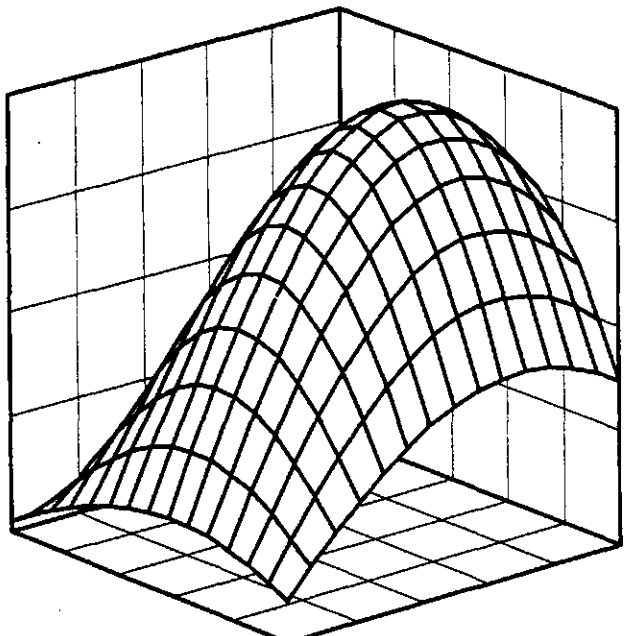
Food security at different scales: demographic, biophysical and socio-economic considerations

Papers of a seminar series,
March-May 1998, Wageningen



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P.S. Bindraban, H. van Keulen, A. Kuyvenhoven,
R. Rabbinge & P.W.J. Uithol (Eds)

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Quantitative Approaches
in Systems Analysis No. 21
March 1999

BIBLIOGRAPHIC DATA

P.S. Bindraban, H. van Keulen, A. Kuyvenhoven, R. Rabbinge & P.W.J. Uithol

Food security at different scales: demographic, biophysical and socio-economic considerations
Papers of a seminar series, March-May 1998, Wageningen / P.S. Bindraban, H. van Keulen,
A. Kuyvenhoven, R. Rabbinge & P.W.J. Uithol. -
Wageningen : DLO Research Institute for
Agrobiology and Soil Fertility ; Wageningen :
The C.T. de Wit Graduate School for Production Ecology. -
(Quantitative approaches in systems analysis ; no. 21)
NUGI 835

Keywords
food security; agricultural production and environment; rural development; global market functioning; food policy; population growth; food and feed demand

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Preface

Agricultural research has played an important role in increasing world food production over the past decades to levels exceeding total food demand. The sad reality, however, of currently one billion food-insecure people, urges us to identify the major causes of the discrepancy between worldwide plentiful availability and insufficient access to food, and to reconsider our research approach and methodologies to help meet the most basic food requirement for all people.

Food security is more strongly related to food entitlement than to food availability, pointing to the importance of poverty alleviation through shared economic development. This has different implications at the scales of the entire globe, nation, region, or household. Continued availability of food depends on natural resources and trade, where issues like sustainability of production and self-reliance under changing global conditions are crucial. Access to food should be assured by sustained income in a secure and stable socio-cultural and political setting. Obviously, food security is a complex issue and recommendations to alleviate food insecurity should be based on multi-disciplinary, multi-dimensional and participatory approaches.

It is towards this end that a seminar series was organized on Food Security at different scales: issues, challenges and opportunities. It offered an opportunity for scientists from a number of relevant disciplines to present their view on food security along with the importance of various production factors, economic conditions, and socio-cultural behavior. The series was initiated from a political perspective, followed by an inventory of the various disciplines presented in these proceedings. We hope that the information reveals the importance of all disciplines involved, and provides some new impulses to the food security debate to encourage innovative and interdisciplinary research approaches. Clearly this initiative needs to be pursued . . .

Prem S. Bindraban
Herman van Keulen
Arie Kuyvenhoven
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1. Policy on food security

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1.1. Why food security?

Should we really devote a whole seminar series to food security? My first thought was: haven't we debated enough the subject, and what do we do with the pile of existing policy papers? Let's not talk, let's implement! Setting goals and objectives is easy. The challenge is to reach them! Twenty-five years on and two World Food Summits later we are still faced with the fact that 800 million people go hungry, and a further two billion suffer from severe vitamin and mineral deficiencies.

That is why food security is still one of the main issues of Dutch development policy. It is important that the right policy choices are made. Policy choices are strongly influenced by r-esearch. Research priorities have a strong influence when it comes to determining which problems and indeed whose problems are solved first, and how, and thus they indirectly help to shape the world of tomorrow. Today I shall examine a few subjects which dominate the international debate and which I believe will play a crucial role in addressing the problem of food security in the future. I hope a few of them will be discussed in depth in some of the following seminar sessions.

As an introduction to the subjects, I will briefly say something about food security in general and its predominant place in Dutch development policy.

Empty stomachs, an outrage and a threat!
It was 1985. I was in Zitenga on the Mossi Plateau in Burkina Faso. It was the first time in eight years of working in the Sahel that I saw women and children who were in such a miserable state of malnourishment and hunger. I felt helpless and experienced a strong urge to do something. Most of you will recognize that feeling. Although thirteen years have since past, that feeling still inspires me to continue the fight for food security. I know that the situation has not fundamentally changed, either in Zitenga or in other rural areas in the developing world.

Besides ethical, there are socio-economic reasons to put food security high on the political agenda. Lack of food security is both the cause and effect of poverty. Poverty alleviation is the core objective of Dutch development policy. Improving the food security situation of individuals and households will make a major contribution to alleviate poverty. Food security also contributes to social and political stability, which form a precondition for macro-economic growth. Finally lack of food security can spark off armed conflicts and civil wars. The recent problems in Kenya and Tanzania find their roots in food insecurity. People's livelihoods are threatened. Farmers and pastoralists literally fight for their access to natural resources to secure their livelihood and that of their families.

1.2. What is food security?

"That at all times, each individual has access to food in such quantities and of such quality as to enable him or her to lead an active and healthy life". This is the definition used by The Netherlands. It is also the most commonly used and internationally accepted one. Over time the production-oriented approach of food security has changed to a more integrated approach, reflecting the different components of food security.

Availability, equal access, stability and quality are the four components that have to be integrated in a food security policy. Only when all these components are integrated in such a policy, is food security likely to be achieved. I will use these four components as a guideline in the analysis of current development policies. I will demonstrate that most policies focus on only one or two components. This is one of the main reasons why attempts to provide food security and eradicate poverty are failing. I will distinguish three levels of food security: global, national and household level. Only when the four components are adequately addressed at these three levels, can one expect real progress to be made.

1.3. Global level

"Will the earth be able to feed its population given current trends in population and economic growth and changes in production technologies?" At the global level availability of food seems the main concern of scientists and policy makers. Numerous research papers deal with the world food situation and the prospects of global food security. In my opinion the focus on availability is too large. I am personally confident that we will be able to find technological solutions to raise productivity in an ecological sustainable way, so as to produce enough food to feed the future world population. I am less convinced that in the future all the people in the world will be adequately fed. At the global level, insufficient account is taken of conditions for equal access, stability and quality. I would like to share with you a few of my concerns.

In the past, strong state interference and donor intervention did not lead to food security for all. The current wind of liberalization that blows through our world economy will certainly lead to accelerated growth. The inclusion of agriculture in the GATT/WTO round in 1994 struck an important blow against the heavily distorted world markets in agricultural products, and is likely to have a positive impact on the food situation at world level. However, whether the benefits of this growth will ultimately have the effect of alleviating poverty and improving food security remains to be seen. Even if one assumes complete trade liberalization in the long term, this would by no means ensure perfect competition and as you know, perfect competition is a precondition for liberalization. Trade liberalization without perfect competition is not a preferable alternative to national protectionism, because of the level of profits made by the holders of monopolies.

In a situation where the conditions for perfect competition have not been fulfilled, market deregulation benefits powerful economic actors, both private and political. But while the powerful gain, others lose! The losers in this case are developing countries. Experience has already shown that low-income countries deficient in food do not share the advantages of a freer world market. In fact they can become even more disadvantaged. In a situation like this, the notion of equal access to food for all countries is no more than a Utopian dream.

The outcome of the Uruguay Round and of the coming WTO Round relates solely to the obligations of governments. It is up to national governments to remove trade barriers, but it is the business community that actually engages in trade. Multinational corporations may engage in strategic alliances to turn terms of trade in their favor and use monopoly margins as a substitute for tariffs. This is reinforced by other trends such as concentration, specialization and chain management. The emergence of multinational firms makes it more difficult for individual countries to fight monopolistic practices. However, at international level there is as yet no institution that can deal with monopolies and cartels. The WTO has no clear competition policy. Who will guarantee perfect competition in the future? Is a code of competition necessary and is there room for an institution at the global level that can ban monopolies and settle disputes? One should not only look at the question of settling disputes between governments, but also at the possibility of creating civil courts that could hear and deal with complaints from private parties about monopolistic pricing. I think that this issue needs a lot of attention in the near future and in the coming WTO Round.

Price volatility is another problem affecting food security. Liberalization is expected to lead to an increase in the price volatility of agricultural commodities, especially grains. This will lead to an increase in macro-economic instability and affect macro-economic growth. Increased price volatility will particularly hit food-importing developing countries and major exporting countries of agricultural commodities. Appropriate price risk management instruments should receive more attention in food security policies. The Food Aid Convention, which aims to assist food-deficient developing countries with balance of payment problems does not contribute structurally to problems related to price instability, nor did Stabex, Sysmin or other Agricultural Commodity Arrangements. There is a need for better stabilizing instruments. Much has been written on this subject, but up to now, ideas have not been translated into practical options.

At global level the quality aspect of food is addressed under the heading of consumer concerns, that is to say concerns expressed by consumers regarding the safety of food and in the way food items are produced. Consumer concerns are becoming more and more important in trade relations. However, I would like to issue a warning in this respect. Consumer concerns can lead to unfair competition and trade restrictions, especially when very high quality and safety standards are set, and thus prevent developing countries from entering the market. They can also squeeze developing countries out of existing markets. A good example is the EU's decision to limit the import of fish products to countries that fulfill certain EU criteria, concerning hygiene and sanitation, becoming effective the first of January 1999. Countries who want to export to the EU must prove that they fulfill the conditions. Countries like Ghana and Mozambique will not be able to export to the EU any more. A similar measure on beef imports, led to a sharp reduction in the number of developing countries that export beef to the EU. Although concern for food quality and sustainable or ecologically produced food products is legitimate, it can help to prevent developing countries from participating fully in world food trade and, ultimately affect food security. Consumer concerns should not be redressed by restricting imports from developing countries, but by assisting them to overcome obstacles. Thus a positive and constructive approach is necessary.

To summarize: At global level there are three important issues which, in my view, need further debate and research. Firstly, the problem of perfect competition; how and by whom can perfect competition be guaranteed? Is a special code of competition a solution? Secondly, the problem of price volatility and the search for better price risk instruments and, lastly, consumer concerns: how can they be addressed impeding developing countries integrating in the world market?

Solving these problems will help to bring food security within the reach of most developing countries.

1.4. National level

Food security is the prime responsibility of national governments. In the past, food availability was the prime objective of food security policies. This led to food self sufficiency strategies with measures such as import restrictions, subsidies on inputs, price subsidies and food aid. Active state intervention was an accepted instrument. Research on high yielding crop varieties was seen as a logical policy. However, food security for all has not been achieved. Even where progress has been made, a large part of the population still lives in extreme poverty and in a food insecure situation. India is an example of a developing country that has gone from being a net food importing country to a net exporter. Despite this, India is home to many of the world's malnourished.

Nowadays food insecurity is more a poverty issue. Food self sufficiency is no longer seen as the key issue. The focus is more on good governance and sound macro-economic policy. The neo-liberals have taken the lead. Far-reaching state intervention made way for market orientation. The private sector and the market are supposed to do a better job. Liberalization and privatization are part of all macro-economic policies in developed as well as in developing countries.

For some time now, developing countries, especially the vast majority of African countries, have accepted the need for fundamental policy reform. Most countries are working with the World Bank and IMF to implement tough, politically risky adjustment programs. It is undeniable that some progress has been made, the question is whether the gain justified the pain.

In general the food security situation did not improve indeed; the situation often worsened. In adding social dimensions to adjustment programs, the most negative effects of adjustment have been cushioned, but no measures have been taken to tackle fundamental shortcomings. Why did the adjustments not have the expected results?

In the first place: liberalization took place in a situation governed by imperfect markets and without accompanying public investments in agricultural infrastructure.
The liquidation of the state-controlled marketing boards in Africa did not bring about the expected gains in efficiency, nor did it boost exports. Sometimes private monopolies or oligopolies took the place of government monopoly, sometimes the private sector did not react adequately. Ivory Coast and Cameroon lost their export market for cocoa because the private sector was not able to maintain quality standards after the liquidation of the cocoa marketing Boards.

The withdrawal of subsidies often failed to produce the desired effect. Effective demand for food and non-food products decreased as food prices rose. Higher producer prices did not, generally speaking, lead to an increase in food supply, because of the lack of private investment in productive technologies. Private investments will only be remunerative if basic agricultural infrastructure, which cannot be financed by the individual farmer, such as feeder roads, a credit system for small farmers and market information systems, is present.

Structural Adjustment Programs were most probably too much tailored to the western situation, where strong institutions and a dense infrastructure permit the private sector to take over from government.

Secondly, if developing countries are told to liberalize and open up their markets for foreign competition, it would be nice if developed countries did the same. Unfortunately this is not always the case. The best example is the EU, with its highly protected agriculture. It is only under strong pressure and very gradually, that the EU has been prepared to change its Common Agricultural Policy. In spite of promises to grant least developed countries (LDC) better access to the markets of developed countries, the first EU proposals in Agenda 2000 do not contain any offer to developing countries in this respect. Moreover, this cannot give the developing countries much confidence in the recipes they get prescribed.

What have been the consequences of these policy reforms for food security? Availability of food, especially the capacity to produce food, has decreased. In this respect I would like to draw special attention to the soil fertility problem in Africa. Soil fertility is becoming a serious limiting factor in efforts to increase food production, even more than the lack of precipitation. Availability of food, especially the capacity to produce food, could be increased if Agricultural Structural Adjustment programs and Agricultural Investment Programs gave more priority to food crops, public investments in soil fertility and the agricultural institutional infrastructure. Attempts to solve balance of payments problems, focus predominantly on commercial crops. Public investments in credit systems, marketing and research, just as in the past, concentrate on boosting commercial crops. Food crops are neglected and, together with price liberalization, often lead to rising food prices, stagnating food supply and rising import bills for food. In Africa the increase in the yield and productivity of the basic food crops for domestic consumption in the last 20 years was on the average 5 kg per hectare compared with over 30 kg per hectare yield for export crops.

Access to food can easily diminish in a situation of liberalization. In the short term, price liberalization and the withdrawal of food subsidies push up food prices. Privatization and the liquidation of state enterprises increase unemployment, leading to falling incomes and decreasing purchasing power. Low-income groups in cities are particularly hit by food insecurity. Strong economic growth in the mid term does not guarantee increased access to food, because of rising income inequality. Social safety nets may form temporary solutions, but there should be a much greater focus on income distribution and employment policy.

Access to food can also be increased by raising the production capacity of the rural poor, especially small farmers both male and female. Higher prices for food crops are not enough. Access to land, security of tenure, agricultural and institutional infrastructure such as credit, market access and input supply are more important. Research should focus on improving agricultural productivity, with particular emphasis on small farmers in low-income countries. A focus on labor-intensive technologies could help them to make better use of their comparative advantages.

The stability of supply is influenced by weather conditions and increased price volatility as a consequence of liberalization. Bad harvests require coping mechanisms at national and local level. Experiences with cereal banks in the Sahel show that they can form a successful coping mechanism at local level, but require a lot of institutional capacity building.

The grain marketing boards were supposed to stabilize food supply and prices. They failed to do so at national level, and most of them were liquidated. Additional food imports often caused balance of payment problems and had a negative impact on overall economic growth. Food aid can be used as import support, but it's negative effects on local food production is difficult to assess. At this moment there is no coping mechanism that can effectively counter the negative effects of price volatility on economic performance. Price risk management instruments are needed, and require further discussion and elaboration.

In short, food security policies should form an integral part of macro-economic policy and be reflected in agricultural policy. Although in recent years more attention has been paid to the social dimension of structural adjustment, most adjustment programs fail to pay explicit attention to or develop a policy on food security. More priority for food crops, price coping mechanisms for stability and supply, imperfect markets and public investment in soil fertility and agricultural institutional infrastructure are, in my opinion, the issues on which researchers and policy makers should concentrate.

1.5. Household level

The food security situation can be measured with a simple yardstick: the nutritional status of individual family members.

For years Malawi was cited as the example of an African country that had made tremendous progress in development after independence. Impressive growth rates, progress in education and health services, and food self sufficiency at national level. It took quite some years, and hard statistical evidence, before donors and the government were willing to acknowledge that a malnutrition rate of 40 to 45% among children was not cause of euphoria.

Malnutrition is not easy to tackle. It demands more than just secure food and income. In fact it requires a varied range of activities for different target groups. In 1994 a Conference on Nutrition took place, in 1995, the Social Summit, which resulted in the 20/20 initiative and in 1996 we had The World Food Summit. Objectives are no problem, the political will is there, relevant theories and knowledge are available, there is no lack of policies. We are simply failing to put what we know into practice. Admittedly, developing countries lack the means and capacity to take the required action, but donor countries face similar problems. We have no nutrition specialist on our embassies. The World Bank reduced the number of nutritionists in their staff to three, so their programs no longer address nutrition.

I have said that there are enough nutrition policies and that all we need to do is implement them, I will nevertheless elaborate shortly on a few elements. Empowering the rural and urban poor to strengthen their socioeconomic security is a first step towards bringing food security within the reach of individual families. Equal access of women and men to production assets is probably the most important policy measure a government can take to achieve food security at household level. Food security within households has much to do with equity. Gender relations often determine the way different members within a family have access to food. It is also at household level where the quality aspect of food should receive most attention. A well-balanced diet and good nutrition can only be secured at the household level. Women play a crucial role here.

At the household level food security policies largely focus on equal access to food and production assets, but also to health, education and social policies.

Ladies and gentlemen, there is one issue I have not addressed, but which I think is of the utmost importance for our future food security: the sustainable use of natural resources. In a liberal economic environment, sustainable use of natural resources may become threatened. Especially in developing countries, where institutional capacity is limited and market relations are imperfect, increased agricultural production and growth are often achieved at the expense of the natural environment and hence at the expense of future food security. As stated earlier, in an increasing number of countries reduced soil fertility is threatening sustainable agricultural development and food security. But attention also needs to be paid to the abundant use of fertilizers, insecticides, pesticides and bioengineering, because this can threaten human health.

At the beginning of my paper I remarked that researchers can help to provide more insight, to find solutions to existing problems, and to clarify policy options. I have elaborated on a few of the issues, that relate to food security and which need our full attention. I hope that they will stimulate the debate and contribute in setting research priorities.

2. Integration of biophysical and economic analyses for food security studies

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Abstract

This paper deals with analyses on future food demand and supply, considering biophysical and socio-economic possibilities. Analysts have recognized that the global demand for food will climb dramatically as population increases and income rises. There are however, substantial different views on the possibilities to supply the world population and obtain food security for all on earth. These differences are based on differences in vision or interpretation, resulting in different methodological approaches. It is important to recognize that conclusions of the various approaches serve different purposes. Most analyses are extrapolations, presuming past trends to continue. These analyses are meaningful to identify problematic developments that need to be addressed. Predictive analyses give a fairly accurate image of the near future, on the basis of integration of a substantial amount of information on past developments, but the accuracy rapidly deteriorates when the time horizon is extended. These two approaches do not permit sudden changes, while breaks in trends are more decisive for development. Moreover, options to change past trends towards desired situations are not explored. Explorative analyses do indicate feasible options, explicitly addressing sustainability issues. However, such options, mainly based on biophysical production potentials are considered too remote from reality. Therefore, an integrative approach is needed to identify ways to realize future increase in food production in a socially acceptable and economically feasible manner and in a way which also warrants the environmental quality to be sustained or even improved. Holistic modeling approaches do potentially permit interactive analysis of biophysical and socio-economic possibilities. Such analyses would allow more realistic development of scenarios on sets of attainable crop production and economic policies that could be used to achieve food security.

2.1. Introduction

Since Malthus, food shortages in our world have been forecast by many, but none have become reality. Instead, food production per capita has been rising for decades. Still however, over a billion people are not food secure and suffer from under-nourishment, which results from poor distribution due to major differences in wealth and social instability rather than supply of food. Food security refers to a condition in which all people at all times have both the physical and economic access to safe and nutritious food to maintain a healthy and active life (Alexandratos, 1996). Considering the fact that agricultural efforts to increase food production have been so successful, what than is the role of agriculture and biophysical and socio-economic analyses on the issue of food security?

Firstly, dramatic increase in demand for food due to population increase and income rise affecting consumption habit is widely recognized. World agricultural production will have to triple over the coming three to four decades to meet growing food demand (WRR, 1995). These assessments have a fairly common basis, and projected demands for food reveal comparable rates of increase (*e.g.* World Bank, 1997).
Secondly, future increase in production will have to come primarily from increasing productivity, as area expansion is not desirable, because it would require the cultivation of natural and fragile lands (Alexandratos, 1996; IFPRI, 1994, 1995). A major concern, therefore, is the increasing pressure on land resources, which can lead to various forms of degradation, negatively affect the production capacity of land (Bindraban *et al.*, 1998).
Thirdly, the drastic increase in global economic activity will severely affect the natural resource base. There are many uncertainties whether economic growth can be continued at the long term as environmental degradation starts to manifest itself in some situations (WRR, 1995).
Fourthly, the global system is becoming increasingly complex and so many factors affect food security, that we loose sight of possibilities and limitations of our globe. Policy makers have to take (strategic) decisions on the basis of ambiguous views of global, regional and local potentials and limitations.
Finally, despite the successes in the past to increase food production, still many expect the increasing trend to finish on short notice and to result in vast food shortages (Brown & Kane, 1994).

Due to such threats on declining agricultural productivity and uncertainties on future developments, producers, researchers and policy makers are interested in options for sustainable development. The future increase in food production should not only be obtained in a socially acceptable and economically feasible manner, but should also warrant the environmental quality to be sustained or even improved. Given the various components of food security, availability, access, stability of supply, and quality, determination of options to realize food security requires an integrative approach, considering both biophysical potentials and socio-economic attainable solutions.

This paper describes various procedures that assess future food production potential in relation to food security. Major differences among the analyses are based on strongly differing principles and assumptions, resulting in different methodologies (Rabbinge, 1997; Van Ittersum *et al.*, 1998). Methodological approaches to integrate biophysical and socio-economic analyses are considered to inherit powerful possibilities to investigate the impact of policy measures on food security.

2.2. Approaches for future analyses

Scientific analyses of complex systems are achieved by simplified description of those systems, by setting bounds and considering major processes only. The effect is that links between endogenous and exogenous variables are ignored. Little may be lost when these links and feedbacks are weak, while much is gained in terms of transparency and focus. For instance, short-term analyses ignore feedbacks that occur with a lag greater that those allowed for the description of the system, while long-term analyses may not comprehend factors important at the short-term (Perrigs, 1997).

Food security comprehends all aspects of life, which makes it unfeasible to account for all relevant factors and processes. Comprehensive, holistic descriptions of systems cannot escape from describing parts of the global systems only. The impact of exogenous factors needs to be considered in ex-post evaluations. The relevance of the results of the various attempts and approaches to address food security and sustainable developments can be great, depending on the objective of the study. Therefore, the purpose of the analyses should be clearly determined with clear relevance for the stakeholders.

2.2.1. Extrapolations

Brown and Kane (1994) assessed future developments for three distinguished food sectors by extrapolation of their recent past trends. The fishery and rangeland sectors are already overexploited and future increase is not possible. Therefore, the only system left to realize increase in food production is cropping. Contrasting to the past when food production kept pace with demand, various reasons were mentioned that would constrain future production. While the world could rely on new technologies in the past, these have been exhausted, leaving us without a technological backlog. Water supply will be limiting and fertilization has little impact on production increase. The loss of cropland will be faster than rise in productivity. With demand reaching limits of supply of seafood and rangeland, social disintegration will further deteriorate the situation.

Even stronger deteriorating developments were projected for China's future (Brown, 1995). The rapidly industrializing economy of China was compared to those of Japan, Taiwan and South Korea in the past, as they were also densely populated in agronomic terms, *i.e.* all having a high number of people per hectare of cropland. Cropland area shrunk in the latter countries by 1.2 to 1.4% per year. Similar rates occurred in China from 1990 to 1994, because of demand for land by other sectors. Starting from low levels of productivity, the other countries could still increase their yields. Additionally, mainly Japan could escape to seafood to meet its increasing demand for food. These options are not feasible for China, placing it in an even worse situation. Production and consumption in China are extrapolated to respectively decline and increase causing a vast deficit.

Extrapolations enforce a continued trend to the future of past developments without consideration of underlying causal mechanisms.

2.2.2. Predictions

FAO's global study on world agriculture towards 2010 emphasizes food security, nutrition, sustainable agriculture and rural development (Alexandratos, 1996). Predictions are based on detailed information on a large number of commodities, countries and land use for the historical period of 1961 to 1990, considering specialists' opinions on feasible developments. Demand for food is based on exogenous assumptions of population and GDP growth. Projections of production start with provisional targets of production for commodities and countries, separately, followed by several rounds of iterations and adjustments in consultation with specialists, with particular reference to what are considered to be "feasible" levels of land use, yields and trade. Accounting controls, *e.g.* on land area, were applied to avoid erratic calculations. The results of the analysis reveal that progress will be slow and uneven, also beyond the end of this century. Some enhancement of food security and nutrition is expected by the year 2010, mainly resulting from domestic production and food imports. However, a

number of developing countries are likely to face serious constraints, in particular in sub-Saharan Africa. With regard to sustainable agricultural development, it is concluded that the pressure on resources will continue to build up, with the vicious circle of poverty and resource degradation to accelerate the process.
The large information base used in predictions results in more emphasis on causality in projecting near future developments.

2.2.3. Explorations

The Netherlands Scientific Council for Government Policy (WRR, 1995) analyzed the limits to food supply and the consequences for natural resources in a quantitative way for the population of 15 major regions, comprising the world, in 2040. The consequences of two alternative agricultural production systems and three diets for three population scenarios were analyzed to address different perceptions on socio-economic developments and environment. Food production was assumed to take place under best technological means and depended on biophysical conditions. Production potentials were calculated on the bases of model analyses considering eco-physiological processes. The results indicate that sufficient food can be produced for 10 to 40 billion people at world level, depending on production system and consumption pattern. However, in the most populous regions, South- and Southeast Asia, food supply does not exceed demand twofold, indicating potential hazardous situations.
In the early nineties the WRR (1992) performed an analyses to explore long term consequences of policy objectives, combining agro-technical, socio-economic and environmental aspects for rural areas of the EU-12. Four major objectives that were considered concerned minimal costs for agricultural production, regional employment, greatest possible area for natural environment and strict environmental requirements. Interactive Multiple Goal Linear Programming (IMGLP) was used to optimize objectives under production constraints and possibilities as set by the agricultural production systems under best technological means. Significant differences in input requirements, production and environmental load among various objectives indicated substantial scope for policy. The results have strongly enhanced discussion on European agriculture in relation to the role of the EU in the world market and the GATT negotiations, the attention on aspects other than agricultural production of the rural areas and the budgetary consequences of production.
Explorative analyses, in essence, differ from the previous two methods described, as it is based on process knowledge of the system that is described, *i.e.* agricultural production system, with explicit assumptions regarding exogenous factors.

