and aquaculture [18], stressing that groups at risk (field workers and their families, crop handlers, consumers of crops and people living near to wastewater-irrigated fields) should be protected through the application of four integrated measures: wastewater treatment, crop restriction, wastewater application techniques and human exposure control [19].

Saline waters

Saline waters are found in estuaries, coastal lagoons, land-locked lakes, the ground of many desertic areas of the world, and as drainage from irrigation fields. While large volumes are available, most of such resources remain untouched because technical and economic factors limit their reuse or treatment to produce water with adequate quality for most beneficial uses. However, many countries with critical water shortage problems have enforced reuse, or have installed large sea water and brackish water desalination plants for the production of water for drinking as well as for irrigation [20,21].

The cost of treating water from conventional sources ranges from US$ 0.1/m^3 to a maximum of US$ 0.5/m^3 depending on difficulties in treatment and each country's economic situation. For brackish waters the desalination cost varies from US$ 0.4 to US$ 1.2/m^3 and for seawater from US$ 1.2 to about US$ 2.0/m^3.

The use of drainage waters is spreading in many countries since it allows for the expansion of the irrigated area and reduces the problems related to environmental pollution.

It is now recognized that waters of much higher salinity than those customarily classified as suitable can be used for irrigating selected crops [22]. Waters with salinity ranging from 3 000 to 5 000 mg/litre of total dissolved solids will produce high yields of crops such as cotton, barley, wheat, sugar beet, rye, grass and certain wheat-grasses. Salt-tolerant trees include the date palm, olive, pomegranate, and pistachio [23].

Several countries with acute water shortage are making use of drainage water for irrigation [24]. At present, approximately 4.6 million cubic metres of drainage water are used annually for irrigation in Egypt and several land development projects are under way to increase this to about 7 billion cubic metres per year by the year 2000. The general expectation is that the overall agricultural production in Egypt will increase by 10-15% with this additional source of water for irrigation. The use of saline water for irrigation must be done under appropriate management to prevent salts from building up in the soil. Management methods include irrigation methods, scheduling of wastewater application, appropriate drainage to facilitate leaching and monitoring of the chemical characteristics of the wastewater (such as sodium absorption rate, technical exchange capacity, presence of heavy metals, boron, refractory organics, etc.).

To extend the use of saline water for irrigation, considerable research is being carried out by several institutes and research centres around the world. Basic themes of investigation include genetic improvement of crops for production under stress conditions; crop management to increase productivity of stressed, water-logged and salt-affected lands; cultivation of non-conventional salt-tolerant crops on problem soils; changes in the reproductive physiology of some plants; and induction of salt tolerance through hormones or radiation [25,26,27,28,].

Other potential sources of water

Other theoretical possibilities of increasing access to water which is not naturally available are: rainfall harvesting [29,30], rainfall augmentation, subsurface dams [31], fog harvesting [32], and ground water mining of deep, unrechargeable aquifers.

Water conservation

Worldwide, the average efficiency of irrigation systems is estimated at only 37%, and in many developing countries the efficiency of water-use can be as low as 20% [33]. Water losses are very high in distribution canals through seepage and because of lack of appropriate maintenance of dykes and ditches. Appropriate lining of canals will provide considerable water savings.

There are many other possibilities of economizing in the agricultural use of water. Some of them are controversial or are in the early stages of development, or can provide substantial water savings only when applied under special conditions. These are the techniques related to: reduction of evaporation from water surfaces; reduction of evaporation from soil surfaces; reduction of cropland percolation losses; and the use of appropriate irrigation techniques [34,35,36,37,38].

Water management

Planning and appropriate management of the available water resources are certainly the most reliable and efficient ways to optimize water use and crop yields in irrigated agriculture.

The planning process should start with the development of national policies based on resource availability and potential for meeting crop demands at regional levels. Action to build new irrigation systems, or to extend or improve performance of existing ones, should be focused on potential projects that respond to urgent needs and appear technically and economically feasible.

Water supply for irrigation should be managed at basin level, supported by hydrometeorological and agrometeorological networks on the one hand and crop-water irrigation simulation models on the other. This will improve supply conditions during water shortage situations, favour more rational water allocation, and improve irrigation scheduling. Demand management of the irrigation system may include changes in water allocation to users, reduction of periods of supply and even reduction of volumes of water delivered.

Farmers should be urged to adapt farm and crop management to enforced rules on water allocation and delivery. To do so, farmers should have technical and institutional support in the following areas: the selection and optimization of cropping patterns according to water availability; scheduling irrigation, taking into consideration restrictions on water volumes; the improvement of irrigation efficiencies; and the limitations of the irrigation system and of its operation and maintenance [38]. The on-farm demand management should be directed to making the best possible use of the water conservation methods.

Water charges may also play an important role on demand management. In many countries, water charges are not based on volumes of water delivered, but the operation and maintenance costs of water supply are recovered on the basis of the land area irrigated, or on water shares owned by the farmers [39]. However, there is no doubt that volumetric water charges and progressive tariffs are some of the most effective mechanisms to improve demand management.