2.3. Regional approaches

Analyses of extrapolative and predictive nature are useful to indicate how developments are likely to evolve under current behavior and to identify developments that may turn out to become problematic. Alternative developments should therefore be explored to address these expected problems and to give guidance to realize breaks with trends. While the extrapolative and predictive approaches do not permit sudden changes, explorative analyses do indicate alternative feasible solutions (Van Ittersum *et al.*, 1998). Explorative analyses are, however, argued not to offer options for an audience which expects to hear about solutions to the world food problem (Tims, 1995), as they are too remote from reality. Therefore, the approaches have to be combined to more realistically identify ways in which future increase in food production can be realized. The methodology should integrate analyses of biophysical and socio-economic models to reveal options to achieve food security through sustainable production practices.

Planning is a concept based on the notion that the process of development can be influenced. In other words, it is possible to indicate feasible paths from the present situation towards desired situations in the future. Agricultural land use planning should bridge the gap between macro policy and specific project planning. The former deals with sectoral growth at the national level, but does not pay attention to the spatial distribution of investments. The latter is usually so detailed that the broader socio-economic framework in which it has to operate remains out of sight. Both approaches operate for a great deal independently from each other. Regional agricultural planning can be considered as the intermediate planning level, which is on one hand sufficiently specific for guiding action and on the other hand general enough to be placed in national context (Hengsdijk & Kruseman, 1993).

A region can be identified by its natural, administrative and socio-economic boundaries, within which land use and changes results from important relations between agro-ecological and socio-economic factors. Such an eco-regional approach emphasizes (clarifies) the specific characteristics of a region, which may help to identify possibilities and constraints of the region. These constraints may be of biophysical or socio-economic nature (Rabbinge, 1995).

2.3.1. Integrated approach to regional planning

Land use potentials can be identified, based on the assessment of available natural resources, soil, climate and crops (WRR, 1995). Land use options can be explored by MGLP techniques through optimization of specific objectives, say maximum income, minimum environmental load *etc.*, within the boundaries set by bio-physical and market constraints (WRR, 1992). Major limitations of MGLP within this *resource-based approach* refer to the static character of the analysis, the discontinuous nature of the optimization technique, and the absence of an economic analysis of motives and costs associated with land use adjustments. Moreover, the lack of economies of scale, absence of multiplier effects, and price exogeneity pose serious questions for the application in economic analysis (Kuyvenhoven *et al.*, 1995).

Econometric *supply-response models* are based on continuous homogeneous production functions. Optimization is performed on a household utility function. The procedure permits analysis of adjustments in the farming system as a result of changes in the economic environment. A major constraint from agronomic point of view is the use of production functions to account for the effects of agronomic input to outputs. Interactions among inputs, say nutrients, which are crucial, are not considered (De Wit, 1992).

There is an additional fundamental difference between the two approaches. While the supply response models start their analysis at the current production system and indicate the pace and direction of adjustment as result of policy change, the resource based IMGLP analyses, are focused on potential land use independently of actual production systems.

Decisions on land use depend on resource endowment, (multiple) objectives and expected prices faced by individual actors (Kuyvenhoven *et al.*, 1995). Comprehensive analyses of these factors require integrative resource based supply-response approaches.

2.3.2. Integration of agro-ecological and socio-economic information

Within a research project to explore options for sustainable land use and food security at regional level in developing countries a methodology was developed which integrates agro-ecological and socio-economic information, with the aim to formulate recommendations to aid policy makers (Hengsdijk & Kruseman, 1993).

Individual farms in two distinct regions, the fifth region of Mali and the Atlantic zone of Costa Rica, were studied and categorized. Economic relations were determined for the farm-types like the impact of the price of nitrogen on nitrogen input in the production system. On the basis of input-output relations, production levels of various crops were determined. Given a set of input conditions, like inputs of fertilizers, biocides, labor, *etc.* related crop yields/outputs were derived from biophysical modeling. Inputs and outputs are prices. Depending on the objective that is aimed at, for instance maximization of income, or minimization of risk, optimal production systems for the farm-types would be determined using linear programming techniques.
The production of all farmers and farm-types is aggregated to obtain regional production. In order to maximize their income farmers will produce in this analysis, the most profitable crops, given the initial prices considered. As a result, regional production of a certain commodity/crop might become too large, reducing prices. The MGLP optimization routine will be performed with the adjusted prices of inputs and outputs, giving another optimal solution. This iterative process is continued towards an equilibrium condition.

In this methodology, the actual situation is described in much detail in both biophysical and socio-economic terms. The analyses allow to "realistically" analyze the impact of policy measures on agricultural production for the region that is being studied. It was found that in the low-income region, like South Mali, with not well-developed markets for land and capital, classical price policy measures are less effective than exogenous measure, like infrastructure. For Costa Rica, with a relatively well-developed infrastructure, price policy appears stronger in affecting the production system (Van Keulen & Kuyvenhoven, 1997).

2.4. Discussion

There is an obvious need to investigate the impact of policy measures on food security and vice versa to formulate recommendations to policy makers, producers and scientist on options to address food security. Though food security comprehends all aspects of life and no analysis can account for all relevant factors and processes, it is recognized that integrative analyses of biophysical and socio-economic models inherit powerful possibilities to meet these aspirations.

While extrapolations are not reliable for the long-term and do not allow sudden changes, they do have an alarming nature. The world watch institute (Brown & Kane, 1994; Brown, 1995) for instance, has a major impact on setting the agenda on issues related to food security, by alarming the society on problems to be expected. This is an extremely important component of a complete package to address future problems.
Predictions may be fairly accurate on the short term, but are less suitable for the long-term, and neither allow sudden changes in developments. FAO in 1996 (Alexandratos, 1996) concludes that progress on food security has been slow and uneven, as their study from 1987 had warned. The current analysis reveals that the slow and uneven progress is, unfortunately, likely to prevail

also beyond the end of this century. These results indicate that drastic changes are needed to alter the situation in the future, but though their analysis is claimed not to be extrapolative, it does heavily rely on current developments, not allowing drastic changes in development. But then, these results showing that progress on food security in the world is likely to remain slow in the future actually are a plea for drastic changes to turn that tide.
Explorative analyses do indicate alternative opportunities, but do not indicate what measures are needed to realize these options. The studies of the Netherlands Scientific Council for Government Policy (WRR, 1992, 1995) have opened up discussions on the usefulness on explorative studies. It emphasizes that the eminent question now is on how a technically feasible and politically desired situation might be attained, given the present situation and information on behavioral constraints of all parties involved (Van Latesteijn, 1995).

As a response to these methodological limitations, an integrative biophysical and socio-economic modeling approach was developed to explore options for development and indicate required measures to attain these options (Hengsdijk & Kruseman, 1993). This methodology (DLV) is ready to be implemented in other regions, where the exercise can be used to further improvement (Van Ittersum, 1998). The methodology is suitable for relatively detailed studies at relatively small regions. The agricultural system is described at the level of a farm household, which requires a large amount of data before such an exercise can be performed. Transaction costs in the current procedure are expressed in one value that describes the bulk of all other factors that are exogenous to the system as it is described. Bulking exogenous factors in one pricing mechanism does not allow analyses of the exogenous factors that are really limiting. Is it the dirt road that has to be paved, or is it the lack of trucks to transport the inputs and outputs, or is the market too small? These aspects make the procedure to be strongly related to "reality" or the current situation, and limit options to explore the impact of drastic changes.

The DLV methodology is suitable for detailed studies at relatively small regions. It may prove difficult, if not impossible to aggregate such analyses to larger scale in order to formulate policy recommendations at national level or higher.

Integration of the various biophysical and socio-economic aspects of agricultural production should therefore take place at a higher aggregation level. Prices are not affected by changes in the production at the farm level. The success or failure in production of an individual farmer will not affect the price, but prices will be affected if the bulk of farmers in a region are successful, or fail. Therefore aggregated analyses at the regional level, with generic descriptions of farm household types should suffice for analyses at higher levels of policy making. From a biophysical point of view, analyzing agricultural production at the level of eco-regions is most appropriate. These regions are relatively homogenous in terms of biophysical/ecological characteristics. Analyses at this meso level offer the advantage that processes at lower, micro, levels can govern the procedure of the analysis, while they can be aggregated to the higher levels. This would be a more appropriate starting point to analyze issues on food security at larger scale and a longer time horizon.

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3. Socio-economic aspects of food security

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3.1. Introduction

Nearly one billion people are undernourished in a world plentiful of food. That is not a matter of insufficient availability. Expanding world food production by a few percent would in theory be sufficient to provide the poor and needy with a basic diet for a healthy life. Moreover, real food prices have decreased for more than a century now, thanks to continuous advances in technology and farming practices. Never before was good food so cheap but went so many people hungry. Have we come to tolerate hunger as part of our modern world, much like drugs or crime?

Nobel Price Laureate Amartya Sen has convincingly argued that the problem of securing sufficient food for a productive life is basically solvable. To achieve such a solution, however, food security needs to be properly understood. In addition, societies need to be prepared to pursue the proper institutional responses to the challenge of hunger. Food security is multi-dimensional as it is embedded in three concepts: *access* (the entitlement to establish command over an adequate diet and related necessities), *availability* (sufficient supply through production or trade) and *sustainability* (the ability to maintain or reproduce the resource base and assimilate wastes). While availability is a necessary condition to achieve food security, it is by no means sufficient to establish someone's access to daily food requirements. Failing to understand the significance of access to food and the role of economic policies to maintain entitlements, has for instance led to incorrectly equate food security with food production or, at the national level, with self-sufficiency. Sustainability, certainly in more fragile areas, is an all-important long-term context factor.

Food security, or absence of hunger and malnourishment, is one of the oldest and most persistent issues in economics. It is put in a historical perspective in 3.2. Current trends in food security by major regions and medium-term prospects are described in 3.3. Projections cover the next decade and are taken from a recent USDA study. Concerns like the recent leveling-off in grain yield growth and a possible end to food price decreases are discussed in 3.4, and elaborated in terms of agreed findings and policy dilemmas in 3.5. In the final part, conclusions are drawn with regard to policy support and reform to achieve better food security.

3.2. Two centuries of debate

In a world with slowly changing technology (like the introduction of enclosures, crop rotation, mixed farming) and regularly visited by famines, discussions on food security in the sense of absence of hunger have a tendency to focus on availability, *i.e.* the ability to produce enough food. That is exactly how the debate on hunger was characterized two centuries ago when Thomas Malthus expressed his pessimism on resolving poverty and hunger in his famous *Essay on the Principle of Population* of 1798. As Rosegrant and Ringler (1997) recently argued, that is not to say that Malthus was a dogmatic population pessimist who did not understand the implications of advances in technology. Rather, in the absence of it, population growth and decreasing marginal returns go a long way to explain the perpetuation of poverty and hunger. In much the same way, poverty and risk averseness explain today why so many African farmers continue to mine their soils, the very resource on which their future depends, and in doing so are caught in a poverty trap.

In one of his contributions to the problem of hunger, Amartya Sen (1993) argues another, more philosophical point. Well before Malthus, the French enlightenment thinker Condorcet had already identified the possibility of population growth being too fast. Where Malthus disagreed, however, "was in Condorcet's belief, and that of many other rationalist thinkers of that period such as Adam Smith, that by reasoning about the nature of solvable problems and by understanding the appropriate actions to be undertaken to avert these problems, we can prevent their occurrence, whereas Malthus saw no such hope and spoke instead of the need for compelled suffering on the part of much of humanity" (Sen, 1993, p. 86). To Malthus' credit should be added that he later openly amended his view. In 1817 he wrote in the fifth edition of his *Essay* that people did in fact control the number of their offspring and thereby avoided famine and misery (Rosegrant & Ringler, 1997).

History, as we know now, has not given much support to Malthus. Birth rates have greatly decreased with education and economic development, and many technological changes have occurred because population pressure became an incentive for innovation through *e.g.* intensification (Boserup). In fact, agricultural economics is one of the few disciplines, which can pride itself to have developed an endogenous theory of technological change, with changes in factor proportions and market configurations as explanatory variables.

In terms of food security, all this has important implications. If supply factors determining food production can be considered largely endogenous, hunger and undernourishment cannot be explained by a failure to supply food (availability), but rather by a failure to have access to whatever is available. Access in this sense means a source of command over food (an entitlement in Sen's words) such as income, social security or simply a job. Only for the farmer who grows his own food, availability and access overlap, and bad weather hits both. With off-farm income, however, access can be maintained when alternative sources of food supply are available.

Sen (1993) draws three important lessons for successful prevention of a food insecure world. First, with availability being only a necessary condition to prevent hunger, a focus on per capita food supply (a most popular statistic) may create a false sense of security at all levels of scale, be it a household or a country at large. Second, where long-term food security requires broad-based and shared economic development, more immediate concerns can only be resolved via redistribution mechanisms that restore access to food. Cash transfers, direct food distribution and public works (generating employment) are well-established interventions to overcome periods of food insecurity. The redistributional effort, though often hard to organize and to target effectively, is not excessive, and usually not exceeding a few percent of total output. Finally, there remains the political dimension: governments do not always act in the face of even widespread hunger. Here Sen (1993, p. 80) argues for democracy and a free press ("good governance" and "accountability" in the development jargon). It is a subtle argument that addresses information failures (to act is to know) and political survival (re-election in the face of famines is a foregone conclusion).

Summarizing, to understand food security for the social scientist is primarily to understand access. To achieve the latter, a society needs sustained development and public action to ensure entitlements. In this process, public debate, participation and effective co-operation are among the indispensable ingredients. They define the enlightenment of our time.

3.3. Current situation and prospects

Most recent studies exploring the prospects for food security at an aggregate level agree that the number of people suffering from hunger and undernourishment are likely to increase to well over one billion, though in relative terms the share of those who are food insecure continues to decrease. (The current economic upheaval in East and Southeast Asia is likely to interrupt this trend). Poverty and hunger in the years to come will be increasingly concentrated in sub-Saharan Africa. While absolute numbers are still increasing, the regional share of food insecure in Asia steadily declines. Persistent income inequality in Latin America remains a major factor threatening food security in low-income households.

The latest USDA report (1997) on this subject confirms much of the current findings, and its approach clearly illustrates the three dimensions of food security (3.1 and 3.2). Food gap calculations up to 2007 indicate that the most vulnerable regions (large parts of Sub-Sahara Africa, low-income Asia and low-income households in Latin America) would need a 4.4% higher availability of food on aggregate to meet minimum nutritional standards (NS), up from 3.5% in 1997. If only current levels (1994-1996) of food consumption (CL) are to be maintained, 3.4% more food is needed than projected, against 2% in 1997. The gap between what is needed and what is locally available is most dramatic for Sub-Sahara Africa where the NS gap is expected to increase from 10 to 13.5% during the decade 1997-2007, and the CL gap from 4 to 7.5%. By contrast, the aggregate NS food gap in Asia remains less than 2% in 2007; only the projected CL gap would go up, from less than 1% to almost 2%.

Figures like these underline the access dimension of food security. Increased production and/or imports would suffice to close the gap in most areas, but distributional problems and foreign exchange shortages remain formidable hurdles to better access at the household level. This applies in particular to sub-Saharan Africa where a deteriorating nutritional situation lasting already three decades is likely to continue. It is in Asia that natural resource constraints to further production growth are becoming manifest. Although population growth is substantially on the decrease, industrialization and urbanization compete on a large scale for land, water and research resources.

North Africa is an interesting example of how food availability adjusts to higher effective demand via increased commercial imports of grain. Local production in the area is erratic and has a limited potential to expand. Nevertheless, food security is easily achieved through imports (which now equal domestic production) because foreign exchange is sufficiently available. The growing grain import dependency of North Africa points to a general trend in securing sufficient supply of food: where land and water resources become binding and levels of living increase, food security will increasingly depend on the role of international trade to supplement domestic supply. Table 3.1 shows the importance of this trend in the USDA projections.

Table 3.1. Commercial import dependency of aggregate food availability (%).

Year	Asia	SS Africa	North Africa	Latin America	World
1988	4.0	7.3	71.3	28.9	9.5
1997	6.1	9.3	77.2	65.1	14.2
2007	6.5	8.5	73.7	68.3	14.2

Source: Calculated from USDA (1997). Country coverage by region is not complete.

In terms of future food availability at large, the USDA projections confirm current concerns about the expected growth rate of production. For the first time since the 1970s, food prices have increased substantially in the course of 1994, then stabilized by the end of 1996 and continued to decrease – in real terms – since then. Although real prices are projected to decrease well after 2000, the rate of decrease is expected to be substantially lower than in the past (Fig. 3.1).

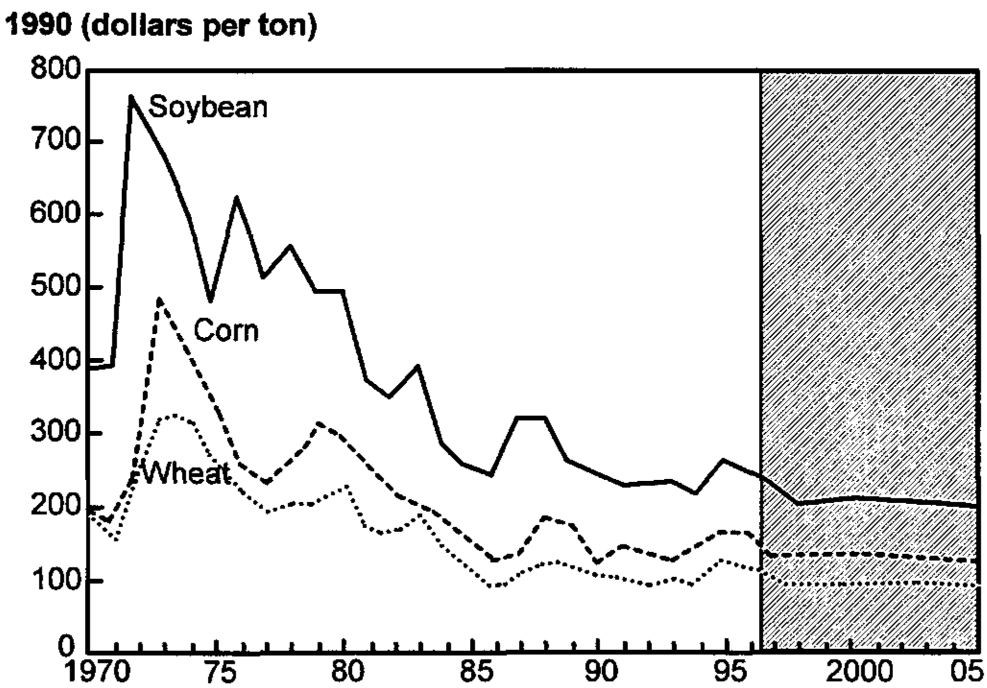

Figure 3.1. The pattern of declining real prices is slowing.
Source: USDA (1997).

A more serious concern is the decline in the rate of growth of research and development expenditures in agriculture in both developed and developing countries. This decline has been particularly manifest in the public sector, and has already caused a flattening out of total factor productivity growth in agriculture in the USA and major EU countries. If this trend continues, the long-term decline in real food prices might well come to an end.

In the developing world, in particular the rice economies of Asia, yield increases have been leveling-off lately. To the extent that less yield growth is a response to shifts in demand away from basic food staples, this need not be a cause for concern. However, in a world with annual population increments of around 100 million people and, hopefully, better future access to food for those presently malnourished, declines in rate of growth of crop yields and agricultural research and development cannot be dismissed too lightly.

3.4. Why do people worry?

The leveling-off in the growth of grain yields world-wide in the 1990s, the interruption of the long-term decrease in real food prices since 1994, and the recent decline in stocks have raised old Malthusian fears. Could the stagnation in grain production be structural, while demand for food continues to grow? Are we finally approaching the limits to further yield growth? In a recent analysis of price movements in the world food market, Stolwijk (1997) points to a number of factors that lend little support for these neo-Malthusian concerns, at least in the short run. Against the background of numerous studies showing that agro-ecological and bio-physical limits to higher grain yields are far from binding in most parts of the world, it does not come as a surprise that the explanatory factors for yield stagnation and price hikes are largely policy-induced and demand-related.

First, food production in Central and Eastern Europe (CEE) has dramatically declined in recent years, but so has consumption and intermediate use. On balance, the process of restructuring in arable farming in CEE appears to be accompanied by less rather than more imports, and its effect on the world market has been negligible. Second, lower internal prices and set-aside arrangements have curtailed grain output in the USA and the EU. These changes are policy-induced in an effort to gradually liberalize domestic agricultural markets. Third, exporting countries in the rest of the world have cut back their exports as a response to low world market prices. Fourth, China has emerged as a new importer of grains, but partly because domestic production is presently constrained by low internal prices and a relative decline in public investment in agriculture. Finally, bad weather has affected harvests all over the world in 1995-96.

Convincing as these short-term arguments may be, they are not likely to appeal to those who argue that over longer periods lack of arable land, limits to irrigation, overgrazing, erosion, water logging, and especially the lack of technological break-throughs on the shelf will cause serious problems in food availability. Lester Brown's Worldwatch Institute and many in the green movement share this pessimist view on future food security. A recurrent dilemma in discussions of this type is the question of how to perceive the various constraints to further output growth. Are they factually correct, are they so universal in time and space as often suggested, and if so, why can they not be modified or why do they not induce further innovation? Some analysts like Rosegrant and Ringler (1997) take direct issue with the facts, methods of analysis and suggested solutions (*e.g.* short-term trends are incorrectly viewed as portents of disaster; long-term trends actually contradict Malthusian threats; induced innovation and feedback mechanisms are denied; restricting consumption patterns of the rich or changing life styles will not improve the food security of the poor). Production ecologists can probably answer most of the other questions convincingly and point to a reservoir of unused options to attain much higher production levels. Economists, political scientists and others are then faced with the question of why food security problems perceived as basically "being solvable by rational deliberation and co-operative action" (Sen, 1993, p. 85) are not effectively addressed.

More balanced approaches tend to dominate the view on future food security of institutions like FAO, IFPRI and many donor organizations. On the demand side, many agree, world population growth is projected to decrease from its current 1.6 percent to 1 percent in a few decades from now. With continuing increases in levels of living the income elasticity of the demand for food will fall, and the growth in total consumption demand for food is therefore expected to slow down considerably. With careful resource management and improved farming practices, further yield increases are potentially attainable, certainly if supportive policy interventions are put in place. In this scenario, real food prices need therefore not increase. This is not to deny that serious problems are likely to continue locally or even regionally. In particular for Sub-Saharan Africa, prospects to achieve food security in the next decades remain bleak. A range of complementary measures, both private and public, is required to increase food production. Such an effort means for many countries a major change in the system of incentives towards a more pro-agriculture and pro-rural policy. The political-economy implications of such a policy adjustment are not undividedly attractive in the short run.

3.5. Where do we stand? What are the implications?

When discussing how to feed the world, by and large, we appear to agree on the following factors at stake:

1. There is no *immediate* need for urgent breakthroughs in farm technology to satisfy future demand.
2. Poverty is now widely recognized as the main cause of hunger; and poverty can only be addressed by appropriate long-term development policies.
3. Governments tend to neglect the significance of agricultural science and technology, hence the continued relevance of the yield gap (the difference between actual and potential production). As the Director General of ISNAR, Stein W. Bie, told in his inaugural address: "Many of the food insecure countries never invested significantly in agricultural science, many of their politicians failed to recognize that agriculture can benefit from advances in human thought, and that science has a place in the life of smallholders. The lack of investment in efficient creative science for the rural industries in many parts of the developing world has been a serious political mistake from many rulers of the South, frequently aided and abetted by their Northern advisers, and the lack of Northern interest in creating viable rural primary industries in the South".
4. Finally, governments have often intervened in the market place against the interests of agricultural and rural activities, both at the macro and the micro level. At the same time, many environmental consequences have simply been neglected.

Most studies exploring Walter P. Falcon's (1996) question "Can the world produce enough food at reasonable prices, provide access to the poor, and not destroy the environment in the process?" during the next few decades, would also agree on the following conclusions:

- Growth in food production will globally be enough to keep up with population growth and demand.
- Real prices will continue their long-term trend to decrease, but at a lesser pace.
- Greater world trade can resolve growing disparities between the geographical distribution of production and consumption.

- Yield improvements through further intensification need continued investment in agricultural research.
- A second or double green revolution is needed which enhances the productivity of low-income groups and promotes sustainable intensification and better management of natural resources, with more emphasis on less favorable areas.
- Action to curb fast population growth is desirable.
- Although trade liberalization can contribute to the stabilization of world agricultural markets, there remains the absence of a paradigm for coping with food price instability.
- Transfers and targeted programs can be an effective means to improve access to food and reduce poverty, but are no long-term substitutes for shared economic growth and structural adjustment and reforms.
- The analytical ability to capture large-country effects remains limited; coincidence of bad harvests, consecutive bad years or sudden changes in food policy cannot be properly assessed.

These outcomes pose a number of policy dilemmas in achieving food security, which can be briefly summarized as follows:

1. Low relative prices and a general aid fatigue may slow down technical advances in research and development, and discourage investment in agriculture, knowledge, infrastructure and environmentally related activities.
2. Much of the future increase in food production requires substantial research efforts and a redirection of activities towards eco-regional approaches for sustainable land use and food security, in particular for marginal areas.
3. Food security is a field where market imperfections abound and public action is required as:
   - agricultural research is largely a public good with strong externalities;
   - future shortages and surpluses of a long-term nature hardly affect present prices;
   - environmentally damaging or favorable practices go almost unnoticed in the market place;
   - access failure implies a strong distributional concern.
4. Curbing population growth and liberalizing trade to facilitate access to food are not universally shared instruments.

3.6. Policy support and reform

Keeping in mind the policy dilemmas to achieve better food security, what can we conclude about policy support and possibly reform to fight hunger and malnourishment? On the *access* side, the answer is simple and classical. Long-term food security depends on broad-based and shared economic development. Short-run concerns usually require redistribution mechanisms (national and international) to restore access to food. Policies to achieve this are well documented in the development literature and are not confined to the agricultural sector. Entitlements to food can be created in any part of the economy.

To ensure *availability*, certainly via domestic production, has proven more controversial. Past policies in many developing countries have hardly supported agriculture in an era where pro-urban and pro-industry policies were the rule. Policy reform to restore support for – or at least non-discrimination of – agriculture has come slowly under structural adjustment programs, and has not been helped by the often-inconclusive discussions on market and government failures. Interventions in support of agriculture are believed to be most effective if they create an enabling environment (improving access and correcting for classical market failures) for basically private decision-making, and focus more on structural and competition policy rather than direct price and market interventions. The latter can be confined to policies to stabilize prices, be restricted to a few strategic crops or inputs, and make better use of international (or large national) markets.

The high cost in terms of efficiency *and* distribution of past price distortions in agriculture, insufficient targeting, and under-investment in overhead provisions are by now well known. Allowing for regional differentiation, three conclusions stand out:

- rather than sectoral policies, exchange rate, trade and tariff policies have been the major determinants of agricultural prices;
- agricultural price support, if any, has been insufficient to compensate for the strong price-depressing effect of macro-policies; and
- other compensating interventions (input subsidies) have often been regressive and discriminating against the poor.

To conclude, agriculture's contribution to welfare and food security goals depends on three major areas of policy concern: efficient pricing, improved yields, and gradual shifts to higher-value crops. An integrated approach to agricultural policy will therefore emphasize good macro-economic and trade policies to ensure correct incentive pricing, proper management of the natural resource base of agriculture, and an enabling structural and institutional policy to overcome access constraints to markets, input supply and technology. In general terms this means:

- less direct price and market interventions;
- more emphasis on public expenditure on infrastructure, support services and institutions;
- a shift from commodity to factor taxation; and
- appropriate and targeted interventions in the case of genuine market failures such as food insecurity and natural resource exhaustion.

It is the last argument that justifies fiscal subsidies to alleviate malnutrition, establish credit programs (not subsidized interest rates), encourage positive environmental activities, or promote the transition to new technologies and input packages.

3.7. References

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4. World population trends: how do they affect global food security?