References

1. Irrigation and drainage research - A proposal for an internationally-supported programme to enhance research on irrigation and drainage technology in developing countries, Vol. I, World Bank/UNDP in collaboration with ICID, April, 1990.

2. World agricultural statistics, FAO Statistical Pocket Book, Rome, Food and Agriculture Organization of the United Nations, 1987.

3. Production 1988, FAO yearbook, Vol. 42, Rome, Food and Agriculture Organization of the United Nations, 1989.

4. World Resources 1988-89, World Resources Institute and International Institute for Environment and Development, in collaboration with the United Nations Environment Programme, New York, Basic Book, Inc., 1988.

5. Food 2000, Global policies for sustainable agriculture, a Report of the Advisory Panel on Food Security, Agriculture, Forestry and Environment to the World Commission on Environment and Development, USA, Zed Books, Ltd., 1987.

6. Piper, B.S., Water resources for irrigation, Presented at: The World Water '86 Conference, Institution of Civil Engineers, 14-16 July 1986, at Olympia, Kensington, London, 1986.

7. World Resources 1990-1991. A report by the World Resources Institute, in collaboration with UNEP and UNDP, New York, Oxford University Press, 1990.

8. Postel, S., Water for agriculture: Facing the limits, Washington, DC, December, 1989 (Worldwatch Paper 93).

9. Schaake, J.C., From climate to flow, American Association for the Advancement of Science, New York, John Wiley & Sons, 1990.

10. Meybeck, M. et al., ed., Global freshwater quality: A first assessment, GEMS, World Health Organization, United Nations Development Programme, Oxford, United Kingdom, Blackwell Reference, 1990.

11. GEMS: Global Environmental Monitoring System, Global pollution and health. Results of health-related environmental monitoring, Geneva, World Health Organization/United Nations Environment Programme, 1987.

12. Milde, G. et al., Problems of pesticide use and the impact on groundwater. In: An International Symposium on Impact of Agricultural Activities on Groundwater, Prague, Czechoslovakia, 1982.

13. GEMS/WATER database, Burlington, Ontario, Canada Centre for Inland Waters, 1985-87.

14. Meybeck, M., The GEMS/WATER Programme (1978-1983) Water Quality Bulletin, 10(4): 172-178 (1985).

15. Hueb, J.A., El Programa de Control de Perdidas como Estrategia para el Desarrollo de Instituciones de Aqua Potable e Saneamiento, Hojas de Divulgacion Tecnica, no. 34, CEPIS, Lima, Peru, August 1986.

16. Sustainable water development and management: A synthesis, Geneva, United Nations Environment Programme, 1989.

17. Mara, D.D. & Cairncross, S., Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture, WHO/UNEP, Geneva, World Health Organization, 1989.

18. Health guidelines for the use of wastewater in agriculture and Aquaculture, Report of a WHO Scientific Group - WHO Technical Report Series, 778, 1989.

19. Hespanhol, I., Guidelines and integrated measures for public health protection in agricultural reuse systems, J. Water SRT-Aqua, 39(4): (1990).

20. Dabbagh, T.A. & Al-Sabaqui, A., Desalination, No. 73, Amsterdam, Elsevier Science Publishers B.V., 1989.

21. Desalination of brackish waters for production of fresh water for domestic and agricultural water supplies in selected countries of the ESCWA region, Economic and Social Commission for Western Asia, Natural Resources, Science and Technology Division, United Nations, 1987.

22. Hamdy, A. & Lacirignola, C. Saline water practices management, Presented at: The Regional Seminar on Wastewater Reclamation and Reuse, Cairo, Egypt, Ministry of Public Works and Water Resources, Water Research Centre, FAO/UNDP/World Bank, 1988.

23. NAS, More water for arid lands, promising technologies and research opportunities, Washington, DC, National Academy of Sciences, 1974.

24. Abu-Zeid, M., Egypt's policies to use low-quality water for irrigation, Presented at: The Regional Seminar on Wastewater Reclamation and Reuse, Cairo, Egypt, Ministry of Public Works and Water Resources, Water Research Centre, FAO/UNDP/World Bank, 1988.

25. Abdullah, Z.N. et al., Salinity induced changes in the reproductive physiology of wheat plants. Plant and cell physiology, 19(1): (1978).

26. San Pietro, ed., Biomass production of food and fiber crops using highly saline water under desert conditions, biosaline research: A look to the future, Indiana, Plenum Publishing Corporation, Indiana University, 1982.

27. Abdullah, Z.N. & Ahmad, R., Salinity induced changes in the reproductive physiology of cotton plants, prospects for biosaline research, Proceedings of the US- Pakistan Biosaline Research Workshop, Pakistan, Botany Dept. Karachi University, 1986.