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4.1. Introduction

This paper investigates how current trends of world population growth might affect global food security. It is organized into three parts: First, we give an outline of those demographic trends that are relevant for food security. Then, we analyze frequently discussed links between people and food and show that conceptual confusion and fallacies have obstructed scientific progress towards a better understanding of this relationship. Finally, we briefly discuss what would be necessary to increase worldwide food security in the future.

4.2. Major demographic trends worldwide [1]

World population will grow significantly - despite falling fertility

There is a most striking paradox in global population trends: on one hand we have had a rapid decline in fertility for over two decades in many developing countries - not to mention the already very low fertility in most of the highly developed nations. On the other hand, we will almost certainly experience a further massive increase of the world population. The United Nations Population Division projects a global population of 8.04 billion for the year 2025 and 9.37 billion for 2050 (Fig. 4.1, Table 4.1). According to this medium variant, an increase of some 2.35 billion people can be expected worldwide between 1995 and 2025; and an additional 1.3 billion between 2025 and 2050.

These numbers are a little smaller than previous UN estimates, leading some mass media to jump to the conclusion that world population growth will be over soon. This rash judgment is premature. The UN medium variant projection is based on the assumption that almost all countries worldwide will have a Total Fertility Rate (TFR) of only 2.1 in 2050 at the latest (only for 10, mostly European countries, the UN assumes a TFR in 2050 that is a little less - between 1.84 and 2.1). This assumption would require a further steep fertility decline in many developing nations - especially in Pakistan, Nigeria, Iran or India, where the Total Fertility Rates are still far above the reproductive level of 2.1 children per woman. According to the most recent UN estimates, Pakistan for instance, currently has a TFR of about 5 children per woman - the medium variant projection assumes that it will drop to 2.1 during the next 25 years. In other words, we will only have a world population of about 9.4 billion by 2050, if the Total Fertility

[1] *Parts of this paragraph (Major Demographic Trends Worldwide) have been published previously in: Heilig, G.K. / Fischer, G. (1997)*

Rate, measured as a global average, declines from about 3.0 in 1990-95 to the reproductive level of 2.1 children per woman in 2035-40.

Table 4.1. Total Population by Region in 1950, 1995, 2025 and 2050 (in 1000). Low, Medium and High Variant UN Projection, 1996.

	Historical Estimates		UN Projections, 1996					
			Low Variant		Medium Variant		High Variant	
	1950	1995	2025	2050	2025	2050	2025	2050
World total	**2,523,878**	**5,687,113**	**7,474,059**	**7,662,248**	**8,039,130**	**9,366,724**	**8,580,509**	**11,156,318**
More devel. regions	812,687	1,171,384	1,149,984	959,159	1,220,250	1,161,741	1,286,133	1,351,681
Less devel. regions	1,711,191	4,515,729	6,324,075	6,703,089	6,818,880	8,204,983	7,294,375	9,804,637
Africa	223,974	719,495	1,370,579	1,731,421	1,453,899	2,046,401	1,546,302	2,408,106
Eastern Africa	65,624	221,315	453,249	593,984	480,182	698,596	506,719	812,974
Middle Africa	26,316	83,271	181,841	252,289	187,525	284,821	200,438	336,396
Northern Africa	53,302	158,077	236,621	258,834	256,716	317,267	276,175	381,781
Southern Africa	15,581	47,335	78,449	90,256	82,901	106,824	87,335	124,900
Western Africa	63,151	209,498	420,419	536,058	446,574	638,892	475,634	752,055
Latin Am. & Carib.	**166,337**	**476,637**	**631,598**	**649,866**	**689,618**	**810,433**	**752,670**	**1,000,555**
Caribbean	17,039	35,686	44,778	45,478	48,211	56,229	51,224	65,827
Central America	36,925	123,474	175,438	189,415	189,143	230,425	206,032	282,729
South America	112,372	317,477	411,382	414,973	452,265	523,778	495,414	651,999
Northern America	**171,617**	**296,645**	**336,398**	**301,140**	**369,016**	**384,054**	**393,598**	**451,503**
Asia	**1,402,021**	**3,437,787**	**4,428,376**	**4,405,219**	**4,784,833**	**5,442,567**	**5,108,307**	**6,500,750**
Eastern Asia	671,156	1,421,314	1,572,978	1,374,217	1,695,469	1,722,380	1,785,553	1,999,209
South-eastern Asia	182,035	481,920	634,064	651,846	691,911	811,891	749,613	994,046
South-central Asia	498,583	1,366,866	1,944,779	2,057,954	2,100,034	2,521,304	2,256,712	3,053,930
Western Asia	50,247	167,686	276,556	321,202	297,420	386,992	316,429	453,566
Europe	**547,318**	**728,244**	**669,468**	**537,521**	**701,077**	**637,585**	**736,585**	**742,331**
Eastern Europe	219,296	310,506	271,948	215,673	284,170	255,955	303,706	311,048
Northern Europe	78,094	93,372	89,039	75,785	95,593	94,194	98,776	105,667
Southern Europe	109,012	143,377	131,939	102,990	137,196	119,887	142,603	135,502
Western Europe	140,916	180,988	176,542	143,072	184,118	167,550	191,500	190,115
Oceania	**12,612**	**28,305**	**37,640**	**37,081**	**40,687**	**45,684**	**43,047**	**53,073**
Australia/New Zeal.	10,127	21,427	26,380	24,235	28,809	30,557	30,561	35,495
Melanesia	2,095	5,814	9,636	11,040	10,150	12,972	10,655	15,036
Micronesia	153	481	811	928	857	1,097	905	1,285
Polynesia	237	583	813	879	871	1,059	926	1,257
Least dev. Countr.	**197,572**	**579,035**	**1,092,685**	**1,384,413**	**1,159,255**	**1,631,820**	**1,231,329**	**1,916,482**

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Revision. Annexes I and II. New York.

Obviously, there is no guarantee that this will happen. There could be a much higher increase in world population, as indicated by the "high" variant UN projection: If worldwide fertility would drop to only about 2.6 children per woman we would have a global population of some 8.6 billion by 2025 and 11.2 billion by 2050. This would be equivalent to a 2.89 billion increase between 1995 and 2025 and a 2.58 billion increase between 2025 and 2050. Hence, we cannot exclude another doubling of the world population between now and the middle of the next century.

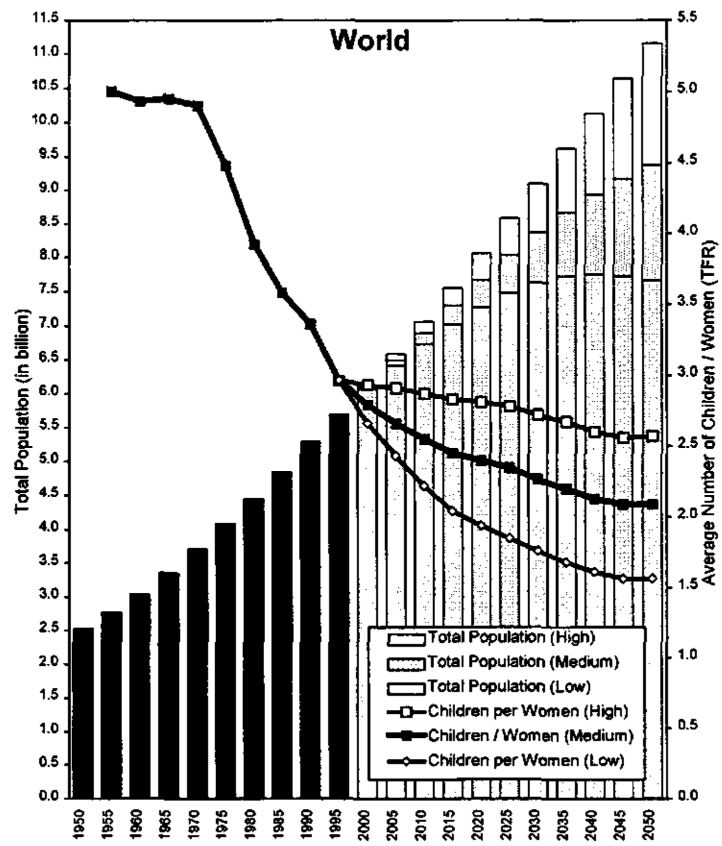

Figure 4.1. Total world population, 1950-2050 (in billions) and average number of children per woman (Total Fertility Rate). High, medium and low variant UN Projections, 1996.
Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Revision. Annexes I and II. New York.

Is it possible to completely stop world population growth during the next few decades? Yes, it is - if fertility, worldwide, would decline to 1.57 children per woman -, the global population could stabilize at about 7.5 billion by 2025. This is the result of the 1996 UN low variant projections. Please note that this variant assumes a drastic drop of average fertility to a level of some 24% below replacement - in all countries worldwide. While such a steep decline, in fact, already happened in many European countries, it is rather unlikely that populous developing nations such as Pakistan, India, Indonesia or Nigeria - which greatly determine world population growth - would follow this trend.

The current annual population increase of about 80 million will remain constant until 2015

Currently world population is growing by about 80 million people per year (Fig. 4.2). This is a little less than in the early 1990s when the growth was more than 85 million per year. According to the 1996 UN medium variant projection this will change very little during the next decades. Only after 2015 will we observe a gradual decline of the annual population increase - reaching about 50 million by 2050. Thus, by the middle of the next century, world population growth (in absolute numbers) will have declined to the level of the early 1950s. However, this is only possible, if fertility - in all developing countries - falls to the "reproductive level" of 2.1 children per woman by 2050.

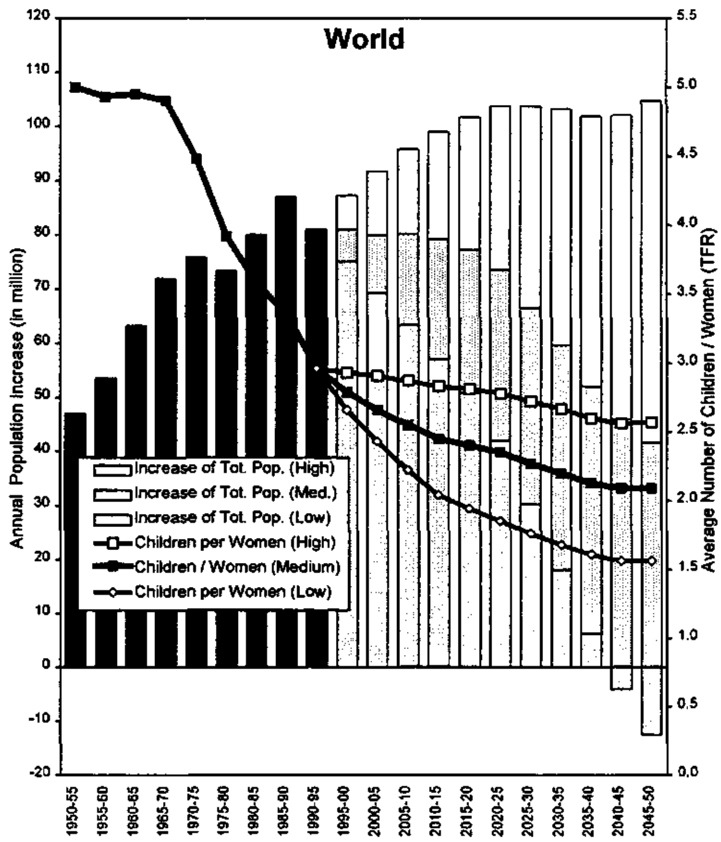

Figure 4.2. Average annual world population increase (in millions) and average number of children per woman (Total Fertility Rate). High, medium and low variant UN Projections, 1996.
Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Revision. Annexes I and II. New York.

This *absolute* population growth of about 80 million people is an important factor of global food security. Despite declining population growth rates and falling fertility, the global food demand will increase by an amount, which is roughly equivalent to the total food demand of Germany (not taking into account diet-related increase of food demand) (Crosson & Anderson, 1992)

Between now and 2050 world population growth will be generated exclusively in developing countries

Between now and the middle of the next century world population will most likely increase by some 3.68 billion people - all of this increase will be contributed by the developing countries (Table 4.2). In fact, the population of the developed nations as a group will most likely decline by almost 10 million people between now and the year 2050 - according to the UN medium variant projections. Most of this population growth in the developing world will occur during the next 30 years: between 1995 and 2025 the population in developing countries will increase by 2.3 billion; between 2025 and 2050 it will "only" grow by 1.39 billion.

Table 4.2. Population Increase (in 1000) and in Exp. Annual Growth Rate (in %) by Region between 1950-1995, 1995-2025, 2025-2050 and 1950-2050. UN Medium Variant Projection, 1996.

	Population Change & Annual Exponential Growth Rates							
	1950-1995		1995-2025		2025-2050		1950-2050	
	(10^3)	(%)	(10^3)	(%)	(10^3)	(%)	(10^3)	(%)
World Total	3,163,235	0.34	**2,352,017**	0.22	**1,327,594**	0.12	6,842,846	0.25
More Dev. Regions	358,697	0.15	48,866	0.03	-58,509	-0.04	349,054	0.07
Less Dev. Regions	2,804,538	0.41	**2,303,151**	0.26	**1,386,103**	0.14	**6,493,792**	0.30
Africa	495,521	**0.49**	734,404	**0.44**	592,502	0.26	1,822,427	0.42
Eastern Africa	155,691	0.51	258,867	0.49	218,414	0.28	632,972	0.45
Middle Africa	56,955	0.48	104,254	0.51	97,296	0.32	258,505	0.45
Northern Africa	104,775	0.46	98,639	0.30	60,551	0.16	263,965	0.34
Southern Africa	31,754	0.47	35,566	0.35	23,923	0.19	91,243	0.36
Western Africa	146,347	0.50	237,076	0.48	192,318	0.27	575,741	0.44
Latin Am. & Carib.	310,300	**0.44**	212,981	0.23	120,815	0.12	644,096	0.30
Caribbean	18,647	0.31	12,525	0.19	8,018	0.12	39,190	0.23
Central America	86,549	0.51	65,669	0.27	41,282	0.15	193,500	0.35
South America	205,105	0.44	134,788	0.22	71,513	0.11	411,406	0.29
Northern America	125,028	0.23	72,371	0.14	15,038	0.03	212,437	0.15
Asia	2,035,766	0.38	**1,347,046**	**0.21**	**657,734**	0.10	**4,040,546**	0.26
Eastern Asia	750,158	0.31	274,155	0.11	26,911	0.01	1,051,224	0.18
South Eastern Asia	299,885	0.41	209,991	0.23	119,980	0.12	629,856	0.28
South Central Asia	868,283	0.42	733,168	0.27	421,270	0.14	2,022,721	0.31
Western Asia	117,439	0.51	129,734	0.36	89,572	0.20	336,745	0.39
Europe	180,926	0.12	**-27,167**	-0.02	**-63,492**	-0.07	90,267	0.03
Eastern Europe	91,210	0.15	-26,336	-0.06	-28,215	-0.08	36,659	0.03
Northern Europe	15,278	0.07	2,221	0.01	-1,399	-0.01	16,100	0.04
Southern Europe	34,365	0.11	-6,181	-0.03	-17,309	-0.10	10,875	0.02
Western Europe	40,072	0.10	3,130	0.01	-16,568	-0.07	26,634	0.03
Oceania	15,693	0.34	12,382	0.23	4,997	0.09	33,072	0.24
Australia-N. Zealand	11,300	0.31	7,382	0.19	1,748	0.04	20,430	0.21
Melanesia	3,719	0.43	4,336	0.35	2,822	0.19	10,877	0.34
Micronesia	328	0.48	376	0.36	240	0.19	944	0.37
Polynesia	346	0.38	288	0.25	188	0.15	822	0.28
Least Dev. Count.	381,463	0.45	580,220	0.44	472,565	0.26	1,434,248	0.40

Note: The exponential growth rate was calculated with the formula: r = (log(Pn / Po)) / n log e.

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Revision. Annexes I and II. New York

Comparing the centennial growth of developed and developing countries reveals a dramatic divergence. The population of the developed countries as a group will have increased by less than 350 million between 1950 and 2050. The developing countries, on the other hand, will have an estimated 6.49 billion people more - thus almost quintupling their 1950 population.

This modern "population explosion" in the Third World is not comparable to the demographic transition of Europe in the 18th and 19th century. It is a historically unique phenomenon. Both the absolute numbers of population increase and the growth rates are without historical precedence. No country in Europe has experienced annual population growth of more than 0.5 to 1% during its "high growth" period.

World population increase is concentrated in Asia

From the 3.68 billion people that will be added to the world population between 1995 and 2050, Asia will contribute some 2 billion (Table 4.2). This enormous increase is due to the already massive size of the population. Most of this growth will occur in the next three decades. Between 1995 and 2025 Asia's population will grow by 1.35 billion - between 2025 and 2050 the increase is projected to be just 658 million (Table 4.2).

Despite a projected increase in mortality due to AIDS, we cannot expect a significant slowing down of population growth in Africa. This continent will contribute nearly 1.33 billion people to the world population between 1995 and the middle of the next century - almost twice as much as its current total population. Fertility is still so high in Sub-Saharan Africa that it can offset the effect of rising mortality. With an increase of 734 million over the next 30 years Africa's population will more than double.

Latin America and the Caribbean, on the other hand, will have only a very moderate population increase of some 334 million between 1995 and 2050 - almost two-thirds (213 million) during the next three decades. This is due to both the smaller initial size of the population and the already relatively low level of fertility.

Europe's population will almost certainly decline - by 27 million over the next 30 years and by another 64 million between 2025 and 2050. Hence, the UN medium variant projection assumes a shrinking of Europe's population by some 91 million between 1995 and the middle of the next century.

Largest growers

According to the 1996 (medium variant) UN population projection India's population will increase by an additional 401 million between 1995 and 2025 - China will grow by "only" 260 million (Table 4.3). The next largest contributor to world population growth - surprisingly - is not Indonesia, which has the third largest population among developing countries, but Pakistan. This country's population will grow by about 133 million between 1995 and 2025. An almost equal contribution to world population growth will probably come from Nigeria - 127 million. Perhaps unexpected, the next largest contributor to world population growth will be Ethiopia, which will have an additional 80 million people over the next three decades. Indonesia will grow by "only" 78 million people. The United States of America will probably grow by 65 and Bangladesh by 62 million. Few development experts would have put Zaire on a watch list for population growth. But this Central African country is projected to have an increase in population of more than 60 million between 1995 and 2025. The tenth largest contributor to world population growth will be Iran - with a population increase of almost 60 million during the next three decades (Table 4.3).

Table 4.3. The 10 countries with the highest population increase between 1950-1995, 1995-2025, 2025-2050 and 1950-2050. UN Medium Variant Projection, 1996.

Past Population Increase, 1950-1995	(10^3)
China	665,464
India	571,444
Indonesia	117,922
United States of America	109,302
Brazil	105,040
Pakistan	96,744
Nigeria	78,786
Bangladesh	76,446
Mexico	63,408
Iran (Islamic Republic of)	51,452

Projected Population Increase, 1995-2025	(10^3)
India	401,196
China	260,206
Pakistan	132,647
Nigeria	126,676
Ethiopia	79,884
Indonesia	77,785
United States of America	65,366
Bangladesh	61,751
Zaire	60,472
Iran (Islamic Republic of)	59,886

Projected Population Increase, 2025-2050	(10^3)
India	173,982
Nigeria	80,945
Pakistan	72,642
Ethiopia	62,534
Zaire	47,987
China	40,372
Indonesia	36,802
Iran (Islamic Republic of)	34,993
Bangladesh	32,585
Brazil	23,143

Centennial Population Increase, 1950-2050	(10^3)
India	1,175,113
China	961,904
Pakistan	317,840
Nigeria	305,575
Indonesia	238,726
Ethiopia	194,298
United States of America	189,730
Brazil	189,284
Bangladesh	176,405
Iran (Islamic Republic of)	153,356

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Revision. Annexes I and II. New York.

Which countries, worldwide, will have the highest increase in population during the 100-year period between 1950 and 2050? If the 1996 UN medium variant population assessments and projections are accurate (and there is no reason to believe otherwise) India will lead the group with an increase of 1.18 billion people - significantly larger than that of China, which will have a population increase of "only" 962 million (Table 4.3). The third largest contributor to world population growth between 1950 and 2050 will be Pakistan with an increase of 318 million people. The ranking of the other 7 countries is as given in Table 4.3.

Please note again that these data are all based on the most recent medium variant UN population projection, which assumes that all countries, worldwide, will reduce their average TFR to 2.1 children per woman by 2050. It is certainly possible, if not likely, that some of these countries, such as Pakistan or Iran, will not be able (or willing) to reduce average fertility to that level. In that case these countries would have an even higher increase in population than reported above.

By far the highest rates of population growth can be found in Western Asia and Africa South of the Sahara

On a country-by-country basis it was mainly the oil exporting nations of Western Asia that had the highest population growth rates over the past 45 years. According to the 1996 revision of the UN population assessments and projections, the United Arab Emirates, for instance, had a mean annual growth rate of 7.7% between 1950 and 1995. This exceptionally rapid population growth was fueled by both very high rates of fertility and immigration. Extremely high growth rates were also estimated for Qatar, Western Sahara, Kuwait, Djibouti, Brunei and Saudi Arabia (Table 4.4).

Between 1995 and 2025 more and more countries in Sub-Saharan Africa will be among those with the most rapidly growing population. Between 1995 and 2025 the fastest growing populations will be those of the Gaza Strip, Liberia, Oman and Yemen. However, there will be also extremely high rates of population growth in Rwanda, Somalia, Niger, Ethiopia, Libya, and Angola.

Which country will have the highest rate of population growth considering the whole century from 1950 to 2050? According to the UN medium variant population projection, it will be the United Arab Emirates, with a spectacular mean annual population growth of 4%. Most of the other "top ten" countries with high rates of centennial population growth are also oil-exporting nations of Western Asia (Table 4.4). This extremely fast population growth over a whole century shows that population density is unrelated to the regional agricultural resources, as long as they can be compensated by other sources of sustenance (such as Oil exports).

India will out-grow China

India has one of the oldest family planning programs. It started way back in the 1950s. The country's average fertility, however, declined only slowly. In the early 1950s both China and India had a Total Fertility Rate (TFR) of about 6 children per woman. But while China's TFR sharply fell to about 2.4 in 1990, it declined only slowly in India and was still above 4 children per woman in 1990. This relatively slow decline of fertility has built up a huge population momentum in India. The country's population structure is much "younger" than that of China. A "broad base" of children and young adults - born during the high growth period in the 1960s, 1970s and early 1980s - will enter reproductive age in the near future. Even if fertility continues to decline to reproductive level by 2020 (as being assumed by the UN projections) the Indian population will probably increase to almost 1.6 billion by 2050 - slightly more than that of China (UN medium variant).

However, India's population might become even much larger. If the average TFR would only decline to 2.6 (instead of 2.1) children per woman in 2020, the population would increase to about 1.9 billion by 2050.

According to the UN low variant projection, India's population would increase to 1.2 billion by 2050. This would require an average TFR decline to 1.6 children per woman by 2010-15. This, however, does not seem to be a very likely scenario.

Table 4.4. The 10 countries with the highest growth rates: average annual population growth rates, 1950-1995, 1995-2050, 2025-2050, and 1950-2050. UN Medium Variant Projection, 1996.

Past Population Growth, 1950-1995

	(% yr^{-1})
United Arab Emirates	7.7
Qatar	6.9
Western Sahara	6.4
Kuwait	5.4
Djibouti	5.0
Brunei Darussalam	4.0
Saudi Arabia	3.9
Libyan Arab Jamahiriya	3.7
Côte d'Ivoire	3.5
Oman	3.5

Projected Population Growth, 1995-2025

	(% yr^{-1})
Gaza Strip	3.8
Liberia	3.8
Oman	3.6
Yemen	3.2
Rwanda	3.1
Somalia	3.0
Niger	3.0
Ethiopia	2.9
Libyan Arab Jamahiriya	2.9
Angola	2.9

Projected Population Growth, 2025-2050

	(% yr^{-1})
Gaza Strip	2.3
Oman	2.1
Ethiopia	1.8
Zaire	1.8
Yemen	1.7
Niger	1.7
Somalia	1.7
Angola	1.7
Congo	1.7
Liberia	1.7

Centennial Population Growth, 1950-2050

	(% yr^{-1})
United Arab Emirates	4.0
Western Sahara	3.7
Qatar	3.5
Djibouti	3.2
Oman	3.2
Kuwait	3.1
Saudi Arabia	2.9
Libyan Arab Jamahiriya	2.9
Gaza Strip	2.9
Niger	2.7

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Revision. Annexes I and II. New York.

Nigeria and Pakistan: emerging population giants

There are not many countries in the world where population projections are more difficult to believe than in Nigeria. It will become an African population giant, well comparable to the most populous Asian nations. In 1950 the West-African country had a population of about 33 million; since then the population has more than tripled. The UN Population Division estimates that Nigeria's population in 1995 was about 112 million (please note that the UN does not revise their estimate according to the most recent Nigerian census, which was significantly lower. Obviously, the UN Population and Statistical Divisions do not consider this census accurate enough). Between 1995 and the year 2050 the country's population will probably triple again and reach almost 339 million (Fig. 4.3). If this does occur, we will have a tenfold increase of a 33 million population within one century. This would have no historical precedence. And this is just the medium variant UN projection.

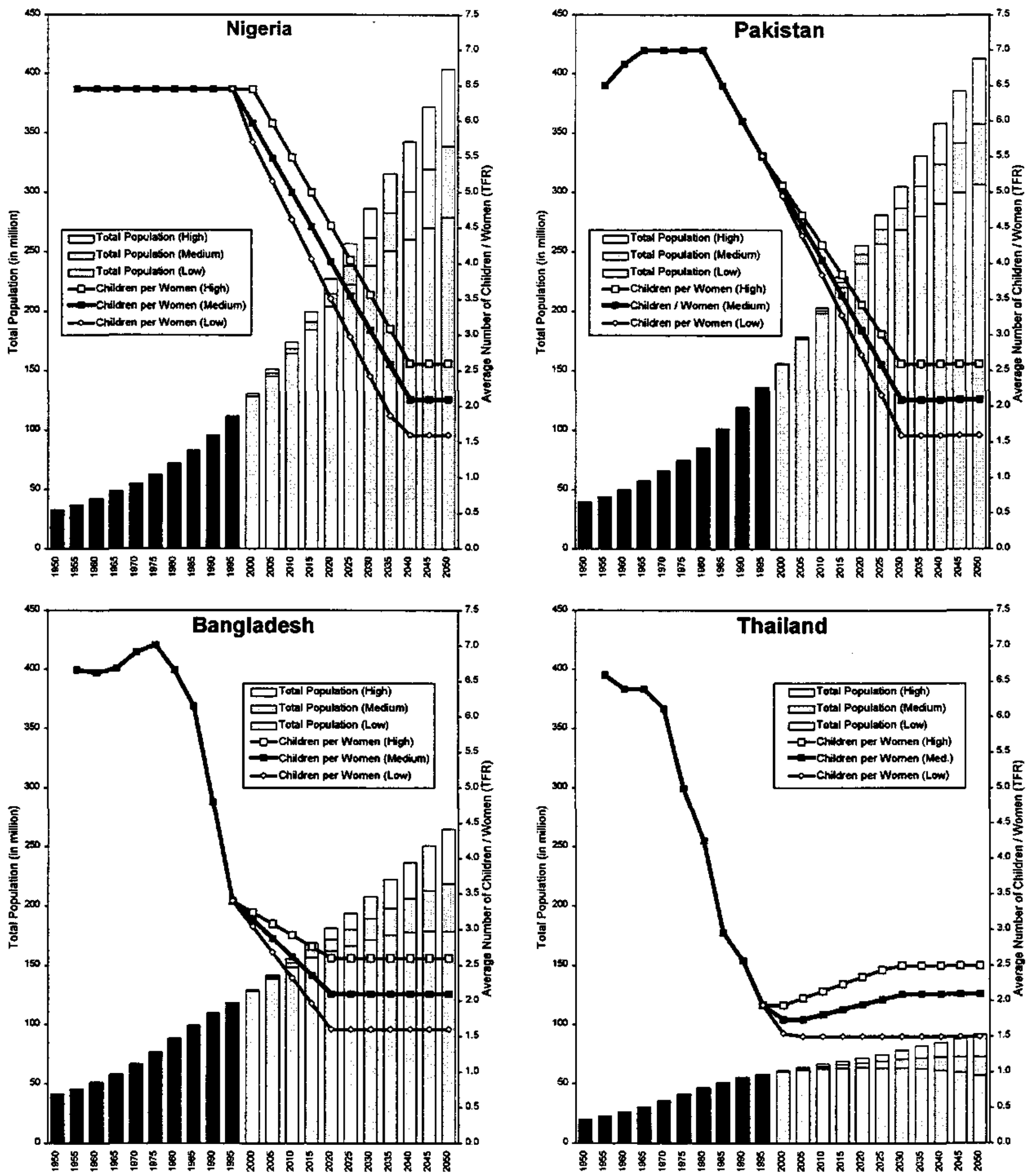

Figure 4.3. Nigeria, Pakistan, Bangladesh and Thailand: Total population 1950-2050 (in millions) and total fertility rate. High, Medium and Low Variant UN Projections, 1996.
Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Revision. Annexes I and II. New York.

There are several overwhelmingly Muslim populations with very high population growth rates, such as those of Saudi Arabia, Kuwait or the United Arab Emirates. But none of them is projected to have such a massive absolute increase of the population as Pakistan. In 1950 Pakistan had a population of about 40 million people. Since then it has more than tripled and stood at 136 million in 1995. But the real population explosion in Pakistan will only come over the next few decades, because the country not only has a very young population, but also still an extremely high fertility - much higher, for instance, than in Bangladesh or Thailand. These large numbers of children and young adults will soon come into reproductive age and will produce a large number of offspring even if we assume, as in the UN medium variant, a rapid decline in average fertility to reproductive level (of 2.1 children per woman) by 2020. Pakistan's population will be about 357 million by 2050 (according to the UN medium variant projection) (Fig. 4.3).

High fertility in the early 1950s was not the only reason for the exceptional population growth in Nigeria and Pakistan. There were other countries, which initially had a similar or even higher level of fertility. Consider the case of Bangladesh and Thailand. The Total Fertility Rate of Bangladesh during the early 1970s was as high as in Nigeria or Pakistan and the initial population size was quite comparable. Yet Bangladesh is projected to have a population of "only" 220 million by 2050 (as compared to 339 in Nigeria). Even more impressive are the demographic trends in Thailand, which reflect one of Asia's success stories in population control. The country's average TFR was comparable to that in Nigeria, but declined sharply in the early 1970s. This "saved" Thailand from building up this massive population momentum, which characterizes the situation in Nigeria or Pakistan. Consequently Thailand will have only a very moderate population increase of 14.7 million between 1995 and 2050 (Fig. 4.3).

The global balance of population is shifting

Europe's share of the world population sharply declined between 1950 and 1995 from 21.7 to 12.8% - Africa's share, on the other hand, has increased from 8.9 to 12.7%. Today, both Europe and Africa are each home of about one eighth of the world population. This will change significantly in the future. Europe's share of the global population will shrink to about 6.8% in 2050. Africa's share will grow to 21.8%. Hence, one century of population growth will completely reverse Europe's and Africa's position. Following the UN medium variant projections we have to expect a dramatic change in the global balance of population: A much bigger share of the world population will live in sub-Saharan Africa. In only some 50 years Western Africa, for instance, will have the same population as all of Europe. Eastern Africa will have many more people than all the countries of South America, the Caribbean and Oceania combined.

4.3. The link between people and food

There are few subjects in demography, which have received more attention than the relation between population and food. Since the times of Rev. Thomas R. Malthus – or even before – numerous scholars have dealt with the question, whether the number of people might eventually outgrow the potential of the arable land to provide food for the people (amongst others Malthus, 1798; Vogt, 1948; Osborn, 1948; Fremlin, 1964; Ehrlich, 1968; Daily & Ehrlich, 1992; Waggoner, 1994; Islam, 1995; Cohen, 1995; Ehrlich *et al.*, 1995; Heilig, 1996).

The most striking feature of this discussion is that it seems to repeat itself with each generation – apparently with little chance to lead to a definite conclusion. A few years ago Joel Cohen published a book in which he systematically discussed a large number of theories and models on how many people the Earth can support. He could show that the range of estimates actually *increased*. "More and more extreme (both high and low) estimates are proposed, challenged and defended" (Cohen, 1995, p. 214).

One reason for this unsatisfactory trend is the conceptual confusion, which plagued the discussion over many centuries and sidetracked scholars to focus on dimensions of the problem, which later turned out to be less important or even irrelevant. There was, for instance, much debate on the so-called "population carrying capacity" which primarily deals with the geo-biophysical characteristics of land, while technological, economic and social questions were ignored. The following discussion is an attempt to outline some of these fallacies. It is organized around seven arguments.

4.3.1. The *local* ratio between people and (cultivated) land is unrelated to food problems

The most basic idea, which links people and food, deals with the ratio between people and (arable) land. The argument goes like this: A given area of land can sustain only a certain number of people. If the population grows above this threshold famine will break out and cut down population to a "sustainable" size. This classical Malthusian argument was repeated by numerous authors – sometimes in its crude original version, sometimes modified. For instance some authors (and the later Malthus) assumed that people might anticipate to food shortages by restricting their reproduction and thus achieve a balance between people and land without having to wait for famine.

There are two fundamental problems with this concept.

First, people often do not (only) feed from the land, in which they live, but are supplied through trade from agricultural areas or fishing grounds *far away*. This is obvious for people living in urban agglomerates, who depend on agricultural "hinterlands", which can be located as far as on other continents. Even traditional self-supply farmers do not exclusively live from the land they cultivate. They usually have access to local markets on which they can supplement food deficits. Thus, the idea of *local* food self-sufficiency is inappropriate at heart. It ignores that human economies – even at primitive levels – use trade and at least a simple division of labor to compensate location disadvantages. Populous ancient trading centers could thus exist in the Sahara and other remote areas.

Second, the food production potential of a certain land area is not a constant – it can be increased by agricultural technology – sometimes by orders of magnitude (for instance, when Libya is growing wheat in the desert). The limitation often is not land or water as such, but the access to technology and investment capital. There are many examples where people suffer from chronic food shortages and famine while living in the middle of extensive areas of arable land, such as in Sudan.

The concept of a *local* balance between people and arable land or water resources is misleading for the analysis of food problems – even in today's least developed countries. Today, no rural area is completely isolated from the impact of the world grain market. Agribusiness, food-aid programs, or international agricultural research centers are heavily changing local conditions for farmers everywhere. Trade regulations, exchange rates, commercial energy prices, and transport technologies have become essential factors of agriculture. Some time ago, during Russia's economic transition, farmers from Georgia used to board *airplanes* with baskets of vegetables and fruits. They flew to Moscow to sell their products. Subsidized flight tickets and the disrupted communist food distribution system opened-up a new profit opportunity. Few countries have a more dramatic imbalance between people and land than Egypt – more than 50% of all the food has to be imported. Yet, food shortages are rare. For Egypt the geopolitics of food aid and the income from crude oil exports are the critical factors of its food supply – not land or water.

4.3.2. The *global* population carrying capacity is more than sufficient

While it has become rather obvious that the idea of *local* food sustainability is an inappropriate concept for studying today's food problems, there are still many debates about the *global* carrying capacity (Bailey, 1993). Especially some biologists have repeatedly tried to convince the public that the world is on the brink of disaster, because global population growth is supposedly outrunning the earth's capacity to produce food (Ehrlich, 1968). However, there is substantial empirical evidence that the global rain-fed crop cultivation potential could easily feed a world population twice or three times the current size.

The International Institute for Applied Systems Analysis (IIASA) together with FAO has undertaken several detailed assessments of the global arable land. They were based on the Agro-Ecological-Zones (AEZ) approach, which uses spatial databases on climate, soil and terrain information to build - in a first step - a detailed inventory of agro-ecological conditions for several hundred thousand land-units worldwide. In a second step, each unit is tested against the growth requirements of 21 major crops that are defined with a Length-of-Growing-Period (LGP) concept. If the physiological requirements of a certain crop can be matched with the soil, climate, and landform conditions of a specific land unit, this unit is marked as suitable. (For a detailed description see: Fischer & Heilig, 1998.)

IIASA and FAO researchers have undertaken several rounds of assessments based on this approach, some of them for specific countries or sub-regions. The first round in the early 1980s included 118 less developed countries (*excluding* China) (FAO, IIASA, UNFPA, 1982). It showed that these countries *as a group* had enough arable land to feed 5.7 billion people with a low level of agricultural technology, 14.4 billion with an intermediate level of technology and 32.3 billion with a high level. The 1996 UN population projections predict that this group of countries (LDCs minus China) will have a total population of 6.7 billion in 2050. In other words, if these countries apply some basic agricultural technology they should be able to support twice their projected population. With currently *available* high agricultural technology, they could feed almost five times their projected population. The results of this first inventory and evaluation of cultivated land were confirmed by several subsequent studies (*e.g.* Eswaran *et al.*, 1998; Penning de Vries, *et al.*, 1995).

Ironically, this did not end the debate. Several authors actually used the IIASA/FAO data to prove *their* argument, that the population was approaching the global carrying capacity. Joel Cohen, for instance, pointed out that at "low levels of farming technology, there would be 64 critical countries, with a projected 503 million people more than they could feed" (Cohen, 1995, p. 118). T.N. Srinivasan criticized the IIASA/FAO study for omitting economic factors. Some authors believe that the global carrying capacity is (much) *lower* than the present world population - without really explaining how this paradox should be understood. Lester Brown, David Pimentel, and Paul Ehrlich are still publishing "warning cries" that the world population (or some specific country) is approaching the maximum food production capacity of the land.

Here we cannot comment on this debate; but one misunderstanding should be clarified: Several authors have used the IIASA/FAO potential land study to prove that a number of countries would have problems at a *low* level of agricultural technology. This conclusion, however, is misleading. The definition of "low inputs" in the IIASA/FAO study was based on a traditional almost *zero*-input agriculture. "Low input" meant that the farmers use hand tools, have no chemical fertilizers or pesticides, no irrigation, no tractor, no high yield seeds. The "low technology" category in the IIASA/FAO studies is equivalent to a primitive slash-and-burn agriculture, which needs long fallow periods to revitalize the soil. It is a *baseline* category. Most *developing* countries have long passed this stage in agriculture – their farmers are now operating on a medium level of agricultural technology. Almost everywhere in Asia, farmers are using chemical fertilizers and pesticides, have high yield crops and irrigation. Those, who predict food deficits for developing countries by assuming a "low level technology", essentially assume that the development in the Third World would be turned *back*. The opposite is more likely: current trends clearly indicate that within the next few decades most developing countries will be able to use even "high" levels of agricultural technology (in the definition of the IIASA study).

Recently, IIASA researchers have replicated the potential arable land study from the early 1980s, using much *improved* global data sets on soil and terrain characteristics, as well as much more detailed climate information (precipitation, temperature profile, *etc.*). It was found that Latin America is currently using about 185 million hectares for rain-fed cultivation. The net-area suitable for crop cultivation, however, is 952 million hectares. Thus, Latin America has a total land reserve of 767 million hectares, which is more than 4 times the currently used cultivated area. Of course, much of this land is covered by valuable forests and wetlands. But even if farmers would not tough the estimated 533 million hectares of forest and wetland some 234 million hectares of "other" land suitable for cultivation would be available. Latin America has *at least* twice as much arable land, as it is currently using (Table 4.5).

Africa has even more land reserves suitable for rain-fed cultivation. Currently, African farmers are cultivating some 248 million hectares out of 978 available for cultivation. Excluding the 447 million hectares of forest and wetland, still more than 283 million hectares would be available for rain-fed cultivation (Table 4.5). However, Africa has not only more than enough arable land – it also has a huge potential for intensification. Currently, its agriculture is mostly operating on low or medium levels of agricultural input. With a huge potential for agricultural modernization and *massive* reserves or arable land Africa should easily be able to feed its projected population. If the continent nevertheless has serious food problems and grim prospects, they are certainly not caused by resource constraints. Africa is a good example that food security can be only analyzed in a framework, which *includes* economic, social, cultural, and political conditions.

Asia, on the other hand is certainly more critical - especially Western Asia. At the moment we have not assessed the situation in Eastern Asia (mainly China), but in Western, South-Central and South-East Asia some 430 million hectares of land (out of 565 available in Asia - excluding Eastern Asia) are currently available. This leaves a reserve of only 135 million hectares. This is significantly less than in Latin America of Africa. Moreover, if we take into account that some 56% of this reserve is covered by valuable (tropical rain) forests and wetlands, just 16 million hectares of other land is available. (This does not include some land reserves in East Asia, which might be in the range of 15 to 30 million hectares). Asia has no alternative to a *rqpid* modernization of agriculture; it is also likely that some of its forests and wetlands have to be used for feeding the projected massive population increase. In addition, Asia will depend, more than any other region, on global grain markets - especially the food-*deficit* countries of Western Asia (4.3.3).

Table 4.5. IIASA estimates of land areas suitable for rain-fed cultivation; estimates of currently unused land-reserves suitable for cultivation.

	Land suitable for cultivation				Currently cultivated	Land *reserve* suitable for cultivation			
	Total	Protected Land	Used for Habitation Infrastructure	Available for cultivation	Total	Total	Forest & Wetland (%)	Forest & Wetland (1000 ha)	Other
LATIN AMERICA	**1,057,856**	**97,256**	**8,728**	**951,872**	**184,774**	**767,098**	**70**	**533,508**	**233,589**
Central America	94,331	5,208	2,073	87,050	34,049	53,001	80	42,506	10,494
South America	963,525	92,048	6,655	864,822	150,725	714,097	69	491,002	223,095
AFRICA	**1,071,584**	**78,083**	**15,416**	**978,087**	**248,345**	**729,742**	**61**	**446,722**	**283,020**
Eastern Africa	297,042	41,155	5,081	250,807	62,835	187,972	70	130,734	57,238
Middle Africa	410,113	23,157	3,616	383,340	43,137	340,203	75	253,572	86,632
Northern Africa	107,390	1,793	1,530	104,067	36,211	67,856	26	17,900	49,956
Southern Africa	45,227	1,157	105	43,965	15,850	28,115	23	6,430	21,685
Western Africa	211,812	10,821	5,084	195,908	90,312	105,596	36	38,086	67,509
ASIA	**629,766**	**25,877**	**39,286**	**564,603**	**429,552**	**135,051**	**56**	**75,727**	**15,736**
Western Asia	43,571	0	1,285	42,286	33,183	9,103	92	8,405	698
South-Central Asia	221,830	5,295	16,865	199,670	182,605	17,065	54	9,279	7,786
Eastern Asia	189,346	/*	14,398	174,948	131,360	43,588	/*	/*	/*
South-East Asia	175,019	20,582	6,738	147,699	82,404	65,295	89	58,043	7,252

/* No data available

Source: Fischer & Heilig (1997): Population momentum and the demand on land and water resources. In: Philosophical Transactions of the Royal Society of London B, Vol. 352, 869-889.

Note: For estimating the land with crop production potential we start by assessing the extents of land where climate, soils and landform are sufficiently suitable for cultivation of at least one major crop ("Total suitable Land"). From this land we subtract areas under legal protection ("Protected Land"). Land required for habitation and infrastructure is estimated using 1990 population levels ("Used for habitation & infrastructure"). By subtracting this land from the total suitable land we get the amount of land "*available* for cultivation". From this we subtract land known to be already used for agriculture ("Currently Cultivated"). The data are from FAOSTAT (FAO, 1996) and FAO's AT2010 (FAO, 1995) study; data for China have been compiled by the IIASA Land-Use Change Project. We then identified the amount of forest and wetland ecosystems using a Global Ecosystems database. The remaining land ("Other Land") is the available land reserve suitable for rain-fed agriculture *apart from* forests and wetlands.

In conclusion, our data and models show that - on a global level - there is more than enough land and water available to feed the world population in the foreseeable future. Especially, South America and Africa have huge land reserves, which are suitable for rain-fed crop cultivation (see also: Tiffen & Mortimore, 1993). Even China has more arable land than previously known (Crook, 1993). According to a most recent IIASA assessment, the worldwide land area with rain-fed crop cultivation potential is at least *twice as large* than the currently used crop area. Moreover, these areas are under *current* levels of agricultural technology, implying that the productivity could be further increased.

4.3.3. We cannot talk about food without talking about *non*-agricultural sectors

There are countries that do not have enough arable land to feed the population – even when the farmers use high levels of agricultural technology. Most of these countries are in Western Asia, South Central Asia and Northern Africa, but there are also some serious cases in Asia and in Eastern-, Western and Southern Africa. On the other hand, some countries have huge reserves. With appropriate technology, the Sudan could easily feed all of Africa; the United States and Canada could significantly step up production; many European countries have explicit policies to *reduce* the cropland in order to prevent over-production.
Countries with deficits in agricultural resource are often considered the most critical for food crises. However, this conclusion is misleading as has been discussed already (4.3.1). There are many examples of resource-poor countries, which have achieved high levels of food security, such as Japan, South Korea or Singapore. Japan, for instance, had a total cereal production of 13.4 million tons in 1995; in that year, the country had a net-import in cereals of 26.8 million tons. South Korea imported 12.4 million tons of cereals, while it produced only 6.9 million tons (Table 4.6).

These countries can feed their population well, because they can trade non-agricultural products for grain. By selling industrial products and services on the world market, they are able to support a population, which is much larger than the carrying capacity of their land. The real disaster in some countries (especially in Africa) is not the lack of agricultural resources, but their inability to develop non-agricultural sectors. With a population carrying capacity of the *global* arable land-resources, which far exceeds the projected world population in 2050, food security is more an economic and development problem – and to a lesser extent – a resource problem.

4.3.4. Food insecurity is often a distribution problem

It has always irritated researchers and the public alike, that there can be hunger in the midst of food abundance. For years the European community had a policy of "taking agricultural excess production *out of the market*" – a euphemism for destroying (or submitting to non-human consumption) huge amounts of food products. On the other hand, millions suffer from under-nutrition.

Between 1961/63 and 1992/94 the *average* food calorie supply increased almost everywhere: in Africa from 2,061 to 2,333 cal. $cap.^{-1}$ d^{-1}; in Asia from 1,865 to 2,577; in Latin America from 2,345 to 2,722; and in the Least Developed Countries from 2,012 to 2,032 cal. $cap.^{-1}$ d^{-1} (Table 4.7). While the increase in average calorie supply was very significant in Asia, it was only moderate in

Latin America and small in Africa. The average calorie supply in the Lest Developed Countries stagnated at a low level.

Table 4.6. Cereal trade and production for selected countries, 1995 (10^3 tons).

	Import	Export	Net-Trade	Production	Net-Trade (% of Production)
Australia	288	10,694	10,407	26,560	39.2
Canada	1,362	21,864	20,503	49,693	41.3
France	1,072	28,447	27,375	53,606	51.1
USA	4,947	104,189	99,242	276,999	35.8
Egypt	7,972	157	-7,815	17,182	-45.5
Japan	27,264	461	-26,803	13,437	-199.5
South Korea	12,440	10	-12,429	6,923	-179.5
North America	18,711	126,907	108,196	357,506	30.3
Europe	44,113	62,483	18,370	268,411	6.8
Oceania	1,247	10,716	9,469	27,415	34.5
Africa	34,539	3,111	-31,429	100,340	-31.3
South America	17,863	15,455	-2,408	90,113	-2.7
Asia	119,226	22,957	-96,269	929,037	-10.4
MDCs	92,273	209,072	116,799	766,858	15.2
LDCs	152,596	40,352	-112,244	1,129,197	-9.9

Source: FAO, PC-Agrostat, 1996

Table 4.7. Average per cap. Supply of Food Calories, Fat and Protein, 1961/63 and 1992/94.

		Calories per person per day		
		1961/63	1992/94	Change: 1961/63-1992/94
World	Calories	2,274	2,709	435
	Fat	48.7	68.3	19.6
	Protein	62.6	71.6	9.0
Africa	Calories	2,061	2,333	272
	Fat	38.7	47.2	8.5
	Protein	53.3	57.9	4.6
Asia	Calories	1,865	2,577	712
	Fat	24.6	51.8	27.1
	Protein	47.2	63.9	16.7
Least Developed	Calories	2,012	2,032	21
	Fat	29.0	32.8	3.8
	Protein	50.6	50.0	-0.6
Latin America	Calories	2,345	2,722	377
	Fat	50.4	76.3	25.9
	Protein	62.2	69.7	7.5

Source: FAOSTAT, 1996

However, the access to food not only differs between regions, but also between social groups within a given country. There are more than enough obese people in India or Africa – regions, where millions have chronic food deficits. Alexandratos (1995) from FAO has estimated that some 780 million people worldwide still suffer from under-nutrition – not because there is not enough food, but because these people are so poor that they cannot get access to it (Table 4.8). Researchers have shown that even in the United States of America where some 50% of the population have overweight the food supply for the poorest 5% is insufficient (at least in *quality*). Even within families, a gender-gap exists in the access to the available food. It is well documented that girls and women are the first who suffer under food shortages.

Table 4.8. Estimates of undernutrition in 93 developing countries.

	Total Population (millions)			**Undernourished * (millions)**			**Undernourished * (% of Total Pop.)**		
	1969/71	1979/81	1988/90	1969/71	1979/81	1988/90	1969/71	1979/81	1988/90
Africa (sub-Sahara)	268	358	473	94	129	175	35	36	37
Near East / North Africa	178	233	297	42	23	24	24	10	8
East Asia	1147	1392	1598	506	366	258	44	26	16
South Asia	711	892	1103	245	278	265	34	31	24
Latin America & Carribean	281	357	433	54	47	59	19	13	14
Total	2585	3232	3905	941	843	781	36	26	20

Note:
* Persons who, on average during the course of a year, are estimated to have food consumption levels below those required to maintain body weight and support light activity. This threshold level (ranging from an average of 1760 cal person^{-1} d^{-1} for Asia to 1985 for Latin America) is set equal to 1.54 times the basal metabolic rate.
Source: Alexandratos, 1995, p.50

A focus on *average* food supply ignores the unequal distribution of food within a society, which is a central cause of today's chronic food problems. The majority of undernourished people do not live in countries with extreme agricultural *resource* deficits, but in countries with highly unequal income distribution, such as in India or Latin America. Especially in Africa, the most vulnerable group is often the *rural* population, which is ignored or even discriminated by national development policies (Paarlberg, 1996). The city population usually is supplied by food imports or food aid in cases of food emergency, while the remote rural population often suffers unobserved.

4.3.5. Food security has a *cultural* dimension

Sometimes it is not the lack of money, which prevents people from getting adequate nutrition, but the lack of education and diet traditions. Various types of malnutrition are linked to traditional eating habits or taboos in certain social groups. In Africa, one can find people with protein deficits who would not eat eggs and fish or drink milk. Some social groups in modern developed societies prefer a diet with extremely high consumption of meat, fat and sugar –

despite the fact that they suffer from a high prevalence of overweight and nutrition-related health problems.

The link between people and food in scientific studies is usually investigated in terms of per capita calorie supply, vitamins or other nutritional components such as vitamins or trace elements. However, people do not eat calories or vitamins – they eat potatoes or yams, fish or pork chops, "hamburgers" or "nasi goreng", fried noodles or milk shakes. Nutrition has an important cultural dimension (Heilig, 1993, 1996). Even if a sufficient amount of *calories* would be available to all people worldwide, food deficiencies could exist, because some people would not get it in a dish they are accustomed to eat. The science fiction fantasy of a world population who lives on mass-manufactured food pills ignores the cultural diversity of nutrition. While certain American restaurant chains work hard in standardizing food preferences worldwide, it is still a long way before we can calculate the food demand of the world population in "Hamburger" equivalents (Ingco, 1990).

4.3.6. A famine does not indicate that the population has out-grown its agricultural resources

A famine certainly is the most dramatic consequence of an imbalance between people and food. This has lead many authors to consider the replication of famines among a population as an indicator that a population has out-grown the *carrying capacity* of its cultivated land. However, there are many reasons for famines where land shortage is the most unlikely (for a detailed discussion of famines in history see: Walter & Schofield, 1989; Watkins & Menken, 1985; Boyle & O'Grada, 1986).

A lot has been published on the ecological collapse of past civilizations (Lowe, 1985; Culbert, 1973; Diamond, 1994). It is, for instance, quite likely that *chronic* food shortages - triggered by a dry period around AD 800 - have contributed to the decline of the Maya civilization (Hodell *et al.*, 1995; Sabloff, 1990, 1995). But that was certainly only one element in a multi-factorial process of socio-economic decline - they didn't just perish all of a sudden in a famine. If food constrains really have contributed to the collapse of the Maya culture, than it was not an absolute limitation of bio-physical resources which caused the decline, but an inability to *adapt* the technology and the economic, social and political organization to the environmental constraints. The correlation between paleoclimatic records and the decline of the Classic Maya civilization is not necessarily a causal explanation of the collapse. For instance, it does not explain why the Mayas moved from the most seriously drought-affected southern lowlands to the *northern* lowlands (to Chichen Itza, Uxmal, Kabah or Sayil) which are not very suitable for agriculture. Why did they not move to the highlands where agro-climatic conditions are much better (Pohl, 1990; Sharer, 1994)?

More recent, there is a long list of severe famines, which are related to policy decisions, military conflicts or terror. A good example is the "Great Leap Forward" in China, which triggered one of the largest famines in recorded history. Between 1959 and 1961 Mao's communist regime started a scrupulous economic and social experiment by forcing a crude industrialization onto China's agricultural society. Millions of farmers where removed from the agricultural communes and ordered to work in primitive village industries. While the farmers tried to produce steel in their backyards, not enough labor was available to bring in the harvest. There might have been other factors involved in the rapidly developing famine, such as regional harvest losses due to bad weather conditions, or communication problems between the cadres. But there can be no doubt that the main cause of the disaster was a political decision for a bad economic program (Becker, 1996; Piazza, 1983).

The famine under Stalin's terror regime is another example of a food crisis, which was unrelated to land shortage. Through forced collectivization and deportation of peasants, he triggered a large famine in 1930-1933, especially among the rural population of the Ukraine. Most estimates range from 3 to 5 million excess deaths due to starvation (Nove, 1990). Some authors, however, have estimated that the total famine-related death toll of Stalin was in the range between 9 and 12 million (Ellman, 1991; Conquest, 1991). The Kasakhs, a semi-nomadic people, especially suffered from Stalin's destruction of traditional agriculture. When Stalin ordered their sheep population, on which they depended, to be wiped out in 1931 to 1933, many Kasakhs fled to China and other republics. However, some 1.3 to 1.75 million died due to malnutrition. If the high estimated is correct, some 42% of the entire Kazakh population perished within only three years.

In Rwanda, some 800 000 people were killed during the civil strife that ravaged the country in 1994; more than 2 million fled into neighboring countries, and another 380 000 sought refuge in camps within Rwanda. The conflict led to widespread famine.

Of course, not all famines have been triggered by economic mismanagement of authoritative regimes or political conflict and terror. We can identify many other obvious reasons for great famines – above all, natural catastrophes, such as hurricanes, floods, droughts, crop pests or volcano eruptions. In 1984/85 a devastating drought afflicted Ethiopia and several other African countries, triggering a famine which killed more than 1 million people. A cyclone that struck Bangladesh in May 1991 left the lives of an estimated 140 000 people in ruins.