28. Ahmad, R. & Abdullah, Z.N., Biomass production on sandy deserts using highly saline waters, Biotechnology and Bioengineering Symp. No. 12, New York, John Wiley & Sons, Inc., 1982.

29. Dillaha III, T.A. & Zolan, W.J., Rainwater catchment water quality in micronesia, Water Research, 19(6): (1985).

30. The introduction of rainwater catchment tanks and micro-irrigation to Botswana, London, Intermediate Technology Development Group, Ltd, ITDG, September, 1969.

31. Wolde, Gezahegne, Sub-surface flow dams for rural water supply in arid and semi-arid regions of developing world, No. B18, Tampere, Finland, Tampere University of Technology, 1986.

32. Schemenauer, R.S. & Cereceda, P., The collection of fog water in Chile for use in coastal villages, Presented at: The 6th IWRA World Congress on Water Resources, Ottawa, Canada, May 29 - June 3, 1988.

33. Brown, R.L. et al., State of the world 1986, A Worldwatch Institute report on progress toward a sustainable society, London, W.W. Norton & Company, 1986.

34. Pereira, L.S. & Teixeira, J.L., Irrigation under limited water availability: Water saving techniques, Portugal, Department of Agricultural Engineering, Technical University of Lisbon, (in press).

35. Rangeley, W.R. & Barnsley, R., New developments in surface irrigation, Presented at: The World Water '86 Conference, 14-16 July 1986, Olympia, Kensington, London.

36. Economising the use of agricultural water, Water & Sewage International, 2(7): (1990).

37. Pereira, L.S., Mitigation of droughts; 2. Irrigation, ICID Bulletin, 38(2): (1989).

38. Squire, M.D., Recent developments in sprinkler and drip irrigation, Presented at: The World Water '86 Conference, 14-16 July 1986, Olympia, Kensington, London.

39. Jensen, M.E. Irrigation research and development in the next decade, Presented at: The Irrigation Research and Development Conference, Lethbridge, Alberta, Canada, 17-20 July, 1990.

7. CONSEQUENCES OF ENVIRONMENTAL CHANGE FOR FOOD AND AGRICULTURAL PRODUCTION

Environmental degradation due to population growth

The increase in the human population has important consequences for the resources entering agricultural production; firstly through the rising demand for these resources, and secondly, because of a reduction in the quality of these resources. Each year, an additional 80-100 million people have to be fed, clothed and their other needs provided for. In this process and due to general worldwide economic growth, environmental resources will be used, and could be irreversibly degraded, by deforestation, unsustainable land use, over-exploitation and pollution of water resources.

Climatic warming

The greenhouse effect is not new. It has been keeping the Earth warm for billions of years. Gases are mainly responsible for this natural greenhouse effect, the most important being water vapour and carbon dioxide which contribute about 65% and 22%, respectively, of the effect [1]. With greenhouse gases present, the long-wave radiation emitted from the surface of the earth is partly absorbed and then re-emitted by the gases of the higher troposphere.

The "man-made" greenhouse effect is primarily caused by an increased production of gases. Additional carbon dioxide is responsible for 60% of the man-made effects, methane for 20%, and chlorofluorocarbons, ozone and nitrous oxide together account for 10%. The agricultural contribution to the total man-made carbon dioxide production of 5 600 million tonnes per year is estimated at 400-1600 million tonnes, the result of burning wood in the process of deforestation and decomposition of organic matter of deforested land [2]. The global production of methane reaches 220-460 million tonnes per year, 70-80 million tonnes through enteric fermentation in domestic ruminants, 60-140 million tonnes through anaerobic decomposition of organic matter in paddy fields, and 30-100 million tonnes through the burning of biomass during land reclamation [3].

According to climatic model projections till the year 2050, the impact of this additional greenhouse gas production on average temperature increases depends on the geographic latitude [3,4]:

- low latitudes (tropics and subtropics) less than +3 °C;
- mid-latitudes (from the subtropics to 60 °N and 60 °S, respectively, where the most important food producing regions of the world are found) +3 °C ± 1.5 °C; and
- high latitudes (from 60 °N and 60 °S to the poles) up to +7 °C in summer and up to +4 °C in winter.

A general implication of these projected climatic changes in lower latitudes is that any possible positive consequences, such as the effect of additional carbon dioxide production on plant growth, will be outweighed by a deterioration in other important factors, such as decreased water resources and increased desertification [5]. The regions in the middle and higher latitudes may be relatively better off compared to the lower latitudes.

The subject is briefly reviewed in the Report of the Panel on Energy of the WHO Commission on Health and the Environment which draws on two recent authoritative accounts [6,7].

Air quality

Agriculture is especially affected by two types of air pollution: direct harmful effects such as are caused by acidifying substances, and indirect effects induced by secondary pollutants.

The acidifying atmospheric substances that are of major environmental concern are man-induced higher concentrations of sulfur dioxide and nitrogen oxides which are of particular importance at local and regional levels. There is strong experimental evidence of the negative effect of acid rain on plant growth rates [8], and of shifts towards acidity in the pH of lakes and rivers which cause a decline in fish populations and in their fecundity. There is concern that acid precipitation may mobilize metals locked in soil and thus cause them to enter the human diet through drinking-water and food.

Ozone is a secondary pollutant which is formed by complicated photochemical processes from primary air pollutants. Its negative impact on crop yields is best documented for the USA [9], which reports a yield reduction of 5-10% for the majority of crops tested. Estimates for 1984 put the economic benefits (consumer plus producer surpluses) of a 25% ozone reduction in the USA at US$ 1.8 billion [10]. Data on damages are not available for other situations and hence no economic studies have been carried out.

The production of various air pollutants, such as chlorofluorocarbons, may have an indirect adverse impact on agricultural production [11]. By destroying the stratospheric ozone layer they lead to an increase in ultraviolet B radiation which is known to be harmful to the biota and to human health.

Growing populations and economies will increase energy demand. Due to the wide area of soils with low pH and reduced buffer capacity, harmful effects of primary and secondary pollutants on soil quality are to be expected, especially in developing countries. In addition, it is likely that these countries will not be able to afford more expensive technology to reduce air pollution.

Water resources

Global water use can be subdivided into three broad categories: irrigation, industrial use and public use. Total annual water use reached 3 500-4 000 km^3 in 1985 with an average rate of increase of about 6% a year [11]. In the developed countries, industries account for 40% or more of all water use, while in developing countries, the overwhelming share of water is for irrigation. From 1900 to 1985 the irrigated crop land area has trebled from 40 million to 120 million hectares [12]. According to different sources, some of this expansion has been at the cost of using fossil water and of the overdrafting of rechargeable aquifers. These problems are aggravated by the fact that each year inefficient use of irrigation water is considered to render unproductive some 1-1.5 million hectares of good crop land. It is estimated that throughout the world only some 37% of irrigation water is consumed by plants. These problems are especially acute in India and Pakistan [13].

The global average rainfall is expected to be higher by about 10% due to the greenhouse effect [14]. This figure tends to increase with the magnitude of the regional warming, 10% corresponding to a warming of about 4 °C. Due to the combination of the effects of changes in temperature and rainfall, increased soil humidity can be expected, especially in high latitudes. In contrast, a decline in soil humidity is predicted for low latitudes due to higher transpiration rates. This implies a rise in the demand for irrigation water which can be satisfied either by increasing water supply from natural ground or surface water or by building new artificial reserves (dams). Model calculations [15] demonstrate the cumulative effects of climatic change on irrigation water requirements:

- in dry regions, a decrease in precipitation of 25% could only be compensated by a fourfold increase in reservoir capacity; and

- given the same quantity of irrigation water as is available today, a rainfall decrease of 20% and an increase in evapotranspiration of 15% would result in a 75% reduction of the area irrigated.

The warmer air resulting from the greenhouse effect will have a greater moisture capacity. In the future, therefore, heavier rainfall is more likely to occur and this in turn will increase soil erosion and reduce the water and nutrient absorption capacity of eroded soils.

Desertification

Desertification, the ultimate consequence of soil degradation, is a product of climate and human activities such as deforestation and unsustainable land use; it results from salinization caused by inappropriate irrigation methods and all forms of accelerated soil erosion. According to FAO [12], the annual loss of productive crop land due to soil erosion and degradation is estimated at 6-7 million hectares, of which 1-1.5 million hectares are abandoned due to poor irrigation practices. UNEP [11] estimates that each year some 21 million hectares are reduced to a state of near or complete uselessness, and projections to the year 2000 indicate that losses on this scale will continue if nations fail to step up remedial action. Higher average temperatures as a consequence of climatic change will cause increased mineralization of organic matter. The content of organic matter of soils will decrease despite higher production of biomass in many regions and this will aggravate the erosion problem. Table 7.1 shows global estimates of soil erosion in different climates.

Table 7.1. Global estimates of soil erosion (tonnes/km^2/year) in different climates

	Erosion (tonnes/km^2/year)		
Ecological region	Past	Present	Future
Tropical	160	710	1920
Subtropical	130	720	1020
Subboreal	140	1150	1260
Boreal	40	300	470
World	130	710	1360

Source: Ref. 16.

The impact of soil erosion on yield varies significantly according to soil type. Tropical soils having a shallow effective rooting depth, with the concentration of plant-available nutrients and water reserves in the top few centimetres, suffer the most severe erosion-induced declines in productivity. This can lead to complete yield loss [17].

Estimates for the USA put annual yield and fertilizer losses due to soil erosion at US$ 5 billion, the short-term on-site costs of erosion totalling US$ 18 billion [18]. Agricultural non-point sources are thought to be major contributors of conventional pollutants (sediment, biochemical oxygen demand, dissolved solids) and of chemical pollutants (fertilizer, pesticides). The off-site environmental costs of erosion are estimated to total at least an additional US$ 6 billion annually [19]. These off-site pollutants have a negative impact on aquatic ecology. They reduce the productivity of aquatic systems and the water storage capacity in lakes and reservoirs and decrease drinking-water quality.