These natural disasters can cause great suffering and social disruption; they often have demographic consequences, such as emigration waves or increased mortality. However, they do not indicate that the population has outgrown the food production capacity of the land. When the natural disaster is over the food situation usually normalizes - and very often, the population begins to grow again. Consider the case of India, where floods and monsoons frequently destroyed the harvests. Historians have documented numerous famines of apocalyptic dimensions in India, such as the great famine of 1630-31 which affected all of India or the food crises between 1555 and 1596 in the northwestern part of the country (Braudel, 1990). Yet none of these disasters decimated India's population in the long run. Today it is the second largest in the world, and by 2050, India will be the most populous country. The sustained *post-famine* population growth clearly indicates that it was not a tight people-land ratio, which caused the disasters.

4.3.7. It is *not* clear whether anthropogenic changes of the environment will affect *global* food security

A widely used argument predicts that environmental change, caused by global population growth and industrialization, is threatening the global food supply. In recent years, a number of studies have been published analyzing environmental impacts on agriculture (Chen & Kates, 1994; Parikh, 1994; Pimentel, 1991). Mainly four types of impacts are discussed:

- the possible impact of global climate change on rain-fed agriculture;

- the impact of industrial and urban pollutants (ozone, sulfur, heavy metals) on soils and water used in agriculture;
- the loss of arable land due to urban expansion, infrastructure construction and resource exploitation;
- the impact of over-exploitation (nutrient mining) or inadequate technology (salinization) in intensive (irrigated) agriculture.

Before we briefly discuss the various impacts, the reader should be reminded that this paper deals with *global* food security. It is obvious that environmental destruction or degradation caused by human activities has in many places already affected agricultural areas – such as around Lake Aral or in the neighborhood of urban agglomerations. However, we want to know, whether these impacts can affect the *global* food supply - a system, which has various mechanisms to counterbalance local or regional production problems.

Of course, potentially the most serious threat to global agriculture is a climate change (Chen & Kates, 1994; Council for Agricultural Science and Technology, 1992; Fischer *et al.*, 1994; Fischer & Van Velthuizen, 1996; Rosenzweig, 1994; Rosenzweig & Parry, 1994; Pimentel, 1991). The impact could be – at least – twofold: climate zones with favorable growing conditions could shift to areas with poor soils or inadequate terrain. If in Russia the area with a precipitation and temperature profile optimal for agriculture shifts to the North (as predicted by the GCMs) it will move to areas of poor soils or wetlands (such as in large parts of Siberia). The other possible impact is the increase in weather variability – especially the increase in extreme weather events, such as hailstorms, hurricanes, typhoons, blizzards, or draughts. Several studies have been conducted to clarify the issue. The debate is still ongoing, but it seems that the negative consequences of climate change for agriculture would be more serious than the positive impacts. Does this threaten *global* food security? This is hard to say. The range of uncertainty in the models, which are used to predict climate change and the subsequent consequences for agriculture is still very high. Substantial change is expected only in the far future (50 to 150 years from now). We have no idea what kind of (agricultural) technology will be available even 30 years from now to counter-balance the climate-related food production deficits.

Industrial and urban pollutants are certainly a local or regional threat to agricultural productivity. The sulfur emissions from China's coal-based energy system threaten agricultural areas – not only in China but also in Japan (Niu & Harris, 1996). Low-level ozone pollution from urban-industrial agglomerates has a measurable impact on agricultural productivity nearby (Chameides *et al.*, 1994). Many agricultural soils are polluted with heavy metals or chemical residuals from warfare. In the Ukraine, a significant agricultural area is radioactively contaminated. However, it is unlikely that these local or regional impacts could threaten the *global* food supply. There are still huge areas of unused arable land far away from urban-industrial centers. There is also reason to believe that mitigation technologies will be available and implemented, which will eventually minimize these environmental impacts from industry and urbanization.

The conversion of arable land into cities, infrastructures and resource extraction sites is certainly an important problem – especially in countries with rather limited resources of arable land, such as China or Japan. But again, this is not a universal problem – arable land in Australia, New Zealand, Canada, the United States of America, France or Russia is certainly not affected by urbanization to the same extent. In quantitative terms the loss of land to urban areas and infrastructure it is *much* less than 1% of the size of agricultural areas worldwide (Heilig, 1994).

Some authors, such as Vaclav Smil, have predicted food problems due to agricultural over-exploitation (Smil, 1987; 1984). This problem can have two "faces": (a) farmers can use methods that lead to nutrient-mining, which means that soil nutrients are extracted through harvesting at a higher rate than they are recycled (fertilizers) or generated within the soil. There is a consensus among experts that this is certainly a problem in *some* areas, such as in Eastern Africa, where farmers do not have access to adequate amounts of fertilizers. (b) The other types of over-exploitation are the problems of intense (irrigated) agriculture – especially on difficult or marginal soils. There can be numerous problems, from acidification to salinization, from soil erosion to the loss of vital microorganisms in the soil. All these problems, however, can be handled (or at least minimized) with adequate agricultural technology and soil management. They are usually related to a lack of know-how, investment capital, or incentives – factors, which can be changed.

4.4. Six key-factors of future food security and their relation to population trends

Future food security worldwide will depend on six key factors (for a recent review of the world food security situation see: FAO, 1998):

- the further development and dissemination of agricultural **technology** – in particular the question, whether the expected advances in bio-technology can be actually used by farmers worldwide;
- the worldwide implementation of those **economic structures** that promote efficiency in agriculture, liberalize trade and provide incentives to food producers;
- the development of **human resources** – the training of farmers, but also the implementation of education programs, which qualify rural populations to participate in *non*-agricultural sectors;
- the further improvement of **early warning systems** and effective **emergency food aid programs**;
- and least, but not last, the question, whether **violent conflict** and the rule of **terror regimes** can be stopped.

Agricultural technology

When we discuss global food security, two numbers have to be taken into account before and above everything else. First, we must always remember that the farmers are currently feeding some 5.5 billion people worldwide – as compared to 2.6 just 50 years ago. Second, we must be aware that with very high probability the number of people to feed will further *massively* increase – probably to some 9 billion people within the next 30 years. This population increase will be *exclusively* in developing countries.

Taken serious, these numbers lead to three conclusions: First, there is no way back to a traditional low-input slash-and-burn agriculture, which was common only 50 years ago in most parts of the less developed world. Without modern agricultural technology, it would not be possible to feed a 5.5 billion global population – not to speak about the 9 billion people in 2030. It was the use of chemical fertilizers, advanced irrigation, crop sanitation products (pesticides, herbicides, *etc.*), high-yield seeds, agricultural machinery, modern transportation systems and expanded infrastructure, which ended the age of famine. This is a "bitter pill" to swallow for those anthropologists, ecologists and biologists, who are by principle skeptical about modern agricultural technology and praise the advantages of traditional small-scale, ecologically adapted farming (Bartlett, 1956). Fact is - those traditional agricultural systems could not sufficiently feed a world population of *half* the current size.

Second, as resource studies have shown, there are a number of countries and regions with severe land and/or water constraints (China, Bangladesh, India, Pakistan, and Western Asia). Since their food demand will nevertheless increase, a significant improvement of agricultural productivity will be necessary, because reclamation possibilities are limited. Only the implementation of very advanced agricultural technology can help those countries to supply at least part of the massively rising food demand from *domestic* production.

Third, the productivity gains in agriculture since the late 1960s (production more than doubled while the cultivated land area remained almost unchanged) could be achieved in a very short period. The Green Revolution in Asia was implemented in less than two decades. The older among us will still remember the barrage of criticism, which academic scholars have blasted against the Green Revolution in the 1970s. Today, this is history. Even small farmers in remote areas of Asia use chemical fertilizers, pesticides, high yield grain and small tractors.

The prospects for improvements in agricultural and food technology are good. Due to spectacular advances in microbiology and plant and animal genetics, a new agricultural revolution is around the corner. It is very likely, that we will have genetically modified plants with much better pest or draught resistance and higher yield. New technologies, such as the bioreactor micropropagation for cloning, have the potential to lower the costs of breeding and speed-up adaptation and improvement of high-value crops.

Functioning economic structures

So much has been written on the economy of hunger that it is certainly impossible to review the main arguments in this short paragraph (Norton & Alwang, 1993). However, in my understanding, three "schools" of economists have driven the debate (Meyers & Simon, 1994):

- Those, who see hunger primarily as a distribution or entitlement problem, which has to be solved by **state intervention** and **development aid** to eradicate poverty;
- those, who believe that the "invisible hand" **of free markets**, combined with private (land) property and free international trade will increase everyone's income and thus eliminate poverty and hunger (Simon, 1981); and finally
- those, who have focused their attention on more **specific economic factors** that can slow down agricultural development and trigger hunger, such as lack of small agricultural credits, or the impact of food aid which can harm domestic agriculture.

While the debate will certainly go on among the economists, a few conclusions are meanwhile possible from a demographer's point of view:

- As we said, there is a small number of developing countries, which will *not* be able to feed their rapidly growing population from their own land – even if they implement advanced agricultural technology. These countries essentially have two options: they can either step-up appealing to international food aid agencies and development organizations, hoping that international donors will provide the food they need; or they can develop their *non*-agricultural sectors, and use the export earnings for buying food on international markets. In *both* cases, it is clear that the idea of national food self-sufficiency is inappropriate for these countries. In other words: a functioning international grain market with low prices is an important condition of future food security for these countries. Trade restrictions or high tariffs will especially hurt these food deficit nations.

- The increase in food demand, driven by massive population growth, will require agricultural expansion. Expressed in economic terms: we are not only talking about a distribution problem, but also about a growth problem. It is not sufficient to *distribute* the "cake" more evenly to prevent hunger, we must also make sure that it *grows* significantly. Conventional wisdom and recent experience with Eastern Europe and the former Soviet Union suggest, that economic growth in agriculture is greatly facilitated, if farmers are not tyrannized by a command and control system, but can make their own decisions. Economic incentives for farmers are crucial for increasing food production. With its economic reforms China has demonstrated in the last 15 years, how this can be achieved (Prosterman *et al.*, 1996). Much remains to be done to implement these incentives – especially in Africa.

Human resources

Sustained economic growth and agricultural modernization – two cornerstones of food security – will only be possible in Asia, Africa, and Latin America, if education and basic health services can be brought to the massively increasing number of people. It is true, as some economists have pointed out, that not only the number of mouths to feed will grow, but also the number of arms to work. This argument, however, only holds, when the working "arms" are healthy and guided by educated brains. Where education, training and public health deteriorate, because high population growth thins-out the resources, the balance of "arms" and "mouths" gets disturbed. This is not just metaphorical talk, but bitter reality in countries such as Botswana. Recent surveys have found that up to 20% of the population is infected with the Human Immunodeficiency Virus (HIV) (US Bureau of the Census, 1996) and will die of AIDS. If we take into account the elderly and children it is likely, that one third of the productive population in Botswana is weakened by a lethal virus. Some 30 million people in the developing countries are suffering from HIV infection; hundreds of millions – mainly in rural areas - are weakened by malaria and other tropical diseases, which seem to spread considerably (Garrett, 1994). The deteriorating public health situation in some (developing) countries especially in Africa (Bongaarts, 1988) and Russia (Shkolnikov *et al.*, 1996; Eberstadt, 1993; Ryan, 1995) will be a major risk of future food security.

It is also not sufficient that the current level of education and training is just maintained – it must *increase* in developing countries, if these nations should have a chance to modernize their agriculture and to develop industrial and service sectors. By 2050 Asia, Africa, Latin America, and the Caribbean will have a combined projected population of roughly 8.3 billion – as compared to 4.6 billion in 1995. Only a massive wave of modernization will allow their agriculture to keep up with the corresponding food demand. In resource-poor countries only industrialization and the development of a service sector (such as tourism) can generate the income necessary for food imports and eradication of poverty. All economic sectors must become much more productive and that is only possible through the development of human resources. Each Dollar invested in education, training and basic health services - in both rural and urban areas - brings Asia, Africa and Latin America one step closer to food security.

Early warning and emergency aid systems

Draughts, floods, typhoons, tsunamis, hail, pest epidemics and other natural catastrophes have always threatened agriculture and thus the food supply of regions or nations. With the possibility of greater weather variability due to climate change (especially in the tropics), we must expect even more frequent disaster-related food crises in the future. Population growth will amplify these risks, because it will lead to high population concentration in countries and regions, which are especially vulnerable to natural catastrophes, such as Bangladesh, India, Pakistan, Java, and Southern China. The FAO and other organizations have established very effective early warning systems and food emergency programs. The bill for emergency operations managed by FAO has climbed from $150 million for the entire decade of the 1980s to $170 million for just six years since 1991 (FAO newsletter).

Early warning systems are essential to cope with disaster-related food crises. Remote sensing makes it possible for national and international agencies to generate highly accurate harvest forecasts. The US Department of Agriculture is routinely monitoring the status of grain areas in various parts of the world, providing information which can be downloaded worldwide by everyone through the INTERNET. The Foreign Agricultural Service (FAS) of USDA collects, analyzes, and disseminates information on crop and livestock production conditions worldwide. One most valuable source of information is the analysis of digital satellite imagery, developed by the FAS Production Estimates and Crop Assessment Division (PECAD). PECAD also collects extensive weather information as it relates to agricultural production. A range of crop models is used to assess attributes such as yield, growth stage, soil moisture, and winterkill. Examples of crop-analysis products for the United States, China, Korean Peninsula and Former Soviet Union are available. From USDA one can also download vegetation condition images based on the so-called Normalized Difference Vegetation Index (NDVI). It measures vegetation vigor caused by chlorophyll activity; which is sometimes called "greenness". These data have been used to locate and monitor the effects of floods, freezes, or draughts on crop areas (see for instance the web site at: http://www.nass.usda.gov/research/). In principle, the technology, the logistics and the economic structures are in place to detect and handle future food emergencies worldwide; however, these mechanisms have to be maintained and fine-adjusted.

Paradoxically, the greatest danger of food emergency systems is their *effectiveness*. Today, large amounts of food can be rushed to almost everywhere, if necessary even being dropped from airplanes in remote areas. There is also great commercial interest from leading agricultural producers (USA, Canada, France) to fill the international grain reserves – as long as the price is attractive (or subsidized). In fact, the logistics and supply volume of emergency food aid have been so massive that it harmed domestic food markets in disaster regions. For instance, traditional African agriculture has not only suffered from regular grain imports, but also from food emergency aid programs to urban poor, which were extended more than necessary. Repeatedly, corrupt regimes (for instance in Russia, former Yugoslavia, or North Korea) have channeled emergency food aid away from the suffering. It was misused to supply armed forces or generate profit on the "black market" – thus destroying the market for domestic farmers.

Direct food aid must be strictly targeted to the needy; it must be continuously monitored and *terminated* after the emergency period. This can be best achieved by international humanitarian organizations (of volunteers), which have direct operational control of the low-level food distribution to suffering people. Government-administered food emergency programs have often been slow, ineffective, politically biased, and costly due to administrative overhead. In less developed countries an emergency food operation can only be a first step to restore food security. Usually it is necessary to implement a follow-up program of agricultural reconstruction. Depending on the type of crisis the agricultural infrastructure may be destroyed by a natural disaster, the farmers may be displaced by military operations, and the fields may be unusable due to land mines. In all those cases, the farmers do not have the resources for reconstruction. A reconstruction aid program is necessary to build up the agricultural infrastructure and provide basic inputs to the farmers.

Violent conflicts

One dimension of global food security, that must never be forgotten, is the political environment. No food security can be achieved under a terror regime or in the turmoil of civil war. It is a sad reality that violent conflicts are a *major* factor of Africa's food problems today. From Somalia to Rwanda people's stomachs ache, not only from hunger, but from fear. Terror and (civil) war are – and probably will be - the root problem for many food crises. With increasing population density, the potential impact of violent conflict will further grow. We still remember the humanitarian disaster in densely populated Rwanda/Burundi, where hundred thousands where killed, partly due to a tribal conflict over scarce arable land. With rapidly growing population at already very high levels of population density Pakistan, parts of India, Bangladesh or Java are facing a high risk of conflict over agricultural resources. Countries in West Asia and Northern Africa must be careful to avoid conflicts over scarce water resources.

Conclusion

It is a symptom of today's academic tunnel-view in agricultural research that global food security is often analyzed in a rather biased way. It is either understood as a biophysical resource problem, as a problem of lacking economic entitlements, or as a question of agricultural technology. This paper argues that food security is a *multi-criteria* problem – based on physical, biological, economic, technical, socio-cultural, demographic and political factors. At times, one factor can override all others, but usually all factors play a role.

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5. Emerging trends in demand for cereal crops

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5.1. Introduction

The world as a whole has made significant progress towards improved food security and nutrition over the last three decades. In the 1960s concerns were raised about impending famines in many parts of the globe, particularly in Asia, because of the explosion of the population growth and the closing of the land frontier. But the subsequent history has proved that such concerns were unfounded. The per capita availability of food for direct human consumption are today about 16% higher than 30 years ago. The proportion of undernourished population in developing countries declined from nearly 36% in late 1960s to 20% by early 1990s. But the progress has been slow and uneven. Indeed many countries and population groups have failed to make significant progress, and some, particularly in Africa, have even suffered setbacks in their already fragile food security and nutrition situation. Chronic undernutrition still affects some 800 million people, 20% of the population in the developing world and over one-third in sub-Saharan Africa (Alexandratos 1995, Bender & Smith 1997). We are at the doorsteps of the 21st century, but with all the remarkable developments in modern science and technology, we are yet to eliminate the scourge of hunger and undernutrition.

Indeed, the world's capacity to sustain a favorable food-population balance has again come under spotlight in view of the continued degradation of the natural resource base, and a drastic slowdown in the growth of cereal production in 1990s (Brown 1995, 1996). At the same time, rapid economic growth and urbanization in many developing countries particularly in Asia, have also been changing the food consumption patterns with significant impact on demand for different types of food. An important issue in this context is whether the deceleration in the growth in cereal production is in response to a slackening of demand for these crops. In this presentation, we would like to dwell on this issue by examining the forces governing the demand for rice, particularly in Asia. We will report the results of the projections made by the International Food Policy Research Institute for their 2020 vision on food security (IFPRI, 1995), and a subsequent revision made in collaboration with the International Rice Research Institute. Although these projections were made upto 2020, we shall also present the demand forecasts for 2010, because many exogeneous factors that will govern these changes cannot be predicted with confidence beyond that time horizon.

5.2. Determinants of demand

5.2.1. Level and growth of income

The most important factor that influences the per capita consumption of staple food is the level of income of the consumer. At low levels of income, meeting energy needs is the most basic concern for an individual. Staple foods, such as starchy roots, rice, wheat and coarse grain provide the cheapest source of energy. Poor people spend most of their income on such food. The choice of the staple depends on culture, local production and availability and relative prices of different food items. As the income increases, the consumer shifts from low quality to better quality products within the food staple. For example, rice is the most preferred food staple in Asia with 90% of the world's rice production. At low levels of income rice is considered a luxury commodity. At times of scarcity, and the very low-income consumers are often satisfied with coarse grains and sweet potatoes, which are the cheapest source of energy. As incomes grow, per capita rice consumption increase with consumers substituting for rice the coarse grains and root crops. But as income increases beyond a threshold, people can afford to have a high cost balanced diet containing foods that provide more proteins and vitamins, such as vegetables, fruits, fish and livestock products. Thus, per capita rice consumption starts to decline.

The above pattern of changes in food consumption with economic growth is amply demonstrated by the experience of Japan and South Korea, which made a transition from a low to a high-income level within a very short period of time. The trend in the Japanese per capita rice consumption since the Second World War is shown in Fig. 5.1. The consumption increased with economic growth and reached the peak by the early 1960s, and then started declining. By the late 1980s, the per capita rice consumption in Japan was about 40% lower compared to the level in the early 1960s. As income rises, the consumer is willing to pay higher prices for better quality production. In Japan, the share of higher quality rice has increased over time at the expense of the standard quality. In South Korea, the per capita consumption of rice increased from 318 grams per day in mid 1960s when it was a low-income country to 386 gams by 1979 when it reached the middle income level. Since then the per capita consumption has been declining. The changes in the composition of the per capita food intake in South Korea over the last two decades can be seen from Table 5.1. There has been a substantial reduction in the consumption of cereals and root crops, but a surge in the demand for livestock products, fish, fruits and vegetables. We can expect these changes to occur to other countries as they move along the path of economic development.

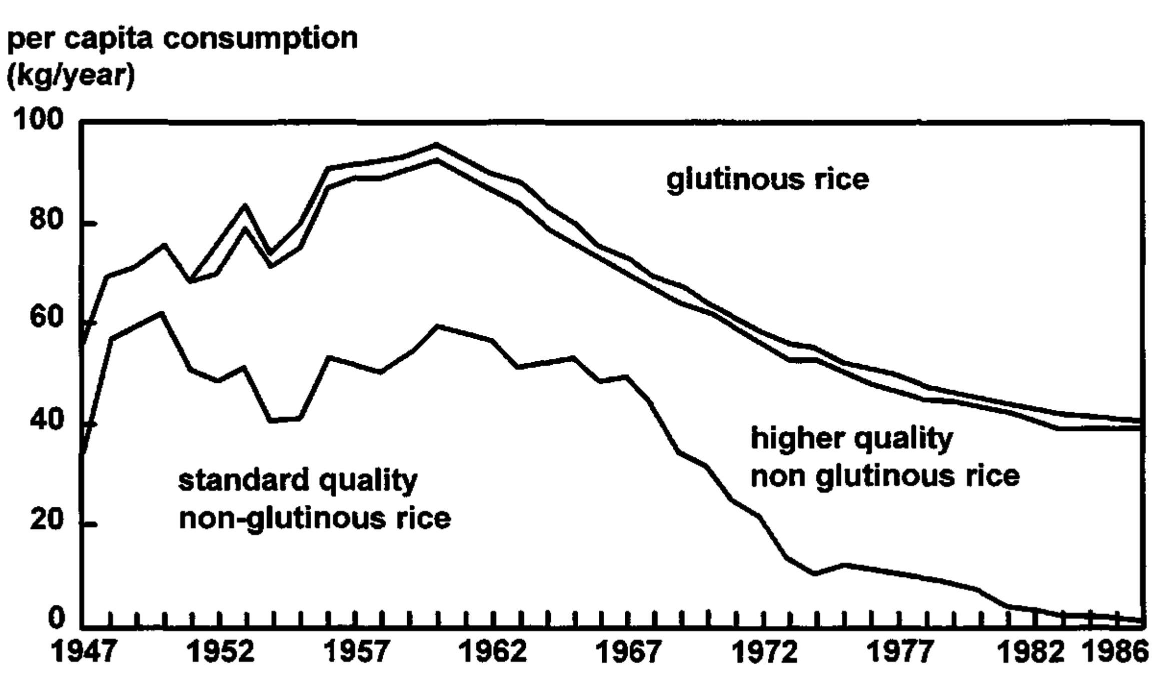

Figure 5.1. Changes in rice consumption in Japanese non-farm household (per capita annual data). Source: Comprehensive time series report on the family income and expenditure survey 1947-1986.

Table 5.1. Changes in food consumption pattern in South Korea, 1974-75 to 1992-94 (g $capita^{-1}$ d^{-1}).

Food item	1974-76	1992-94	Change
Cereals	686	513	-173
Roots	101	43	-58
Vegetables	373	511	138
Fruits	63	229	166
Sugar	23	88	65
Oils and fats	11	35	24
Fish	132	181	49
Meat and eggs	32	124	92
Milk	12	58	46
Total	1433	1782	349

Source: FAO 1996.

In many countries in East and Southeast Asia, the income has reached a level (Table 5.2) where we expect the per capita cereal consumption to decline in future. The FAO food balance sheet show that among Asian countries, per capita cereal consumption has declined substantially in Japan, Taiwan, South Korea, Malaysia and Thailand, all middle and high-income industrialized countries that have passed the income threshold mentioned above. China and Indonesia, two giant Asian nations which account for over one-third of the global cereal consumption are approaching the threshold of peak per capita consumption from where we may expect a declining trend to set-in soon. But in South Asia, Philippines and Vietnam in Southeast, 30 to 50% of the people live in poverty who do not have adequate income to access food required for a healthy productive life (Table 5.2). With economic growth and reduction in poverty, the per capita cereal consumption is expected to further increase in these countries, since the poor could then afford to satisfy their unmet demand for staple food. The rate of change in the per capita consumption of food staples in Asia will then depend on the relative strength of the upward pressure for the low-income countries and the downward pressure for the middle and high-income countries.

5.2.2. Urbanization

The other force that dampens the demand for staple food with economic growth and modernization is the trend of urbanization. As people move from rural to urban areas, the energy needs become somewhat lower as the occupational composition changes from physical labor-based to mental labor-based jobs. Also, the cost of meeting non-food basic needs, such as education and health care and transport and recreation services increase and a smaller share of the family budget is available for staple food. The composition of consumption between staple and non-staple food also changes because of greater nutritional awareness for having a balanced diet, and the practice of eating outdoors with the availability of market for food services. Hence, for the same level of income, the per capita consumption of cereals will be lower in urban areas compared to rural areas. This is demonstrated by the evidence from Bangladesh as shown in Fig. 5.2. In Asia, the level of urbanization is still low but will be growing over the next two decades (Table 5.3). Thus, urbanization is going to dampen the growth in demand for cereals, particularly of rice in the coming decades.

Table 5.2. Level of development, economic growth and incidence of poverty in selected Asian countries.

Country	Population (millions, mid-1995)	Per capita income 1995 (US$)	Per capita income PPP 1995 (US$)	Average annual growth (%) 1985-95	Fraction of poor people (%)
China	1200	620	2920	8.3	29
India	929	340	1400	3.2	53
Indonesia	193	980	3800	6.0	15
Pakistan	130	460	2230	1.2	12
Bangladesh	120	240	1380	2.1	51
Vietnam	74	240	n.a.	n.a.	n.a.
Philippines	69	1050	2850	1.5	28
Thailand	58	2740	7540	8.4	12
South Korea	45	9700	11450	7.7	0
Nepal	22	200	1170	2.4	53
Malaysia	20	3890	9020	5.7	6
Sri Lanka	18	700	3250	2.6	4

Source: World Bank, 1997.

Note: The per capita income in purchasing power parity (PPP) dollars are estimated with reference to prices in United Sates. Incidence of poverty is measured in terms of the number of poor people living on less than one US dollar per capita per day. Estimates of poverty for Bangladesh and Thailand are from national sources.

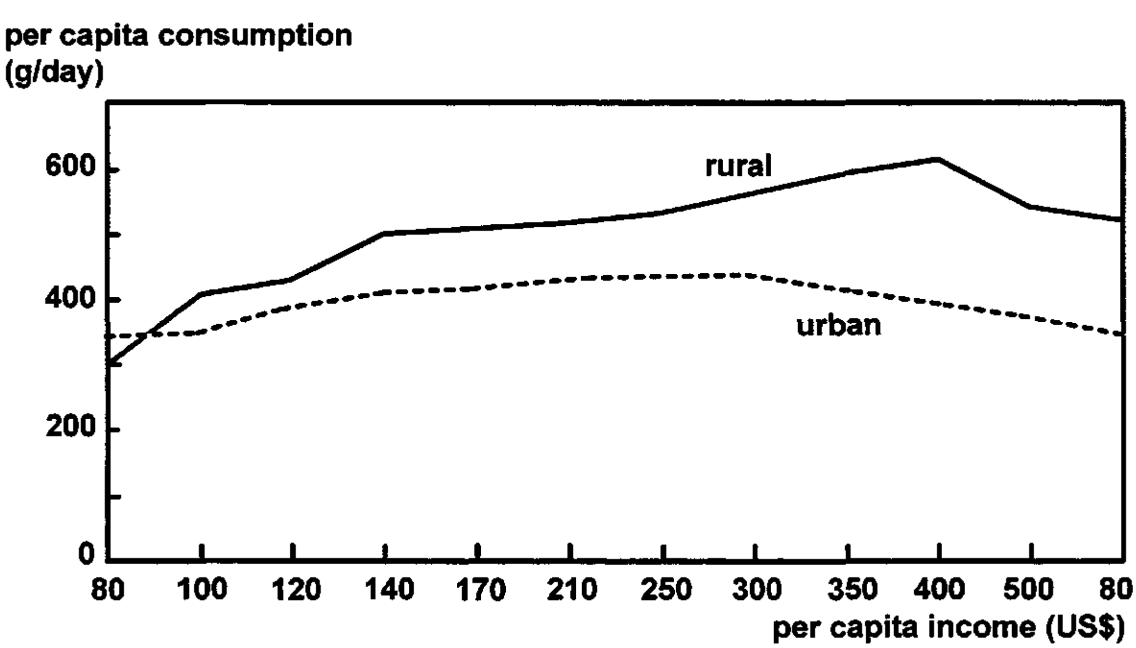

Figure 5.2. Rural-urban differences in rice consumption, Bangladesh.