An increased number of extreme climatic events in the context of the expected greenhouse effect, such as heavy rainfall, droughts and storms, could aggravate all forms of soil erosion with the negative ecological and social consequences and costs described.

Genetic resources

Concern over the loss of biological diversity has so far been defined almost exclusively in terms of species extinction. Although extinction is perhaps the most dramatic aspect of the problem, it is by no means the whole problem. The diversity of genetic resources must be maintained at three different levels: the ecosystem, the species and the genetic levels [20].

The primary cause of the decrease in organic diversity is not direct human exploitation or malevolence, but the habitat destruction that inevitably results from the expansion of human population and human activities. The most important reason for preserving diversity is not to endanger the role that microorganisms, plants, and animals play in providing free ecosystem services, without which society in its present form could not exist [21].

The use of high-yielding varieties narrows dangerously the genetic basis of agricultural production. Valuable but primitive or locally distributed varieties are to some extent the victims of their own utility, since the higher productivity and greater disease and pest resistance that give the advanced varieties such an advantage are in large measure derived from them [22]. The genetic uniformity of modern cultivars has led to greater vulnerability of crops, due to a narrow genetic base and large acreages under single cultivars [23].

Recently, concern has been expressed over the patenting of living organisms which may have undesirable consequences on biological diversity. Such legislation could contribute to a reduction in the sharing of germplasm and information between researchers [20].

Economic and social context

It is essential to consider the various environmental influences described in relation to the general social and economic context, some important aspects of which are briefly outlined below:

- The ratio between commodity prices and the prices of production factors such as labour, land, seed, fertilizers, pesticides and water influences the farmer's choice of the agricultural production systems, in terms of input level, crop rotation and the yield obtained. This in turn has an impact on the sustainability of agricultural production systems.

- Commodity prices have an impact on the area cultivated. Higher prices induce the cultivation of marginal land (e.g., investments for irrigation) and a higher portion of the area sown is harvested [24]. Total future agricultural output will therefore not depend exclusively on the crop area potentially available but will be the product of the crop area harvested multiplied by the yield. On the other hand, dumping of agricultural surpluses by industrial nations leads to unstable world market prices. These act as disincentives to local producers in unprotected developing countries markets.

Agricultural production is thus hampered as is the protection and development of production resources [10]. Furthermore, world market prices for agricultural commodities are unstable due to an inelastic reaction of prices to variations in supply. More frequent regional yield losses due to extreme climatic events, such as droughts caused by the expected man-made greenhouse effect, could increase this instability.

- Technological progress and its application will largely determine the extent to which the potential for future sustainable and expanded production in agriculture can be realized and used to meet world food needs. However, these are influenced decisively by national economies, the world economy and by the market situation. The development and use of new technologies will depend on the incentives offered by these three elements.

- Finances, banking and credit systems are indispensable elements for the successful introduction of new technologies and sustainable production methods.

- Education and training systems are equally necessary. It can be expected that the conflicting interests of ecological sustainability and economic demands of providing for growing populations will increase, especially in countries in low latitudes.

References

1. Deutscher Bundestag, ed., Schutz der Erdathmosphäre: Eine internationale Herausforderung; Zwischenbericht der Enquete-Kommission des 11. Bonn, Deutschen Bundestages "Vorsorge zum Schutz der Erdatmosphäre, 1988.

2. Detwiler, R.P. & Hall, C.A.S, Tropical forests and the global carbon cycle, Science, 239: 92-93 (1988).

3. Bolin, B., et al., ed., The greenhouse effect, climatic change, and ecosystems. Chichester, New York, Brisbane, Toronto, Singapore, John Wiley & Sons, 1986 (SCOPE; 29) (edition 1988).

4. Schönwiese, C.D. & Diekmann, B., Der Treibhauseffekt: Der Mensch ändert das Klima. Stuttgart, Deutsche Verlags-Anstalt, 1987.

5. Flückiger, S., Auswirkungen möglicher anthropogener Klimaveränderungen auf die Entwicklung in der schweizerischen Landwirtschaft. Diploma thesis, Zurich, Institute of Agricultural Economics, Swiss Federal Institute of Agricultural Economics, 1990.

6. WMO/UNEP, IPCC First assessment report, the report of the Intergovernmental Panel on Climate Change to the Second World Climate Conference, Geneva, WMO/UNEP, 1990.

7. WHO, Potential health effects of climate change, Report of a WHO Task Group, Geneva, World Health Organization, 1990 (unpublished document WHO/PEP/90.1).

8. Chadvik, M.J., Acid depositions and the environment, AMBIO, 12: 80-82 (1983).

9. Irving, P.M., Gaseous pollutant and acid rain impacts on crops in the United States: A comparison. Environmental technology letters, 8: 451-458 (1987).

10. Adams, R.M. et al., A reassessment of the economic effects of ozone on US agriculture, JAPCA, 39: 960-968 (1989).

11. United Nations Environment Programme, The state of the world environment, UNEP, Nairobi, 1987.

12. FAO, Sustainable agricultural production: implications for international agricultural research, Rome, Food and Agriculture Organization of the United Nations, 1989, (FAO research and technology, paper 4).

13. Maurits la Rivière, J.W., Bedrohung des Wasserhaushalts. Spektrum der Wissenschaft, pp. 80-87, November 1989.

14. Rowntree, P.R., Predicted climate changes under "greenhouse-gas" warming. In: Jackson, M.T. et al., ed. Climatic change and plant genetic resources, London, New York, Belhaven Press, pp. 18-33, 1990.

15. Nemec, J., Climate and development: Agricultural practices and water resources. In: Kape, J.-J. et al., ed., Climate change and variability and the resulting social, economic and technological implications, Berlin, Heidelberg, New York, Springer-Verlag, 1990.

16. Golubev, G.N., Soil erosion and agriculture in the world: An assessment and hydrological implications. IAHS Publ. No. 137, p. 261 (1982).

17. Lal, R., Effects of soil erosion on crop productivity. CRC Critical reviews in plant sciences, 5: 303-367 (1987).

18. Pimentel, D., Soil erosion effects on farm economics. In: Harlin, J.M. & Berardi, G.M., ed., Agricultural soil loss: processes, policies, and prospects, Boulder and London, Westview Special Studies in Agriculture Science and Policy, pp. 217-241, 1987.

19. Clark II, E.H., Soil erosion: off-site environmental effects. In: Harlin, J.M. & Berardi, G.M., ed., Agricultural soil loss: processes, policies, and prospects, Boulder and London, Westview Special Studies in Agriculture Science and Policy, pp. 59-89, 1987.

20. OTA (Office of Technology Assessment), Technologies to maintain biological diversity. Science Information Resource Center, Philadelphia, J.B. Lippincott Company, 1988.

21. Singh, D.P., Breeding for resistance to diseases and insect pests. Berlin, Heidelberg, New York, Springer-Verlag, 1986 (Crop Protection Monographs).

22. Ehrlich, P.R., The loss of diversity: causes and consequences. In: Wilson, E.O., ed. Biodiversity, Washington, National Academy Press, pp. 21-27, 1988.

23. IUCN (International Union for Conservation of Nature and Natural Resources), World Conservation Strategy, Gland, 1980.

24. Rosenberg, N.J., Global climate change holds problems and uncertainty for agriculture. In: Tutwiler, M.A., ed. Agriculture in a global setting: an agenda for the future. Washington, DC, National Center for Food and Agriculture Policy, 1987.

8. FOOD PROCESSING - FROM RAW MATERIALS TO FULLY PROCESSED PRODUCTS

While much effort has been directed to increasing food production in developing countries, substantially less attention has been paid to the problems of food processing and distribution. Moreover, the studies that have been done have concentrated on the development of new technology. It is only recently that any inquiry has been directed towards the impact of these technologies on the economy and environment of the countries in which they are introduced.

Increasing demand for food processing

Great demands will be placed upon global food processing and distribution systems as a result of the increasing urbanization of the world's population. To provide urban consumers, often at great distances from the sources of production, with safe and nutritious food requires a food processing industry and a distribution system of some sophistication. The increasing separation of the consumer from the food production sector results in a loss of the traditional means used by the consumer to ensure the quality and safety of food, thus making the consumer even more dependent on a functional and responsible food processing industry.

Food enrichment and fortification

It seems likely that the development of new food products will increasingly result in the use of nutrients for the purposes of enrichment and fortification. Continuing public concern over chemicals in food, at least in the industrialized countries, will lead to the development of more rational mixtures of additives composed of judicious combinations of synthetic and natural products.

Presentation and production processes

It is probably in packaging that the most significant changes with an impact on the environment will occur in the food industry. In spite of the diversity of materials used in packaging before the 20th

Century, it was the introduction of plastics, beginning in 1936 with the discovery of polyethylene, that led to major environmental problems. Plastic's light weight and relative unbreakability appeared to make it clearly superior to any other form of packaging material. There is no question that plastics do have many advantages. They can be engineered to provide a range of desirable in-use characteristics, in many cases equal to or better than that of other packaging materials. Moreover, the ability to manufacture containers on site and to produce unique containers has led to the exceptional growth of plastics in food packaging.

Development of regulatory infrastructure

Contamination of foods and spoilage are responsible for considerable losses of food. Although a substantial portion of these losses can be prevented by better, carefully controlled technology, the safety of the increasingly complex technological base of the food industry will require the development and implementation of enforceable regulations and their associated infrastructure. Such structures are present in much of the industrialized world, but often do not exist in developing countries. Not only may the food laws in these countries be inappropriate, when they exist at all, but the infrastructure of inspectors, scientists and regulatory authorities is inadequate. The useful application of modern technology cannot occur without effective regulatory structures.