Table 5.3(a). Projection of urban population, by region (% of total population).

Country	1990	2010	2020
Asia	32	44	51
Africa	32	44	51
Latin America	71	81	83
North America	75	80	83
Europe	72	78	82

Source: United Nations, 1995.

Table 5.3(b). Projection of population residing in urban areas, selected Asian countries (% of total population).

Country	1960	1990	2010	2020
Japan	56	77	81	84
South Korea	28	74	91	93
Thailand	13	19	31	35
Indonesia	15	31	54	57
China	19	26	43	51
India	18	26	34	41
Bangladesh	5	16	28	36

Source: United Nations, 1995.

The influence of the level and growth of income and of urbanization is captured by economists in the income elasticity of demand. It measures the degree of increase of demand for a commodity in response to a change in income. For low-income countries, the income elasticity of demand for staple food is typically over 0.5, indicating a 5% increase in demand in response to a 10% increase in income. But for the middle and high-income countries to income elasticity of demand for cereals is often negative, indicating that with further increases in income, the people will reduce the expenditure on staple food. The estimates of the income elasticity of demand for rice and wheat and the expected change over the next two decades assumed by the IFPRI model (Rosegrant *et al.*, 1995) can be seen from Table 5.4. The inverse relationship between the level of income and the demand response to income growth is amply demonstrated by the figures. Since the income elasticities are very low, the rapid growth of income in East and Southeast Asia is not going to have much effect on the growth for rice. But for wheat the positive income effect will be quite substantial.

Table 5.4. Projection of income elasticity of demand for foodgrains.

	Per capita income	Rice		Wheat		Maize	
Country	(US$)	1993	2020	1993	2020	1993	2020
Japan	39640	-0.05	-0.15	0.25	0.24	-0.18	-0.26
South Korea	9700	-0.20	-0.40	0.32	0.13	-0.20	-0.30
Malaysia	3890	0.06	-0.06	0.30	0.25	-0.15	-0.29
Thailand	2740	0.04	-0.06	0.29	0.22	-0.07	-0.17
Indonesia	980	0.15	-0.03	0.36	0.28	0.05	-0.10
Philippines	1050	0.21	0.05	0.33	0.27	0.21	0.05
China	620	0.10	-0.05	0.23	0.03	-0.07	-0.22
India	340	0.14	0.02	0.22	0.12	-0.01	-0.10
Bangladesh	240	0.21	0.00	0.28	0.23	-	-
Brazil	8512	0.21	0.13	0.07	0.00	0.06	-0.04
Nigeria	260	0.47	0.47	0.48	0.47	0.15	0.11
Madagascar	230	0.43	0.38	0.49	0.48	0.13	0.09

Source: IFPRI IMPACT Model; World Bank, World Development Report, 1997.

5.2.3. Indirect demand in livestock production

The other important factor that we must take into consideration in projecting the growth in demand for cereals is their indirect demand as livestock feed (Alexandratos 1995). Although the income elasticities for cereals as human food are small and declining, those for livestock products are relatively large and vary within a range of 0.5 to 0.7. This explains the significant expansion in the consumption of livestock products worldwide over the last three decades, particularly in Asia where economic growth has been the fastest. Between 1965 and 1995, food demand for meat increased more than fourfold, from 2.6 million t in 1965 to about 10.7 million t in 1995 (FAOSTAT, 1997). Even in South Asia, where people prefer primarily a vegetable-based diet, the consumption of meat has increased by over four million t over this period. Asia, as a whole, has thus emerged as a major importer of meat, with its share of global meat imports reaching about 28% in 1995. It takes 2, 4 and 8 kg of grain to produce one kg of poultry, pork and beef, respectively. The increase in the demand for livestock product implies a fast growth in the demand for cereal grains, mostly corn.

The present level of per capita meat consumption in Asia is very low compared to the standards for the developed countries. It is less than 18 kg per capita per year in South Asia, Indonesia and Myanmar; 17 to 26 kg in Vietnam, Philippines, and Thailand, and between 39 to 44 kg in Japan, China, and South Korea. Only in Malaysia, the per capita consumption is high (50 kg). So, with rapid economic growth, we can expect a surge in the consumption of livestock product and hence, the demand for cereals as livestock feed. The IFPRI projections show that during the 1993-2020 period the world demand for meat will grow at a rate of 1.8% per year, and of eggs and milk by 1.6% and 1.1% respectively. Most of this growth will be accounted for by the developing countries. The demand in the developed world will continue to slow down because of very low and declining income elasticity of demand for meat (as people become more health conscious), the stabilization of population and the slow growth of per capita incomes. In Asia, the demand for meat is projected to grow at a rate of 3.2% per year, and will account for most of the increased in demand for the world as a whole. The upward pressure on feedgrain consumption in response to economic growth can be assessed from Table 5.5, which compares the per capita cereal consumption as direct human food and livestock feed in selected Asian countries at different levels of income, compared to that in USA. The intake of livestock feed is about 12 times higher in USA compared to Indonesia, and four times higher compared to China.

Table 5.5. Consumption of cereals as human food and livestock feed in selected Asian countries, compared to the United States, average 1992-94.

Country	Cereals (g capita^{-1} d^{-1})			Consumption of meat
	As human food	As livestock feed	Total	and eggs (g capita^{-1} d^{-1})
Indonesia	561	54	615	32
China	614	146	760	121
South Korea	513	388	901	125
Japan	400	408	808	170
USA	315	610	925	370

Source: FAO 1996.

Given the level of per capita consumption, the most important factor that is going to push the demand for cereals is obviously the rate of population growth. In the developed world, the demand for cereals has been stagnating because most of them have achieved a stationary population. But most developing countries are still having a population growth from 1.5 to over 3.0% per year. However, with growing economic prosperity the growth of population will decline substantially. According to UN projections, annual growth of population in developing countries will decline from the present level of 1.9% per year to 1.1% per year by 2025. But due to the expanded base of the population (from 4.5 billion in 1995 to about 6.8 billion in 2025) the absolute increase in the number of people over the next three decades will remain as large as over the last three decades (Fig. 5.3). Ironically, it is in the poverty-stricken regions, where the per capita cereal consumption is expected to increase, the population growth will also grow faster. In South Asia, for example, the population is projected to increase by 723 million over the next three decades, compared to 656 million over the previous three decades. In Africa, the projected increase during the next three decades is about 78% higher than the actual increase over the last three decades. It is only in the East and Southeast Asia and in Latin America that the additional number of mouths to be fed is going to be lower in the future compared to what they have experienced in the past.

5.2.4. The forecast of the growth in demand

We now present the results of the projections of the demand for cereals considering the above factors. The demand projections are made using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) that was developed at the International Food Policy Research Institute (IFPRI; for details of the model, see Rosegrant *et al.*, 1995). It is specified as a set of country or regional submodels, each with a particular structure within which supply, demand, and prices for the commodities are determined. The 35 countries and regional agricultural submodels are linked through trade, a specification that highlights the interdependence of countries and commodities in the world agricultural economy. The model uses a system of supply and demand elasticities, derived from other studies, incorporated into a series of linear and non-linear equations, to approximate the underlying production and demand functions. Sectoral growth multipliers are used to determine the intersectoral effects of changes in income in agriculture and non-agricultural sectors.

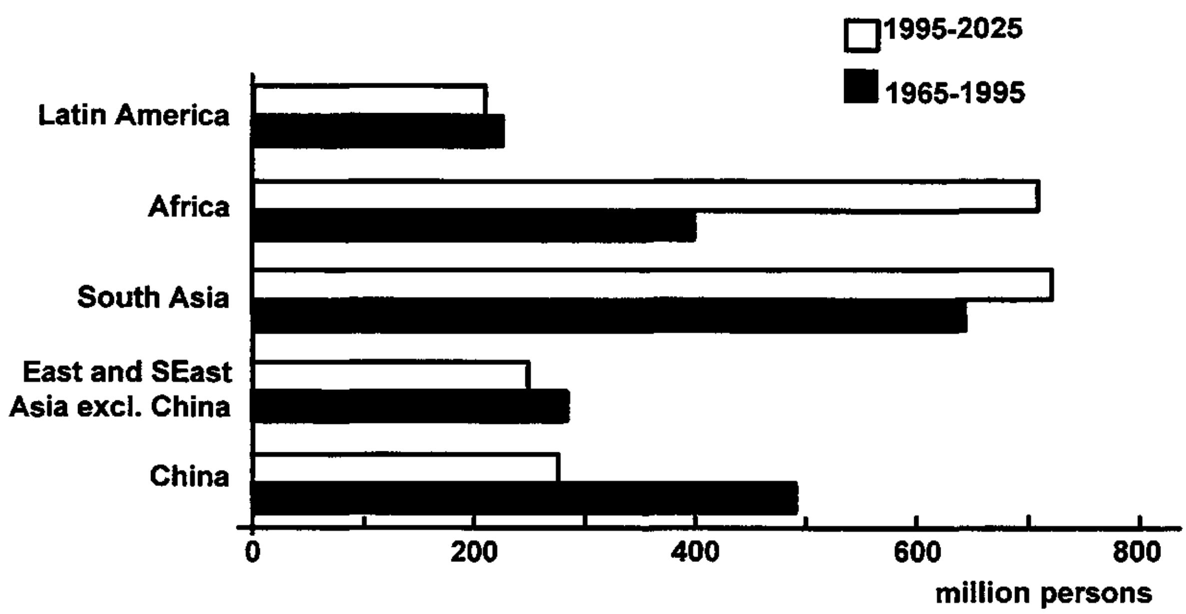

Figure 5.3. Projection of population increase over 1995-2025 compared to increase over 19965-95.

Domestic demand for commodity is the sum of its demand for food, feed and industrial uses. Food demand is a function of the price of the commodity, the prices of competing products, per capita income and total population. Feed demand is a derived demand determined by changes in the livestock production, feed ratios, and own and cross-price effects of feed crops. The function also incorporates a technology parameter that indicates improvements in feed efficiencies. The demand-supply imbalance for a crop results in changes in prices, and international trade, which feedback into the model through iterations, so that an equilibrium demand is equal to supply at the global level.

The initial results of the model for projections for the supply-demand and food security trends for the 1990-2020 period were published in Rosegrant *et al.* (1995). For demand projections, the original model used average income elasticities for the period of projection. A revision of the model done at IRRI used a declining income elasticities for different crops, and also incorporated the revised population projections by the United Nations (1995) which are based on 1991 population census reports. The revised projection gives a more optimistic scenario regarding the growth of population (Table 5.6). The revision also shifts the benchmark to 1993. A major limitation that remains is that the model does not incorporate income and population growth and demand elasticities separately for rural and urban areas.

Table 5.6. Changes in the projection of population trends by region.

Region	Benchmark population In 1990	Projection for 2010		Increase (%)	
		1992 UN projection	1996 revision	1992 projection	1996 revision
Asia					
East Asia	1324	1599	1585	20.8	19.7
Southeast Asia	441	605	592	37.1	34.2
South Asia	1115	1602	1577	43.7	41.4
sub-Saharan Africa	485	806	818	66.2	68.7
Latin America & the Caribbean	435	552	590	26.9	35.6
West Asia & North Africa	309	423	537	36.8	73.8

Source: United Nations Population Council.

The results of the projection for the demand for cereal crops for the developing countries for the 1993-2010 period are reported in Table 5.7. The following major points can be noted from the table. With faster growth in income and declining income elasticities (which is projected to turn negative in the middle and high-income countries), the growth in demand for rice in Asia is going to slow down substantially. The revision shows a demand of only 1.4% per year, compared to 2.0% reported earlier. The demand for feedgrains however is going to increase at a rate of nearly 3.0% per year because of the stronger market for livestock products. The total demand for wheat and coarse cereals will grow at a higher rate than that for rice. As a result the demand for all cereals will increase at a rate of 1.9% per year because of high growth in the demand for livestock feed.

The results show a substantial deceleration in the growth in demand for cereal crops, over the next decade or so when compared to the historical growth of 2.4% per year over the next three decades.

Table 5.7. Projected growth in demand for cereals as human food and feed grains, 1993-2010.

Crop	Benchmark 1993	Projection for 2010		Rate of growth in demand (% increase)	
		IFPRI 2020 vision	Revised estimate	IFPRI 2020 vision	Revised estimate
Rice (milled)	307	430	389	2.0	1.4
Wheat	266	379	371	2.1	2.0
Coarse cereals	161	209	212	1.6	1.6
Feed grains	194	296	313	2.5	2.9
Total	928	1314	1285	2.0	1.9

Source: IFPRI-IRRI revision of IMPACT model (work in progress).

Tables 5.8 and 5.9 provide a comparative picture of the projected growth in the demand for rice as compared to cereals in the major Asian countries. The tables also report the demand forecasts for sub-Saharan Africa and Latin America. The growth in demand for both rice and other cereals is going to be the highest in sub-Saharan Africa, because of the high incidence of poverty and exceptionally high levels of population growth. South Asia will also experience strong demand growth both for rice and cereals. So is the case with the Philippines in Southeast Asia. Japan, South Korea, Thailand and China are going to experience a slow growth in demand for rice, but their demand for other cereals will continue to be high because of the faster growth in the demand for wheat and feedgrains. These countries with the exception of Thailand have extreme pressure of population of land, but have comfortable foreign exchange reserves to import food. Thus, if wheat and corn are available in the world market as prices lower than their domestic cost of production, these countries may opt for imports in meeting the growing deficits in the domestic production of wheat and corn.

Table 5.8. Projected increase in the demand for rice, 1993 to 2020.

	Demand (millions of tons)			Increase over the level in 1993 (%)	
	1993	2010	2020	by 2010	by 2020
Asia:	309	385	410	24.6	32.7
China	125	144	146	15.2	16.8
India	77.4	102.6	112.8	32.6	45.7
Indonesia	32.8	41.7	43.6	27.6	32.9
Pakistan	2.3	3.8	4.7	65.2	104.3
Bangladesh	17.9	24.4	27.0	36.3	50.8
Vietnam	12.8	17.0	18.5	32.8	44.5
Philippines	6.5	9.3	10.7	43.0	64.6
Thailand	7.7	8.4	8.2	9.0	6.5
sub-Saharan Africa	9.6	15.2	21.5	58.3	124.0
Latin America	14.4	18.9	22.2	31.2	54.2
Developing world	341	432	469	26.7	37.5

Source: Revision of IFPRI IMPACT Model.

Table 5.9. Projected increase in the demand for cereals, 1993 to 2020.

	Demand (millions of tons)			Increase over the level in 1993 (%)	
	1993	2010	2020	by 2010	by 2020
Asia:	695	938	10430	35	50
China	344	451	490	31	42
India	167	227	251	36	50
Indonesia	43.2	58.2	63.6	35	47
Pakistan	22.9	38.3	49.9	67	118
Bangladesh	20.5	28.3	31.9	38	56
Vietnam	14.0	18.7	20.5	34	46
Thailand	12.2	15.9	17.8	30	46
sub-Saharan Africa	70.4	117	155	66	120
Latin America	129	174	199	35	54
Developing world	1022	1413	1614	38	58

Source: Revision of IFPRI IMPACT Model.

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6. The role of domesticated farm animals in the human food chain

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6.1. Introduction

The human population in the world has now reached almost 5.7 billion and is expected to grow to about 10 billion in 2050 (Heilig, 1999). About ten thousand years ago, men started to domesticate animals, initially sheep and goats, later followed by cattle, swine and fowl (Von den Driesch, 1995). At present, there are some 18 billion domesticated farm animals, of which 14 billion are fowl and 4 billion cattle, buffaloes, sheep, goats and swine. They supply high quality food (meat, milk, eggs, fish) and most people find animal products tasty, especially after cooking or frying.
Animal products combine high digestibility with high protein quality. Besides, they are a valuable source of B-vitamins and minerals, notably calcium (Ca) and phosphorus (P). Fish products are valued because of their high protein content and quality, as well as the presence of omega-3 fatty acids in their lipids. From a nutritional as well as health point of view, also some negative aspects are known. Examples are the high degree of saturation of animal fats, widespread contamination with Salmonella, and a possible relationship between BSE in cattle and the Creutzfeldt-Jakob disease in humans. Apart from serving as a source of food, animals provide many other valuable products such as wool, hides, manure and draught power. On the other hand, part of the feed given to animals could also be used as human food.
This paper discusses some aspects of the role of animals in relation to world food security, amongst others by comparing regional data on food production and the distribution of humans and animals. For reasons of simplicity the regional distribution is limited to a division in the continents Africa, Asia, Europe, North America and Latin America.

6.2. Size of animal population and rate of production

In numbers and amount of biomass, the world population of domesticated farm animals far exceeds that of the human population (Table 6.1).

The human population accounts for about 226 million t of biomass. The animal population is about twice that size (427 million t), of which nearly 85% is covered by ruminants. The estimated annual production of biomass by farm animals exceeds the growth of human biomass by a factor 9.

Table 6.1. Size and growth of biomass of the 1997 world populations of men and farm animals (Calculated from FAO, Internet, 1998).

	Number ($x10^9$)	Biomass ($x10^6$ t)	Annual Production ($x10^6$ t)
Large ruminants	1.41	332	52.6
Small ruminants	1.57	36	9.9
Monogastrics	1.36	47	87.2
Fowl	13.9	12	58.1
Total animal	18.2	427	207.9
Human	5.7	226	22.5

Table 6.2 shows the number of humans and the total production of meat and fish per (sub-) continent. Worldwide, the average amount of meat plus fish available is 53.8 kg $person^{-1}$ yr^{-1}, but this varies from less than 18 kg $person^{-1}$ yr^{-1} for Africa to more than 150 kg $person^{-1}$ yr^{-1} for North America.

Table 6.2. Availability of animal product/person/year (FAO, Internet, 1998).

Continent	Human Population ($x10^6$)	Animal Production ($x10^9$ kg)	Aquatic Production ($x10^9$ kg)	Animal Product (kg $person^{-1}$ yr^{-1})
Africa	719	8.4	4.5	17.9
Asia	3438	91.5	50.6	41.3
Europe	728	49.9	12.5	85.7
North America	297	37.7	8.5	155.7
Latin America	477	20.4	20.6	86.0
World	5659	207.9	96.8	53.8
Netherlands	16	2.6	0.51	194.8

As can be seen in Table 6.3, there are also large differences between continents with respect to the kind of meat eaten. For instance: only 1% of the meat of Monogastrics (mainly pigs) is produced in Africa, while in that continent nearly a quarter (22%) of meat of small ruminants is produced. The availability of milk (world total 500 million t yr^{-1}) and eggs (50 million t yr^{-1}) shows a similar distribution. In 1995, total amounts of animal protein available per person per day were 12 and 19 g, respectively, in Africa and Asia, while the amounts available in Europe, N-America and L-America were 58, 69 g and 34 g, respectively.

Table 6.3. World distribution of animal (meat) production (FAO, Internet, 1998).

	Large Ruminants	Small Ruminants	Mono-gastrics	Fowl	Total
World (10^6t)	53	10	87	58	208
distribution (%)					
Africa	5	22	1	3	4
Asia	24	55	56	34	42
Europe	23	22	27	18	23
N-America	23	<1	10	26	17
L-America	18	<1	3	11	9

The regional differences in amount and kind of animal products produced are related to cultural and religious differences, but also to differences in resources. Thus, about 40% of the meat in North America is from poultry, produced in intensive production systems using large amounts of nutritionally balanced and cereal based concentrates. On the other hand, many animals in Africa and Asia are scavengers, living on offal and whatever they find around the compound of the household.

6.3. Other roles of livestock

Generally, livestock keepers in the industrialized countries try to maximize the production of eggs, milk, meat, and/or wool. Feed spent to maintain the animal is considered as a price that has to be paid for this goal. The situation in developing countries is often very different. Animals also provide a large part of the tractive power and manure is very important for the maintenance of soil fertility. In some areas (*e.g.* India) manure is also important as fuel for cooking. In addition, it is used for construction. In the absence of reliable banking and insurance systems for the rural poor, animals are not only (or not even primarily) kept for production purposes; they serve also as a savings bank, from which expenses like school fees can be paid, and as a reserve for emergencies like illness or crop failure (Udo, 1996). Under such conditions, the number of animals that can be kept may be more important than the level of production, even to the extent that the total production of all animals is lower than would be possible with a smaller number of animals. It is therefore not surprising that the variation in animal biomass present per person varies much less between the different areas in the world than does animal production.

6.4. Feed consumption by farm animals

The feed consumed by farm animals can be divided in a part needed for body maintenance and a part available for production. The latter includes the growth from newborn to maturity, and the production of offspring and subsequent lactation until the young are weaned (reproduction). In intensive animal production, special measures (improved feeding, health

control, *etc.*) are taken to accelerate this process (faster growth from young to maturity, higher rate of reproduction, and production of more milk than is required for the young). In this way more biomass is produced per unit of biomass present, and a smaller fraction of the feed is lost in maintenance. Consequently, the technical efficiency of the production process (amount of animal product produced per unit of feed or per unit of animal biomass) is increased. This is also a main reason why the ratio (annual production of biomass)/(biomass present) is much higher for farm animals than for humans.
Maintenance requirements are normally expressed as the amount of feed (or feed energy) required per unit of Metabolic Body Weight (MBW = W (Liveweight in $kg^{0.75}$)). Using approximate average weights for each species, the respective biomasses were recalculated as MBW. It was assumed that maintenance of one unit MBW requires 0.05 kg concentrates or 0.10 kg forage of average quality and that forages are used to cover 100% of the maintenance requirements of ruminants and 50% of those for pigs. This gives amounts of forage and concentrates needed for maintenance as shown in Table 6.4.

Table 6.4. Amount of feed (MT) required to maintain the world animal population.

Species	MBW* ($x10^9$ kg)	% Forage	Feed needed (10^6 t) Forages	Concentrates
Cattle	90	100	3285	-
Sheep & Goats	20	100	730	-
Pigs	25	50	456	228
Fowl	15	0	-	274
Total	150	90	4471	502

* Metabolic Body Weight

Estimated amounts of feed required for production are given in Table 6.5. Unlike for maintenance, where the nutritive value of forage was assumed to be 50% of that of concentrates, it was assumed that the feeding value of forage used for production is 0.75 times the feeding value of concentrates. It was also assumed that rations used for the production of milk and beef contain considerable amounts of concentrates (50 and 30% respectively). These are guestimates based on present practices in the intensive production systems (mainly in Western Europe and North America).

The results in Table 6.5 show that about equal amounts of concentrates are needed to maintain the entire animal population and for its (net) production (502 and 492 million t yr^{-1}, respectively). The data in Tables 6.4 and 6.5 indicate that about 70% of the biomass used as feed is covered by forage, and slightly less than 30% by concentrate feeds. For aquatic animals, a distinction must be made between fish caught from the sea, rivers or lakes (fisheries), and fish produced through aquaculture. When caught from natural waters, no competition for food for humans occurs. Of the more than 90 million t of fish landed annually from fisheries, some 30% is used for non-food purposes, *i.e.* mainly as animal feed. About 50% of the world fin-fish and crustaceans produced through aquaculture (total about 25 million t yr^{-1}), is based on concentrates. This adds about 10 million t to the amount of concentrates used for animal production.

Table 6.5. Amount (MT) of concentrates needed for world animal production.

	World[1] Production	% Conc.[2]	Conc./Gain[2] (kg kg^{-1})	Feed (10^6 t)	
				Forage	Conc.
Milk	500	50	0.5	167	125
Beef	60	33	3.0	160	60
Mutton	10	-		40	-
Pork	90	100	2.0	-	180
Eggs	50	100	1.1	-	55
Chicken	60	100	1.2	-	72
Total	770	57		367	492

[1] FAO Statistics, Internet, 1998; [2] Educated guess

6.5. Competition between humans and animals

Except dairy cows and beef cattle kept in feedlots (the latter mostly in North America and to a limited extent in Europe), cattle compete little with humans for feed resources, because they are largely fed with forages. Small ruminants (sheep and goats) are considered even less competitive. On the other hand, monogastric farm animals and fowl consume large amounts of concentrates.

Pimentel *et al.*, (1997) estimate that 40% of the world production of cereals is used as animal feed, primarily in developed countries. Data of De Haan *et al.* (1997) suggest a slightly lower proportion (35%). It is often stated that this is a wasteful process, because the production of 1 kg of chicken, pork and beef requires 2, 4 and 8 kg of cereals respectively, and is therefore a highly inefficient conversion process. However, part of the concentrates used for animal production consists of by-products rather than cereals. Farm animals act then as waste converters rather than competitors for human food, because such feeds become available as offal, notably in the manufacturing of flour (bran, middling, *etc.*), vegetable oil (cakes, oil meals), sugar (beet pulp, molasses), starch (gluten meals, gluten feeds), and in fruit canning (citrus pulp), slaughtering (meat, bone meal), fish processing (fish meal), brewing (spent brewers grains) and distilling (distiller's grains). The size of this proportion is not exactly known, but, also according to De Haan *et al.* (1997), the total annual amount of concentrates used in 1990/92 was 982 million t, of which 600 million t was as cereals, 130 million t as roots, 13 million t as oilseeds, and 119 million t each as brans and oilmeal (cakes). Thus, according to these figures, by-products of the agro-industry accounted for 30-40% of the concentrates, and cereals for about 60%.

6.6. Grain for food and feed

Table 6.6 summarizes FAO data on the production of cereals, oilseeds, pulses, and roots and tubers. The total production (air dry material) is well above 2500 million t per year. When the requirements for nutrition of humans are set at 275 kg per person per year, this would be enough to feed nearly 10 billion people. With 5.7 billion people, between 1500 and 1600 million t would be needed to feed the human population and around 1000 million t is available as animal feed, amply the amount required for maintenance and the present production of the world population of farm animals (1000 million t).

Table 6.6. Primary production of food and feed (FAO, Internet, 1998).

	Cereals	Oilseeds1)	Pulses	Roots & Tubers	Total per person[2]
Africa	109.2	14.0	7.4	135.6	248
Asia	991.2	126.0	27.9	269.8	360
Europe	438.5	25.5	10.3	154.4	726
N-America	427.2	96.3	5.9	29.7	1817
L-America	100.8	56.2	3.9	47.1	372
World	2067	318.0	55.4	636.6	471

[1] Coconuts, cotton seed, groundnuts, rape seed, soy beans, sunflower seed; Oceania excluded

[2] Roots and tubers counted for 35%

As estimated above, world forage consumption by farm animals must be in the order of 5000 million t. Most of this forage is produced on marginal land, not very suitable to produce food or cash crops. Based on these calculations, it could be concluded that there is at present a reasonable balance between the worldwide demand and supply of human food and feed for animals. Especially when it is taken into account that concentrated feeds for animals also include large amounts of by-products of the food industry, it may also be concluded that at this moment animal production does not compete strongly with the supply of human staple food. There appears even to be an excess of grain. In addition, in Western Europe and the USA land is set aside and farmers are being paid not to produce cereals, while in Eastern Europe the potential for arable production is clearly under-exploited at present.