For the industrialized countries, there is a need to harmonize regulations and standards to ensure the free flow of food among all of the countries of the world. The time has arrived to think about one global food supply, rather than a series of individual or regional ones.

Energy and water needs

Among the many factors to be considered in the introduction of new technologies for the processing and distribution of food, the increased need for energy for the operation of these facilities and the availability of potable water are among the most essential. It is important to emphasize that the successful operation of a modern food processing system, no matter how simple its technology, depends ultimately on the availability of potable water. Unsafe water is, by far, the most important source of contamination of processed foods. For this reason, countries must devote a major portion of their environmental control programmes to the assurance of potable water supplies.

Energy needs also rise with the increasing sophistication of the food processing industry. There are, however, a number of possible alternative energy sources available to developing countries. For example, the use of solar and wind energy to dry products represents a considerably lower demand on fossil fuels for the drying of foods than does the use of more efficient, but more energy-intensive mechanical drying devices. The development of technologies appropriate to national or local cultures will have to take the availability of potable water and total energy into account, in order to reach a compromise between the efficiencies of modern technology and the serious deficits in these resources in the developing countries.

Environmental and health consequences

The environmental and health consequences of the growth and development of a food processing industry are substantial. It has been estimated that more than two-thirds of the wastewater and three-quarters of the solid waste per person produced in countries such as the USA are industrially derived, and, of this, a substantial portion is the output from the food industry. Waste from food processing can be a major cause of pollution if not treated before disposal. These wastes are characterized by a high content of suspended solids and a high rate of oxygen demand. While these represent the classical environmental concerns of the food processing industry, there are additional consequences, often not considered in the context of environmental health. For example, one important consequence of increasing dependence on food processing is the possibility of increasing exposure to pathogen-contaminated food.

Efficiencies are generated in any industrial activity by an increase in size, thus decreasing unit cost. Although this is a highly desirable outcome, it is also true that concentrating food processing in relatively few plants makes it likely that any breakdown in the system allowing pathogen contamination of the food will affect an increasingly large number of people.

A special problem exists with the disposal of solid waste materials such as non-biodegradable plastics. One of the important advances in the food industry over the last 30 years has been the development of light-weight, easily produced plastic containers, which are disposed of in municipal landfills. The amount of plastic in municipal solid waste in the USA is a modest 13%, when appraised on a weight basis. Because of their relatively low density, plastics make up considerable volume, with little weight. By the middle of the 1990s, it has been estimated that plastic-based packaging is expected to constitute 25% of landfill volume. The result of these observations has been of increasing concern to environmental scientists and the public. The food industry has recognized this problem and has begun to consider criteria for packages to be environmentally acceptable.

Any such package must also serve the other functional roles of packaging; food stability, preventing contact with insects, spoilage and pathogenic organisms and minimizing shock damage. A number of solutions to the solid waste problem have been proposed, applicable primarily to the industrialized world. These include the development of relatively expensive biodegradable plastic material, reduction in the total package required, and the development of recycling and incineration technologies that are in themselves environmentally acceptable. For the developing world, the problem is more complex since each of these solutions has a relatively high economic cost. It is essential for this issue to be considered early in the development of advanced food-processing industries in the developing world.

A special problem exists for fermentation plants in which microorganisms are used to produce or process food. All food plants suffer from the problem of dealing with release of processing water and solid materials with a very high organic content, but fermentation plants have the additional problem that their outputs consist not only of a dense organic mass, but also contain a large number of viable microorganisms. Such biomasses need to be disposed of in a safe and economical way. Among the proposals suggested is their sterilization and use as animal feed, or with proper treatment to use them as fertilizer. The most efficient way of dealing with all organic outputs from food processing plants, including fermentation plants, is the recycling of this material into fertilizer or animal food. Composting is an excellent way of treating these wastes. One of the goals of modern genetic manipulation might be the development of microorganisms that can compost in a short period of time, thus increasing the efficiency of the process. The output of some kinds of food plants can be used directly on fields. For example, in India the use of dairy waste for irrigation was found to be very successful, whereas to process it in the usual way would have been extremely expensive.

It is clear that there is a substantial number of potentially serious environmental problems associated with the growth and sophistication of the food processing industry. Not only does the distribution of products require a high level of sanitation and enforceable food safety regulations, but national governments must be certain that the application of new technologies does not result in increasing burdens on the environment. Strategies to prevent such negative outcomes must be developed before the introduction of any new technologies. It is easy to overload the natural cleansing processes of the land and of water.

9. HEALTH CONSEQUENCES OF BIOLOGICAL CONTAMINATION AND CHEMICALS IN FOOD

Despite progress in science and technology, contaminated food and water remain to this day a major public health problem. Foodborne diseases are perhaps the most widespread health problem in the contemporary world and an important cause of reduced economic productivity [1]. They are caused by a wide range of agents, and cover all degrees of severity, from mild indispositions to life-threatening illnesses. However, only a small proportion of cases comes to the notice of health services and even fewer are investigated. As a result, it is believed that in industrialized countries only about 10% of the cases are reported, while in developing countries reported cases probably account for not more than 1% of the total.

Despite these limitations, the data that are available indicate that foodborne diseases are increasing all over the world, both in developing and industrialized countries. Experience in Venezuela illustrates this trend (Fig. 9.1) [2].

Biological contamination

Developing countries

Available information clearly indicates that biological contaminants (bacteria, viruses and parasites, see Table 9.1) are the major causes of foodborne diseases.

In the developing countries, they are responsible for a wide range of foodborne diseases (e.g., cholera, salmonellosis, shigellosis, typhoid and paratyphoid fevers, brucellosis, poliomyelitis, and amoebiasis). Diarrhoeal diseases, especially infant diarrhoea, are the dominant problem and indeed one of massive proportions. Annually, some 1 500 million children under the age of five suffer from diarrhoea

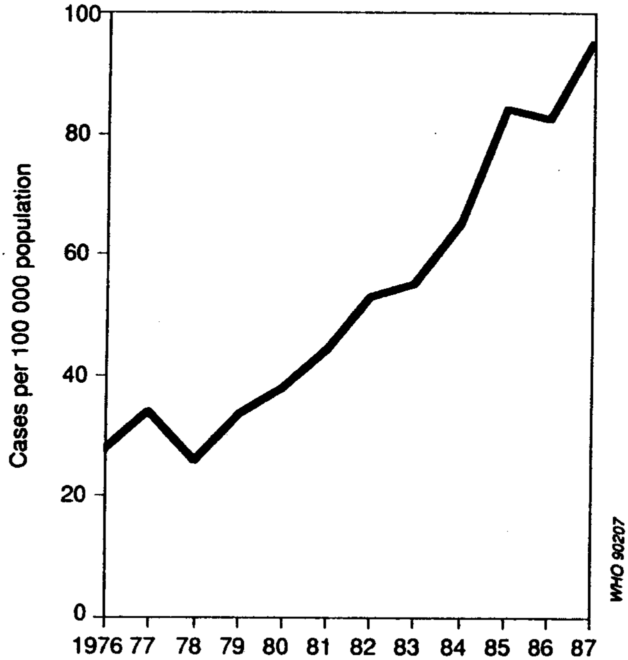

Fig. 9.1. Foodborne diseases, Venezuela. From: Ref. 2.

and of these 4-5 million die as a result. Formerly it was thought that contaminated water supplies were the main source of pathogens causing diarrhoea, but now it has been shown that up to 70% of diarrhoeal episodes may be due to foodborne pathogens [3]. Seven of the ten children who die every minute from diarrhoeal diseases do so possibly as a result of contaminated food.

The pathogens identified as the principal causes of foodborne diarrhoea are: bacteria - *Escherichia*, *Shigella*, *Salmonella*, *Vibrio*, and *Campylobacter*; protozoa - *Entamoeba*, *Cryptosporidium* and

Table 9.1 Some agents of important foodborne diseases and salient epidemiologocal features

Agents	Important reservoir/carrier	Transmission[a] by			Multiplication in food	Examples of some incriminated foods
		water	food	person-to-person		
BACTERIA:						
Baccillus cereus	Soil	-	+	-	+	Cooked rice, cooked meats, vegetables,starchy puddings
Brucella species	Cattle, goats, sheep	-	+	-	+	Raw milk, dairy products
Campylobacter jejuni	Chickens, dogs, cats, cattle, pigs, wild birds	+	+	+	-[b]	Raw milk, poultry
Clostridium botulinum	Soil, mammals, birds, fish	-	+	-	+	Fish, meat, vegetables (home preserved), honey
Clostridium perfringens	Soil, animals, man	-	+	-	+	Cooked meat and poultry, gravy, beans

Table 9.1 (continued)

Agents	Important reservoir/carrier	Transmission[a] by			Multiplication in food	Examples of some incriminated foods
		water	food	person-to-person		
Escherichia coli						
Enterotoxigenic	Man	+	+	+	+	Salad, raw vegetables
Enteropathogenic	Man	+	+	+	+	Milk
Enteroinvasive	Man	+	+	0	+	Cheese
Enterohaemorrhagic	Cattle, poultry, sheep	+	+	+	+	Undercooked meat, raw milk, cheese
Listeria monocytogenes	Environment	+	+	-[c]	+	Cheese, raw milk, coleslaw
Mycobacterium bovis	Cattle	-	+	-	-	Raw milk
Salmonella typhi and paratyphi	Man	+	+	±	+	Dairy products, meat products, shellfish, vegetable salads
Salmonella (non-*typhi*)	Man and animals	±	+	±	+	Meat, poultry, eggs, dairy products, chocolate
Shigella spp.	Man	+	+	+	+	Potato/egg salads