Two observations should, however, be added. Firstly, that the excess of grain is largely concentrated in Europe and America. The amount of grain available in Africa is only just enough to meet the requirements for humans. Reserves appear to be higher in Asia, but estimates may be too optimistic because FAO production figures refer to hulled rice. Deducting husks and bran (accounting for about 20 and 10% respectively), would considerably reduce the estimated excess in Asia. Also on a world basis, the present net-balance between production on the one hand, and amounts needed for humans and used for animal feeding is 261 million t, or 10% of the amount of raw grain produced. Taking not only the hull fraction into account, but also post harvest losses of edible grain, would change the estimated balance from positive to negative. The second point to keep in mind is, that the demand for food will increase due to the increasing population and economic growth (Heilig, 1980; Hossain & Sombilla, 1999). This would absorb the total amount of grain now produced annually, leaving only by-products for animals, even in Europe and America, unless the amount produced is increased. A complicating factor is that the largest rise in demand is expected to occur in Asia and Africa.

6.7. Can more animal product be produced from the same amount of feed?

Animal productivity can be expressed in various ways. When animals are used as an income generator, as is the case in industrialized countries, the primary aim is a positive financial return. Animal productivity is then often expressed in terms of efficiency of production *i.e.* in kg of product (meat, milk eggs) per kg of feed. As indicated earlier, large differences exist between animal species. In intensive systems, fowl are the most efficient converters but they need also the highest quality feeds; therefore they are also the species competing most with humans for the same resources.

An alternative way of expressing animal productivity is the ratio (animal biomass produced annually) / (amount of biomass present). This ratio (Table 6.7) differs widely between animal species and between regions. Also according to this measure, fowl are the most efficient producers of meat. Average values per continent for fowl vary with a factor 3.6, with the lowest value (2.68) in Africa and the highest (9.56) in North America. The same picture emerges for the other species, except that the variation between continents is even bigger for large ruminants (value for N-America more than 6 times the value for Africa). For all species except small ruminants, values for the Netherlands are similar to those of N-America and much higher than the average for Europe. For fish production (aquaculture), the above ratio was estimated to be approximately 1.5, with little variation throughout the world (Verdegem, unpublished).

Table 6.7. Rate of animal (meat) production: (animal biomass produced annually)/(amount of biomass present).

	Large ruminants	Small ruminants	Mono-gastrics	Fowl	Total
Africa	0.08	0.19	0.77	2.64	0.15
Asia	0.09	0.31	1.73	3.64	0.44
Europe	0.35	0.36	2.36	5.86	0.93
N-America	0.49	0.52	2.63	9.56	1.21
L-America	0.15	0.13	0.89	6.09	0.24
World	0.16	0.27	1.88	5.04	0.49
Netherlands	0.50	0.36	2.67	9.59	1.52

Several factors contribute to the large differences between N-America and Europe on the one hand and the other continents on the other. The rate of production is, however, strongly related to the level of nutrient intake and consequently, feed quality. A large proportion of the animals in developing countries is kept as farmyard animals in small holder farming systems rather than in intensive commercial units as in industrialized countries. As explained above, animals in developing countries are not only kept for the production of meat, milk and eggs, but serve also a range of other purposes. The effect of multiple roles of livestock combines often with limited feed resources, both in terms of low quantities of concentrates available and low quality of roughage. In North America and Europe a considerable area of land is used to produce high quality forages such as grass, alfalfa and maize. High levels of fertilization and capital intensive conservation methods are used to assure that high quality feed is available both in the growing season and in winter. In developing countries, forage consists largely of much lower quality grass from natural grassland, roadsides, *etc.* and low quality crop residues. On the basis of feed balance studies it has often been suggested that with a different production system more animal product could be produced with the available feed. Winrock (1978) estimated that in most areas of the world only about half of the metabolizable energy in forages is used. Most of the feed left unutilized is, however, of very low quality. The main effect of including more of the available straw-like materials in the ration is that energy intake and production per animal decrease, to such an extent that the total amount of animal products produced decreases even though herd size can be increased. Low quality straw-like feeds can be very valuable to keep animals alive during limited periods of feed scarcity (survival rations), but this serves only a useful purpose in as far as better feeds are available to support actual production in subsequent seasons (van Bruchem & Zemmelink, 1995). Studies in East Java, Indonesia, indicate that the degree of feed selection performed by farmers is remarkably close to the optimum giving maximum animal production (Zemmelink *et al.*, 1992; Ifar, 1996). It has often been suggested that utilization of low quality roughage could be improved by combining these with small amounts of nitrogenous products like oilseed cakes or urea. The favorable effects of this have been known for several decades, but farmers have hardly adopted this technique, because it is not economical. The suggestion that animal production in developing countries can be based on low quality crop residues plus nitrogenous supplements has proven to be too optimistic.

6.8. World trade in feedstuffs

Table 6.8 presents an overview of the worldwide imports and exports of feedstuffs. The total im- or export accounts for only about 8% of the amount of concentrates consumed by farm animals.

Table 6.8. World imports and exports of feeding stuffs in 1996 (Mt yr^{-1}).

	Imports	Exports	Import-Export
Africa	2.568	1.159	1.400
Asia	21.061	11.486	9.575
Europe	48.331	22.336	25.995
N-America	5.585	21.856	-16.271
L-America	1.809	22.732	-20.923
Total	79.345	79.569	-0.224

The vast majority of exported feed comes from North and Latin America and Europe (each 22 million t per year); African countries export hardly at all, while Asia holds an intermediate position (11 million ton). Europe is a big net importer of animal feeds. An important reason is that the ratio in which protein rich commodities (oilseeds, pulses) and energy rich commodities (cereals) are produced, is much lower in Europe (0.07) than in North and South America (0.23 and 0.48 respectively). Of the net import of 26 million t into Europe, 18 million t were oil seed cakes.

The farmer in Europe has two advantages in his competition for protein rich feeds. Firstly, he can combine them with high quality forages (*e.g.* maize silage) and high energy concentrates and so get a much better physical return than his colleague in Africa and Asia. In addition: he produces for consumers with higher purchasing power, which enables him to pay a higher price for his inputs.

The importance of consumers with a higher purchasing power is also shown by the data for Africa and Asia: the positive import-export balance for these continents is due to large imports by a limited number of countries with a sizable middle class which can afford to eat higher priced animal products (South-Africa, Japan, Algeria, Egypt, China, South-Korea). The amount of grain used for feed in China was stable at slightly less than 20 million t between 1965 and 1978, tripled in the period 1978-1988 and, after a slow-down in growth in the period 1988-1990, increased from 60 to more than 100 million t in 1996. India, which lags behind in economic growth as compared to China, is a net exporter of animal feed even though major programs were developed in the nineteen-sixties and -seventies to increase animal production. In 1980, the amount of animal protein available was the same in India and China (7 g per person per day); in 1995 in was 9 in India and 24 in China.

6.9. Discussion

The role of domesticated farm animals (animal production) in relation to food security is a very complicated one. Farm animals are instrumental in converting huge amounts of crop residues and by-products of the food industry, which could otherwise be an environmental burden, into high quality food. Also the produce of vast areas of marginal land (natural pastures, roadsides, *etc.*) is so converted. In addition to producing high quality food, farm animals contribute to the household income of millions of households practicing mixed farming or are responsible for the entire income of specialized farmers. Further, farm animals contribute indirectly to food production and the income of farmers (mainly in developing countries) by supplying draught power and manure. Lastly, farm animals serve as a living bank account, providing additional economic security for millions of poor households. The total of these benefits from livestock is huge. Nevertheless, a number of questions may be raised.

Increasing animal production does not automatically lead to increased food security. The total amount of animal protein produced worldwide (about 53 millions t in 1994) is equivalent to nearly 26 g person^{-1} d^{-1}. That is sufficient if compared with a norm of 70 g total protein of which one third is recommended to be animal protein. Thus, the main problem is unequal distribution, not total production. Based on various sources, Luyten (1995) suggests that 9 g animal protein person^{-1} d^{-1} is sufficient, if the diet includes not only cereals and potatoes but also legumes, fruits and vegetables. Even the average values for Africa and Asia (12 and 19 g person^{-1} d^{-1}) meet these amounts. Nevertheless, the (average) value for some 20 countries, including India and Bangladesh (together more than 1 billion people), is even below that. In these and many other countries, a large part of the population suffers from under-nutrition. The first priority is then to assure that enough dietary energy and total protein is available. Animal production will contribute to that if it is based on the produce of marginal lands, crop residues and by-products, but for the poor the situation will only worsen if livestock production is expanded beyond that.

Differences between national averages of animal protein consumption (FAO statistics) are clearly related to similar differences in economic development as measured by the Gross Domestic Product per person (UN Statistics). As soon as the economic situation permits, the consumption of animal products starts to rise (Born *et al.*, 1994), with an apparent plateau between 60 and 70 g of animal protein person^{-1} d^{-1} (Zemmelink, unpublished). Thus, per capita availability of animal protein in richer Hong Kong (72 g d^{-1}) and Japan (52 g d^{-1}) is much higher than that in Bangladesh, India and Indonesia (6, 9 and 11 g d^{-1}, respectively). It seems certain that the demand for animal products in many countries will increase when the income of their people rises (Steinfeld *et al.*, 1997). Possibilities to increase production based on crop residues and marginal land are limited (see also De Haan *et al.*, 1997). In accordance with this, the fourfold increase in the per capita production of animal protein in China between 1978 and 1995 (from 6 to 24 g d^{-1}), was accompanied by a fivefold increase in the amount of grain used as animal feed (from <20 to >100 million t yr^{-1}). Thus, to meet the rising demand for animal products, China is in the process of developing intensive systems of production, similar to those used in North America and Europe. Per country data on importation of feedstuffs indicate similar trends for other countries in Africa and Asia with increasing prosperity.

Views vary when it comes to the question how provision of staple food might be affected if more grain is used for animal production. FAO (quoted by Fresco & Steinfeld, 1998) emphasizes the capacity of the livestock sector to draw on different resources and to contract and expand with resource availability. According to these authors, reductions in total cereal supply during the global food crises in 1974/75 and 1982/83 were almost entirely absorbed by adjustments by the livestock sector. On the other hand, Brown (1998a) warns that growth of the world grain harvest is slowing down and that stocks have decreased to levels well below those needed to cushion one poor harvest. Since 1994, grain prices in China have climbed 60% because demand rose faster than production (Brown, 1998b). Estimates of possible increases in grain production vary widely, but there is increasing concern about meeting requirements, both in Africa and Asia and a shift to diets including more animal products may have very large effects on the demand for grain. According to Rabbinge (1999) the required rate of increase in cereal production in Asia will be doubled as compared to that required to meet population growth. In a situation of scarcity, using more grain for animal production could lead to decreased food security for the poor because they cannot afford the higher prices. Brown (1998b) states that this has already led to measures designed to avoid political unrest in 1995 in China and Vietnam, while the European Union imposed export taxes in 1995/96 on wheat as well as barley, to discourage exports.

At present the role of livestock production in many agricultural systems is under discussion, because of a possible negative effect on the environment (Nell, 1998). Animal production can prevent environmental problems by preventing by-products to be treated as waste, but it can also cause environmental problems when the production system is based on high external inputs causing large nutrient surpluses. In many industrialized countries, such problems are already apparent and this results in detrimental effects due to the over-loading of the environment with excess nitrogen (N), phosphorus (P) and potassium (K), and the release of methane (CH_4) by ruminants (Tamminga, 1996; Nell 1998). In The Netherlands this has led to strict legislation to control and improve manure management and more recently to an enforced reduction of the number of pigs. A similar situation exists in many other industrialized countries and future legislation will probably limit further expansion.

In developing countries expansion of the livestock industry may easily result into overstocking, overgrazing and the depletion of the soils. Steinfeld *et al.* (1997) point at environmental challenges as land degradation, soil mining and over-grazing in semi-arid areas of sub-Saharan Africa, deforestation in rain forest frontiers (Brazil), and involution of mixed farming systems in densely populated areas. Shortage of water has also been mentioned as a factor most likely limiting both future plant and animal production in many parts of the world (Pimentel, 1997).

Production could in many areas probably be increased by reducing herd size, so that the remaining animals can be fed at a higher level and less feed is spent on maintenance. Farmers may, however, be reluctant to increase production this way because it reduces other benefits and thereby reduces their food security. It is true that more then half of all people in the world consume very low amounts of animal protein and would probably benefit from eating more. But it is equally true that amounts of animal protein needed to make a healthy diet, are often exaggerated. Certainly, amounts consumed by many in North America and Europe are far beyond requirements.

6.10. Conclusions

Presently no severe competition for food and feed between humans and animals appears to exist. A growing human world population together with an increased wealth will increase the demand for food and feed. This growing demand must be met by increasing productivity, by re-introducing set aside land, possibly by converting pasture into arable land and if necessary by a re-distribution between food and feed, leaving forages and by-products as main sources of animal feed.

Lack of purchasing power must presently be considered as the main constraint limiting animal production and consumption in many developing countries. In developed countries environmental problems associated with animal production may become a limiting factor. In addition in many parts of the world the availability water may become a limiting factor.

Farm animals contribute to the welfare of millions of households through a multiple of functions, including the production of high quality food. There is no doubt that they can and should continue to play these roles. The role of animals varies between regions. To avoid inappropriate allocation of resources and unfavorable side effects, animal production should be treated as an integral part of the total complex of agriculture and food production.

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7. Air pollution and crop production in the developing world

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Abstract

The impact of air pollution on crop production in developing countries is reviewed with the aim to use the information in a broad discussion on food security in these countries.

During the past decade evidence has become available that air pollution adversely affects crop production in developing countries. Yield reductions of up to 40% in major crops such as rice and wheat have been observed. In addition, the quality of crops for human and animal consumption can be reduced by accumulation of air pollutants in plant tissues. Ozone, sulphur dioxide and nitrogen oxides (NO_x) are considered to be the most important gaseous air pollutants on a global scale. Ozone, probably the most important one in terms of yield reduction of crops, is a secondary pollutant that is produced by photochemical reactions in which NO_x and volatile organic compounds (VOCs) are involved. Sulphur dioxide, NO_x and VOCs are primary pollutants, emitted by various sources related to industry and urbanization such as combustion of fossil fuels by power plants and traffic. Global risk assessment studies show that a significant part of the agricultural production area in developing countries is seriously affected by ozone and to a lesser extend by sulphur dioxide and NO_x, with average crop yield reductions greater than 15%. The crop loss due to ozone is expected to increase strongly in the coming 2-3 decades, especially in the crop production areas in a radius of 100-200 km around megacities in developing countries.

On a local scale, several other air pollutants may contribute to the air pollution situation in developing countries. It is observed that emissions of certain halogens (*e.g.* F and Cl), heavy metals (*e.g.* Pb and Hg), VOCs, and suspended particulate matter (dust, soot) can reduce crop production in terms of quantity and quality. Generally, adverse effects of these pollutants on crops are limited to an area of a few km around sources such as industries, mines, waste incineration, but some of these local causes of damage are highly persistent (*e.g.* soil degradation by heavy metals or acidification). Biomass burning and deposition of dust along unpaved roads are eye catching types of air pollution typical for some developing countries, but not a mayor threat for food production on larger scales.

It is concluded from the reported data that air pollution is a serious and continuous threat to crop production in developing countries, and that it should be viewed as a major issue in a discussion on food security in developing countries. For the future, it is expected that the air pollution situation in developing countries will further deteriorate due to rural and industrial developments and their associated emissions of air pollutants. Our understanding of the impact of air pollution on crop production in developing countries would benefit from a systematic monitoring of the air quality situation in the agricultural production areas in these countries,

from studies on exposure-effect relationships under local conditions, and from studies on economic and social consequences.

7.1. Introduction

This paper describes an inventory on effects of air pollution on crop production in developing countries, with the aim to use the information in a broad discussion on food security in these countries. Adverse effects of air pollution can be observed on humans, livestock, crops, natural vegetations, forests, animals, buildings, and soil and water quality. The scope of this paper is narrowed down to adverse effects on crops. The following definition is used: an air pollutant is a substance in the atmosphere that adversely affects crop production. Four categories of adverse effects on crops may conveniently be distinguished (adapted from Marshall *et al.*, 1997):

1. *Direct visible injury.* Visible injuries on leaf tissue usually occur after short-time exposure of crops to relatively high levels of air pollution. Extensive injury may result in reduction of crop yield. Visible injuries can make the crop more sensitive to biotic stresses (see 4) and , thus may increase the need of crop protection. Also, visible injuries reduce the economic value of crops such as vegetables and flowers.
2. *Direct effects on growth and yields.* Productivity of the crop is reduced, generally by a long-term exposure of plants to moderate levels of air pollution, even in the absence of visible injury.
3. *Accumulation of pollutants in crops.* Pollutants may accumulate in crops to levels that are toxic for humans and animals without affecting crop productivity itself. Accumulation can occur by direct uptake from the air as well as by uptake via soil and roots.
4. *Indirect effects.* This category represents a diverse group of effects. Low levels of air pollution may cause a range of subtle physiological, chemical or anatomical changes that will not directly lead to yield reductions. These changes may increase the sensitivity of crops to other stresses such as frost (Taylor *et al.*, 1987), pests and diseases (Manning & Tiedemann, 1995) and drought, thereby contributing to yield reductions and reduced crop quality.

Low levels of air pollution can have positive effects on crops as well. For example, deposition of low quantities of SO_2 may increase crop production under conditions that sulphur is limiting. The same applies to NH_3 and NO_x. This fertilizing effect is generally negligible and, dependent of the buffer capacity of the soil, is counteracted by the adverse effect of soil acidification by those compounds. No attention will be paid to positive effects of air pollutants on crop production. Other effects that are not addressed in this paper are on:

- natural vegetation, although loss of biodiversity by air pollution is evident and has serious impact on food production and quality of life on the long term,
- forest, although forest decline results in increased risks of erosion, of damage by weather extremes and loss of biomass for timber and combustion,
- water quality can be adversely influenced by air pollution, resulting in reduced food production (*e.g.* acidic deposition kills fish in lakes with low buffer capacity),
- livestock, although fodder quality can be reduced (for instance, fluoride deposition can cause severe damage to livestock via accumulation in pasture grass and fodder).

Due to these exclusions the crop loss estimates presented in this paper are underestimations.

Heck & Heagle (1985) have presented an air pollution system (Fig. 7.1). The system runs from sources and emission of pollutants, through atmospheric transport, to emission of pollutants into crop production areas and effects on crops. Monitoring of air quality and effect-assessment studies are essential elements in understanding the relationship between air pollution and food security. The effect of air pollution on crops is a function of the air pollution components present (7.2), exposure concentration and duration, uptake, crop characteristics, and external growth conditions. The effect-assessment studies provide input data for evaluation of agricultural, economic and social risks associated with air pollution effects on crops.

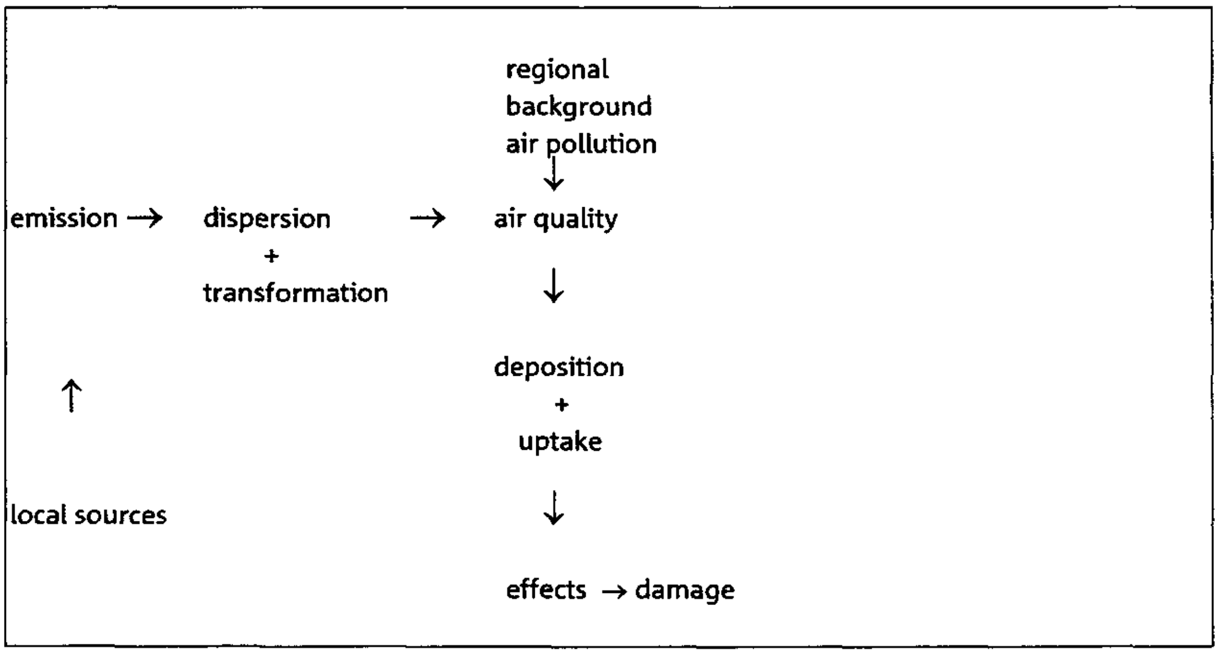

Figure 7.1. The air pollution system (adapted from Heck & Heagle, 1985).

7.2. Air pollution components

Commonly known air pollutants are summarized in Table 7.1, together with some background information about these pollutants.

Air pollutants can be divided into two categories. *Primary pollutants* are emitted directly into the atmosphere. They are generally present in high concentrations in urban areas or near large point sources. SO_2 is probably the most important primary pollutant in terms of impact on agricultural production world-wide. It is emitted in large quantities from coal-fired power plants, and can be spread over relatively large areas around these sources (this is happening at a large scale in China nowadays). Often, the sources that emit SO_2 compounds are also emitters of nitrogen oxides, heavy metals and fluorides.

In several developing countries dust produced by road traffic, excavation and open cast mining is an obvious air pollutant, although generally of a very local and non-phytotoxic nature. Another common practice in developing countries is biomass burning for extending or improving land for agricultural use. It generally is a local phenomenon, but sometimes it can have international dimensions (like in the autumn of 1997 when the fires in Indonesia caused smog on Malaysian Peninsula).

Table 7.1. List and background information of commonly recognized air pollutants from anthropogenic sources.

Description (common or group name)	Dominant form / important sources (or precursors)
Primary pollutants:	
Sulphur dioxide (SO_2)	Gas / power plants, industry
Nitrogen oxides (NO_x)	Gas / traffic, industry, power plants
Halogens (F, Cl)	Gas / industries esp. brickworks and metal smelters
Heavy metals (Pb, Zn, Cd, Hg, *etc.*)	Particulates / industries, mining, power plants
Organic compounds such as ethylene, PCB's, PAC's, *etc.*	Gas / industries, waste incineration
Suspended particulate matter (SPM, *e.g.* soot, dust)	Particulates / power plants, traffic, construction works
Ammonia (NH_3)	Gas / agriculture
Secondary pollutants	
Ozone (O_3)	Gas /secondary pollutant / (NO_x, VOCs)
Peroxyacetyl nitrate	Gas / secondary pollutant / (NO_x, VOCs)
Acidifying substances (H_2SO_4, HNO_3, $(NH_4)_2SO_4$)	Aerosol, rain / (NH_3, NO_x, SO_2)
Ultraviolet radiation (UVb)	Radiation/ (Halogenated hydrocarbons)

Secondary pollutants, such as ground level ozone, are formed by subsequent chemical reactions in the atmosphere. Ground level ozone often spreads at high concentrations over a distance of more than 100 km away from sources of its precursors. Ozone is formed through a series of chemical reactions in the atmosphere, which involve emissions of nitrogen oxides and hydrocarbons, of which traffic is the most important source. Reactions leading to ozone formation are favored by high temperatures and high light intensities and by stable atmospheric conditions (*e.g.* conditions in Mexico City during the summer period). It is considered to be the most damaging pollutant in terms of impact on agricultural production world-wide (Heck, 1989; Fuhrer *et al.*, 1997). Other secondary air pollutants are H_2SO_4, HNO_3, $(NH_4)_2SO_4$ dissolved in aerosols, mist or cloud and rain droplets. They contribute to soil degradation via acidification; their direct effect on crop production is probably small.

The increase in ultraviolet radiation is an other secondary pollutant. Emissions of halogenated hydrocarbons (CFKs) and other compounds can deplete the stratospheric ozone layer, resulting in increased ultraviolet radiation (especially UV-b) on the earth surface. Clear indications exist for a negative effect of increased UV-b radiation on crop production although it varies between species and cultivars. Quantitative estimates are complicated by the fact that both direct (damage of cellular structures), indirect (decomposition processes in the soil) and secondary effects (reduced stress tolerance) are involved (Tevini, 1993; Zepp, 1995).

An impression of the dispersion of the compounds is given in Fig. 7.2.

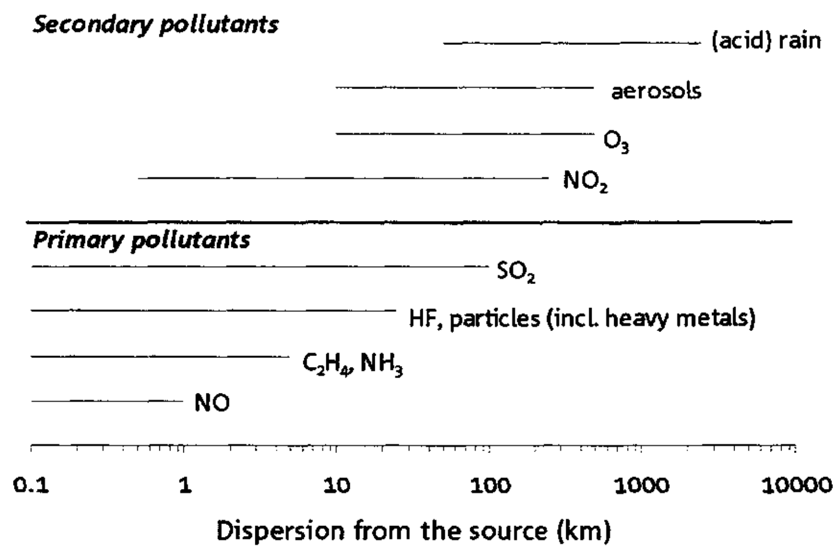

Figure 7.2. Indication of the scale of dispersion of air pollution.

7.3. Air quality in crop production areas in developing countries

Several air quality monitoring programs in developing countries have been established during the past decades. However, the programs were mainly focused on the impact of air pollution on human health and buildings in urban areas of megacities (WHO/UNEP, 1992; Marshall *et al.*, 1997). Observations on O_3, SO_2, NO_2, Pb and soot concentrations in megacities such as Mexico City, Delhi, Beijing and Bangkok reveal a deteriorating situation. Concentrations of pollutants are often above WHO human health standards and they are increasing with time, along with the growth and development of the cities.

There are no systematic data available on air pollution concentrations in crop production areas in developing countries. In general terms, it is likely that the air quality situation is deteriorating because most crop production areas in developing countries are generally situated close to urban areas of megacities. They are found in peri-urban areas of megacities, or just outside megacities in river deltas and valley's (generally less than 100 km away from megacities). Industrial sources of air pollution are generally located close to those megacities as well. Moreover, highly urbanized and industrialized regions are often situated in valleys or river delta's surrounded by hills or mountains. This geographical situation reduces the atmospheric turbulence and dispersion of air pollution, compared to flat areas. Thus, it is obvious that the air quality situation in crop production areas in developing countries is affected by emissions from megacities nearby. The available data on air pollution concentrations in crop production areas in developing countries is presented in 7.4.

7.4. Evidence for yield loss by air pollution in developing countries

Evidence of yield loss due to air pollution in developing countries has become available only since the past 10-15 years (*e.g.* Marshall *et al.*, 1997; Kempenaar *et al.*, 1997). Experimental results of these studies are summarized in Table 7.2.

Table 7.2. Examples of studies showing effects of air pollution on crops in developing countries (after Marshall *et al.*, 1997 and Kempenaar *et al.*, 1997).

Location and reference	Crop(s)	Dominant pollutant(s) (including approximate exposure concentration)	Effect
Indian Punjab (rural) Bambawale, 1986	Potato	O_3	Visible leaf injury
Southern Peru Balvin Diaz (pers.com.)	Several crops	SO_2 (100-1000 ppbv)	Visible injury and 25% yield loss
Valley of Mexico (rural) Laguette-Rey, 1986	Bean	O_3, 100 ppbv (annual, 6 h mean)	40% yield loss in sensitive cultivar
China (rural) Hongfa, 1989	Several species	SO_2, 40 ppbv, NO_x, 25 ppbv, O_3, F	5 tot 25% yield loss
India Farmer 1993	Corn (a.o. crops)	Lime dust >0.5 g m^{-2} d^{-1} (other dust types higher NOECs)	Yield loss
China (rural) Li & Wu, 1991	Several species	Pb, Cd, Zn and other heavy metals	Accumulation to toxic levels
Nile delta (rural) Ali *et al.*, 1992	Several species	Pb, Cd, Zn and other heavy metals	Accumulation to toxic levels
Nile delta (rural) Hassan *et al.*, 1995	Radish, Turnip	O_3, 50-70 ppbv (seasonal 6h mean)	30 and 17% yield loss, respectively
Pakistan Punjab (peri-urban) Wahid *et al.*, 1995	Wheat, rice	O_3, 30-60 ppbv (seasonal 6h mean), NO_2, 20 ppbv	40 and 42% yield loss, respectively

Experimental studies on effects of ambient air pollution on crop production in developed countries show similar or smaller yield reductions than the ones observed in developing countries. An example is given of the effect of O_3 on wheat in Fig. 7.3. The opposite is more exceptional. For instance, crop losses in China by SO_2 + NO_x (Table 7.2) are less than expected on the basis of exposure/response relationship for crops (Van der Eerden *et al.*, 1998).

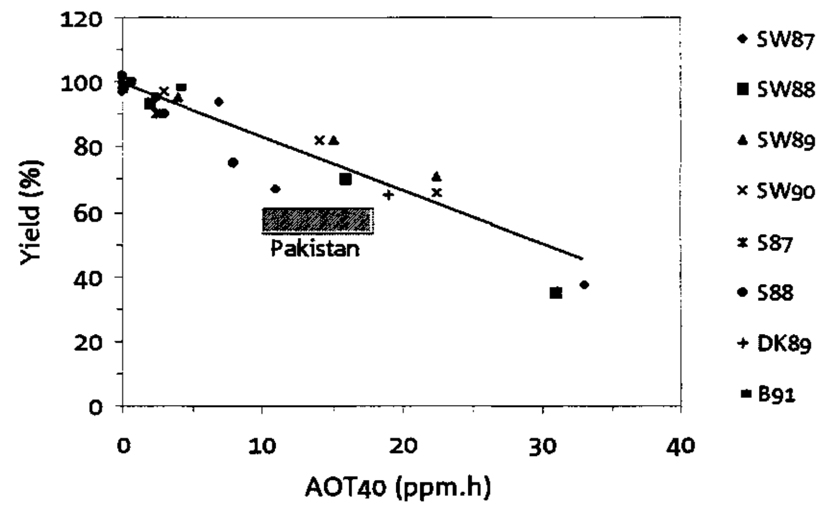

Figure 7.3. Yield of wheat as related to ozone. Results are from Open Top Chamber experiments in Switzerland (SW), Sweden (S), Denmark (DK) and Belgium (B) (After Fuhrer, 1993). The dashed quadrangle refers to results of Wahid *et al.* (1995).

Probably, ozone is the most relevant pollutant in relation to crops, due to its wide distribution, its phytotoxicity and the expectations of still increasing concentrations in the future. In the developed world several studies to quantify the ozone damage have been carried out. In California, yield reductions of up to 23% by ambient ozone have been observed (Olszyk *et al.*, 1988). In the Mediterranean area of Europe yield reductions of up to 20% by ambient air pollution have been demonstrated (Schenone & Lorenzini, 1992). In the Netherlands, ozone-induced yield reductions of 5-10% may occur in sensitive crops such as legumes, potato and fodder crops (Van der Eerden *et al.*, 1988). Western Europe, yield reductions in wheat of 10% or more due to ambient ozone are to be expected (Fuhrer & Achermann, 1993). In Japan, yield reductions of 8% in rice by ambient ozone (Kobayashi, 1992)[1] have been demonstrated.
As there is little systematic data from developing countries concerning concentrations of air pollutants at which yield loss occurs, any assessment of thresholds for adverse effects of pollutants must primarily be based on data from developed countries. For ozone, these data suggest that significant effects (defined as yield loss above 10%) may be seen when seasonal mean concentrations in the middle of the day exceed 50 ppbv (Ashmore, 1992; Marshall *et al.*, 1997). For sulphur dioxide, the threshold concentration for significant effects on crops is considered to be around 10 ppbv (Ashmore, 1992), for nitrogen oxides 20 ppbv (Van der Eerden *et al.*, 1998) and for fluorides 0.3 ppbv (Slooff *et al.*, 1988).

Concentrations of ozone, sulphur dioxide and nitrogen oxides in crop production areas in developing countries (Table 7.2) are regularly above the damage threshold concentrations for air pollutants from developed countries. However, systematic data are missing. For ozone, the available data suggest that damage is to be expected in large parts of agricultural production areas in developing countries (Marshall *et al.*, 1997). For sulphur dioxide and nitrogen dioxides, damage is probably limited to areas in the vicinity of urban and industrial sources (Singh *et al.*, 1990; Marshall *et al.*, 1997), although these areas can be in the order of magnitude of 10^4 km in

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[1] *Somewhat surprising is the estimated high yield loss in rice by ambient SO_2: 35% (Taniyama & Mizuno, 1985).*

parts of China. In several developing countries dust produced by road traffic, excavation and open cast mining is an obvious air pollutant, although generally of a very local and non-phytotoxic nature. Dust can have adverse effects on crop production both by a physical and chemical impact. It can affect photosynthesis, respiration, transpiration and allow penetration of gaseous pollutants (Farmer, 1993). Most of the dust from road traffic on unpaved roads is deposited within 10-30 meters. Per unit of daily passing traffic unpaved roads produce around 50 times more dust compared to paved roads. Particulate matter in car exhaust is strongly dependent of the fuel used: cars using unleaded fuel produce 77% less particulate emissions (on a mass basis) than cars using leaded fuel. Nearly all dust types cause an increased transpiration, but reduction in biomass production depends on the chemical properties of the dust. Cement/lime dust at concentrations as low as 0.5 g m^{-2} d^{-1} can cause adverse effects, like blocked stomata, deficiencies in Fe, Mn, P and Bo, reduction in growth and formation reproductive structures, but smaller deposition can increase crop production by improving nutrients supply. Coal dust contains toxic substances as fluorides, sulphur compounds and heavy metals, but their effects on crop production has not been quantified. Even in the case of inert dust the crop production can be affected by reducing light interception and increasing leaf temperature (via reduction of transpiration, which is a general result of dust deposition). Per unit of dust deposited the threat of reduction in crop production is more severe with lower light intensities (proportional reduction in period with light saturation is less), with little rain fall (less washing off of the dust) and low water availability (less compensation of increased transpiration). Without an in depth modeling effort it in not possible to say which climatic zones are most threatened; by just by expert judgment we assume dry hot climate to be the most threatening. Biomass burning, a common practice in developing countries can have a number of negative effects (*e.g.* Freney, 1997). The burning produces large amounts of compounds that are directly toxic (NO_x, SO_2), or involved in climate change (CO_2, N_2O) and in photochemical smog formation (NO_x, VOCs). Moreover, the light interception of the smoke depresses light interception and thus photosynthesis and crop growth. A mayor reason for biomass burning is deforestation to gain agricultural land, but forest might be needed to protect against weather extremes and soil erosion and as a sources of genes. As far as we know, an integral cost/benefits analysis of biomass burning has not yet been made.

There seems to be a tendency that, after correction for the concentration level, the yield losses in developing countries are higher compared to those in developed countries. These differences may be caused by differences in:

1. *Climatic conditions*. Conditions that favor opening of stomata, such as low atmospheric vapor pressure deficit, low soil moisture deficit and high light intensity (so called modifying factors), increase the damaging effects of air pollutants,
2. *Exposure regimes (concentration * duration) and composition of air pollution*. Much evidence exists for combined effects, often of a synergistic nature. For China, for instance, one may expect that the damaging effect of ozone is probably larger than it would be in Europe because of relatively high levels of sulphur dioxide in the atmosphere of China.
3. *Crops and cultivars* may differ significantly in sensitivity to air pollution (Maggs, 1996),
4. *Interactions with other factors*, such as pests, diseases and production systems.

Few studies aim to understand, explain and generalize these differences (Maggs, 1996). Up to now most estimates of crop loss are based on field observations or chamber studies in which crop growth is compared in filtered and non-filtered air. A substantial step forward in generalization of observational results would be an approach that explains the impact of air pollutants on the basis of physiological mechanisms. In general, mechanistic crop growth simulation models can be used to do so. We made an attempt using the data of Whahid *et al.*

(1995) on yield reductions of wheat by ozone. These data were evaluated using a SUCROS model for wheat production (Goudriaan & Van Laar, 1994). The data are of interest because the observed yield reductions cannot be explained by damage threshold concentrations from developed countries: a 40% yield reduction was observed by Whalid *et al.* (1995), while the air pollution concentration was just around the damage threshold level. Wahid *et al.* (1995) showed that the maximum photosynthetic rate in leaves was reduced, and the senescence rate during the reproductive phase was increased for wheat plants exposed to ambient concentrations of air pollution. Van der Eerden & Grashoff (unpublished) analyzed the data of Wahid *et al.* (1995) with the aim to determine whether altered photosynthetic rates and senescence rates could explain observed yield loss. Physiological and phenological parameters in the model where set to values comparable to those estimated by Wahid *et al.* (1995). Furthermore, location specific weather data were used to run the model. A sensitivity analysis was done in which the maximum photosynthetic rate (AMAX) was reduced twice in steps of 13%, and the reproductive phase (DVRR) was reduced twice in steps of 30%. Results of the analysis (Table 7.3) show that simulated yield reductions were always less than the observed yield loss of 40%. It is concluded that the observed yield reduction of 40% in wheat in the Punjab cannot be explained by altered maximum photosynthetic rates and senescence rates only, and that likely other unrecognized damage mechanisms are occurring simultaneously.

Table 7.3. Effects of altered maximum photosynthetic rates (AMAX) and senescence rates (DVRR) on yield reduction in wheat as simulated by a SUCROS model.

	AMAX		
DVRR	Unaltered	-13%	-26%
Unaltered	0%	7%	15%
-30%	10%	20%	25%
-60%	20%	27%	30%

7.5. Does air pollution affect food security in developing countries?

While the experimental evidence presented in the previous sections does give cause for concern that food production in developing countries can be severely affected by air pollution and by ozone in particular, it is of interest to clarify how this affects food security. Risk assessment studies are a first step in this direction. Secondly, socio-economic impact studies have to be performed. However, in doing so one has to bear in mind that systematic data on air pollution in crop production areas in the developing countries are missing as well as validated dose-effect relationships for the impact of air pollution on crop production. In this section, a few informative studies in the fields of risk assessment and socio-economic impacts are presented.

A. Global risks assessment studies

The Imperial College Centre for Environmental Technology (ICCET) recently carried out a global risk assessment study with the aim to identify crop production areas at high, moderate and low risk of yield reduction from ozone and sulphur dioxide (Ashmore & Marshall, 1997). Global data on air pollution emissions were used to indicate potential pollutant concentrations. These concentrations were compared with crop yield loss in Europe, in order to estimate areas in which crop loss might occur. Fig. 7.4A shows the risk of crop loss due to ozone based on this approach. High-risk areas correspond to exposure that is estimated to cause a yield reduction above 15%. Intermediate risk areas are estimated to have a yield reduction between 5 and 15%.

Almost all areas in developing countries that were identified as moderate or high risk correspond with agricultural areas. Areas of high risk are found in Northern India, China, Korea and Taiwan, with isolated areas elsewhere. Areas of moderate risk are found among others in Egypt, Malaysia, Pakistan, Mexico and Venezuela. Risk patterns in Fig. 7.4A are consistent with experimental observations (see Table 7.2). In addition, patterns in Fig. 7.4A for Europe and the USA are consistent with results of experimental and model studies. Fuhrer *et al.* (1997) has calculated that the ozone exposure corresponding to a 10% yield loss is exceeded over most parts of Europe. The NCLAN program (see section C) in the USA has resulted in a mean crop yield reduction by ambient ozone of 5%; a figure dominated by effects on cereal crops which occupy a large part of the agricultural production areas in the USA, and viewed as relatively insensitive to ozone.

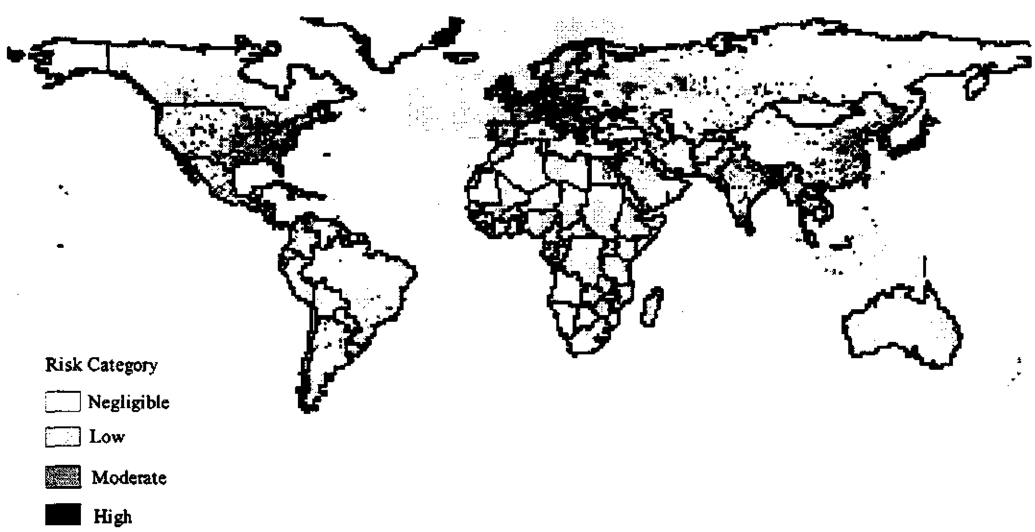

Figure 7.4A.Risk of ozone impacts on crops, based on emissions of nitrogen oxides in 1985 (after Marshall *et al.*, 1997).

Fig. 7.4B shows a projection for ozone effects on crop production for 2025. This predicts how yield losses are likely to increase if emissions continue at their current rate. Whilst in Western Europe and Northern America the risk level decreases due to reduction in emissions, the risk level in the developing countries is generally increasing. In India, China and South Africa most production areas fall in the high-risk category in 2025. Also, in Egypt, Malaysia, Bangladesh, the Philippines, Indonesia, Mexico, Nigeria and Zimbabwe large areas with moderate to high risk are to be expected.

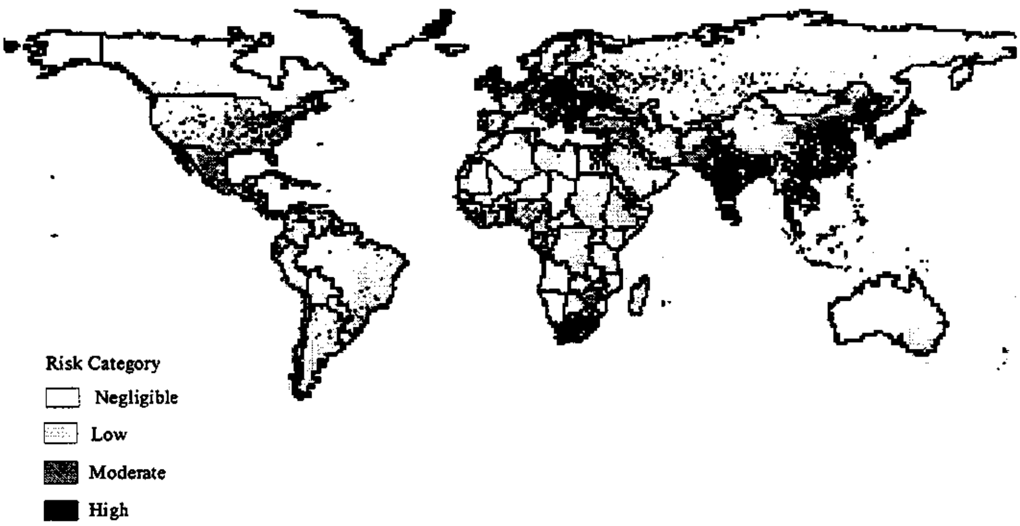

Figure 7.4B. Risk of ozone impacts on crops, based on projected emissions of nitrogen oxides in 2025. (after Marshall *et al.*, 1997).

B. National and local risk assessment studies

Marshall *et al.* (1997) have presented two informative regional risk assessment studies on ozone and sulphur dioxide impacts on crops in India and Pakistan. In the studies, observed air pollution concentrations were used to estimate concentrations in zones up to 80 km around major cities in these countries. Regional-specific dose-effect relationships were then used to estimate yield reduction due to air pollution. For ozone, it was estimated that in 80 km zones around the cities of Lahore, Mumbai, Pune, Ahmedabab and Lucknow crop yields of wheat, rice and soybean were reduced by 12 to 40%, depending on population density and crops grown in the respective zones. For sulphur dioxide, it was estimated that crop yield loss in a zone of 10 km around a thermal power plant is between 10 and 60%.

Another type of local risk is caused by deposition of heavy metals. Although the affected area is generally located within 1-10 km from the source it can damage the soil quality and via root uptake the food production for many decades (Li & Wu, 1991). Most heavy metals have a negative impact on soil biology. Some of them are easily taken up by the plant (making the crop unsuitable for consumption, *e.g.* cadmium), while others are phytotoxic, and thus affect plant growth (*e.g.* zinc and nickel).

Deposition of dust (Farmer, 1993) and fluoride (*e.g.* Zhang *et al.*, 1995) can cause crop losses on a local problem as well.

C. Economic and social impact studies

When considering economic losses the spatial scale is relevant: local emissions can result in serious losses for individual farmers, while it has a negligible impact on food production and product prices on regional or higher scales. But dependent of the of price elasticity of the crop,

a yield reduction caused by a regionally deposited pollutant is increasing the product price for the consumer, which means a partial compensation for the producer.
Quantitative data on the economic impact of air pollution on crop production are available for a few situations in developed countries. Two of these studies are described hereafter because they are useful in understanding a possible economic impact.

Economic damage study: Recently, the extent of crop yield reduction and economic loss caused by air pollution has been estimated for The Netherlands (Tonneijck *et al.*, 1998). The principal aim of the study was to determine economic benefits of pollution abatement with respect to crop production. Ozone is the most important pollutant in terms of crop loss in The Netherlands and concentrations of ozone are sufficiently high to adversely affect crop production throughout the country. Potato, legumes and wheat are among the ozone-sensitive crops. Crop losses and economic consequences have been calculated in response to various ozone exposure levels compared to 1992. Crop volume was expected to increase with 2.3 % when the level of ozone was reduced to background concentrations (circa 70 % of the level in 1992). If ozone decreases to background levels, producers and consumers would experience a net gain of circa US$ 225 million. Consumers are the primary beneficiaries from a decrease in the level of ozone. Results showed that producers and consumers would experience a net loss of US$ 300 million in a high ozone summer (ozone level is 130 % compared to 1992).

NCLAN study: In 1980, the National Crop Loss Assessment Network (NCLAN) was set up in the USA to assess the economic consequences resulting from the exposure of major agricultural crops to the main air pollutants. Of the crop loss due to air pollution, observations have indicated that ozone is responsible for 90% of the whole, which amounts to 2 to 4% of the total crop production (Heck *et al.*, 1982). Calculations showed that the economic benefits from a reduction of ozone levels generally amounted to 1,000-3,000 million US dollars (USEPA, 1996). The results of various studies can vary depending on the extent of ozone reduction and the number of crop species used in the calculations. As for the Netherlands, all results showed that consumers were the primary beneficiaries from a decrease in the level of ozone.

The social consequences of air pollution effects on crop production have not been quantified for developing countries. Some qualitative comments are made. Generally, a significant part of the population of developing countries suffers from insufficient food supply. One could say that any crop loss is undesirable in situations were food supply is limiting. Apart from the direct effect of crop losses, environmental problems are increasingly the cause of social disturbance and political conflicts. Currently this is obviously the case in parts of China (Goldstone, 1992; Smil, 1992). A better understanding of the social consequences of air pollution effects on crop production in developing countries is desired.

7.6. Conclusions and recommendations

The following conclusions can be drawn with regard to air pollution impacts on crop production in developing countries:

- An increase in emissions of air pollution from megacities in the developing world is to be expected knowing present trends in these cities.
- Ozone, sulphur dioxide and nitrogen oxides are likely to be the most important air pollutants in terms of crop productivity in developing countries.

- A variety of local adverse impacts (heavy metals, fluorides *etc.*) can be a threat for the individual farmers and consumers, and can be the cause of social unrest, but generally it has not a major impact on food supply on the regional scale.
- Serious crop yield reductions due to ambient air pollution in developing countries have been reported. Reported reductions are as high as 40%, *i.e.* higher than expected on the basis of existing exposure-effect relationships.
- Information on the air pollution system (sources, emissions, dispersion and transformation, air quality monitoring, deposition and uptake, and exposure-effect) in the developing world is scarce. A further assessment of the impact of air pollution on crop productivity in developing countries requires more information of the air pollution system.
- Socio-economic impacts of air pollution on food security in developing countries cannot be quantified accurately since information is generally lacking. However, in qualitative terms one may conclude that air pollution puts an increasing penalty on food production in developing countries which definitely contributes to an uncertain food production situation, and possibly to social and political problems.

To improve our knowledge on the impact of air pollution on crops in developing countries, and to be able to direct air pollution control strategies, the following recommendations can be made:

- The use of bio-monitoring and air quality monitoring systems should be stimulated in developing countries. Especially biomonitoring is recommended because this technique is a very useful tool in assessing air pollution effects on plants, is relatively cheap, and is rather convincing towards politicians. It makes people aware of a problem.
- Exposure-effect relationships should be determined for situations in developing countries. The focus should be on (tropical) crops grown in the vicinity of megacities. Such studies should also present information on the importance of modifying factors.
- The relative importance of different air pollutants in the developing world should be assessed on basis of information of the developing world.
- The studies on assessment of crop losses in developing countries should be carried out in the scope of other disciplines such as rural/urban planning, economy, and social sciences.

7.7. Acknowledgments

The authors especially thank Fiona Marshall and Mike Ashmore for sharing information on the impact of air pollution on crop production in developing countries.

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8. Food security in Africa: technology and the challenge of HIV/AIDS[1]

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8.1. Introduction

A recent study of the world food outlook (Mitchell *et al.*, 1997) dismisses the idea that the world will face a Malthusian crisis in the foreseeable future. The one exception to a broadly optimistic picture is Africa. Africa already suffers major problems feeding itself. Africa's poor agricultural position reflects war, political failures, and weak performance of African economies, but also lack of attention to technological constraints. Mitchell and co-authors conclude that the nub of the world food problem will remain in Africa. They arrive at this conclusion without taking the epidemic of HIV/AIDS into account. The purpose of this paper is to focus on whether and how HIV/AIDS adds significantly to the problems of agriculture and food security in Africa. The paper summarizes the present state of the debate about agricultural transformation in Africa and then asks what difference does HIV/AIDS make to the way the problem is conceived, and to the solutions being proposed.

8.2. Agricultural transformation in Africa - the debate

Africa is the world's poorest continent. It also has the fastest rate of population growth, but from a relatively low starting point (reflecting the demographic legacy of the slave trade and colonialism). As a result, land is still relatively abundant, though often of low quality. Historically, Africa has suffered more from labor shortage than lack of land. Agricultural technologies and agrarian institutions still reflect this fact (Richards, 1985).

Science-based agricultural technology generation has by-and-large been shaped by different conditions; by the availability of abundant good-quality land in North America, where banks have never hesitated to help farmers' acquisition of advanced machinery, or abundant skilled family agricultural labor in Asia, where wet rice lands are well suited (as Francesca Bray has shown) to the care- and chemical-intensive plant innovations associated with the Green Revolution (Bray, 1986).

In Africa farmers have had neither the time nor inclination to homogenize their land, for machines or chemical-intensive plant ideotypes (Richards, 1995). Scrambling to secure timely labor African farmers tended to work with the land as they found it. Time and again detailed study of African farming systems reveals the great skill of African agriculture as time-dependent

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[1] *This paper combines material from my oral presentation to the DLO symposium on food security and a paper read at the workshop Responding to HIV/AIDS: development needs of African smallholder agriculture (SAFAIDS/ZARC/ISS/LUW Regional Conference for East and Southern Africa, Harare, June 8-10th, 1998).*

capacity for labor-economizing 'precision agriculture', in which a plethora of local crop and animal types are skillfully matched to soil and moisture niches opened and closed by the passing seasons (Richards, 1985; Brouwer & Bouma, 1997).

Until recently, science-based agrotechnology has lacked the language to describe and appreciate these kinds of skills.[1] The labile diversity met with on the African farm was even at times seen as a manifestation of some kind of mental disease - as if the African farmer was afflicted with the hyper-active child's inability to concentrate properly on one thing at a time (Richards, 1985).

Agricultural science - based on one-at-a-time isolation of significant variables - has found it hard to conceive of ways of working with the huge diversity of crops and land types deployed in even the meanest examples of African 'subsistence' agriculture. Instead, efforts have focused on transferring innovation programs designed to impact widely on near-monocrop agricultures such as SE Asian wetland rice farming (Richards, 1986). The story is one of under-investment in locally-innovative agricultural research in favor of 'technology transfer' (Mitchell *et al.*, 1997), often in the form of elaborate extension schemes with nothing to extend, or integrated rural development initiatives where the benefits go not to farmers but to a small politico-bureaucratic elite.

Recently, understanding of the technical issues has begun to change, and there are now science-based precision and eco-dynamic approaches to agricultural innovation that hold out considerable hope for African agriculture (Brouwer & Bouma, 1997). But meanwhile Africa struggles with an inappropriate institutional legacy. This includes an underfunded and demoralized scientific research community trained primarily to support adaptive modification of Asian-style Green Revolution initiatives, bureaucrats dreaming of the return of McNamara-style World Bank Integrated Rural Development schemes, and an action-oriented non-governmental sector unsympathetic to the long lead-times associated with true problem-solving research.

Meanwhile, aware that among poor consumers (where food accounts for 50-70% of household expenditure) food and politics are inseparable (Richards, 1996a), the political classes in Africa, seek popularity in a democratic age through consumer subsidies that ultimately undermine prospects for long-term transformation in their own agricultural sectors. If local-funded food subsidies for the urban poor and party faithful are insufficient some countries are not above manipulating drought or civil conflict to gain access to international relief. Controversially, de Waal (1997) has charged that the 'humanitarian international' is willingly complicit in this manifest manipulation of democratic politics in Africa.

The debate about agricultural transformation in Africa has paid less attention to some demographic issues with great bearing on the HIV/AIDS crisis. Current high rates of population growth imply very high percentages of dependent young people. Sociologically, one might speak of a crisis of youth (or a deficit of parental support). In Europe and North America the economically active age cohort (the mainstay of dependent youth) is over 50% of the total population, and over 40% in India in China; in Africa the equivalent figure (for the age range 25-64) drops to 30%. Dependent youth in Africa are further disadvantaged by the 'structurally adjusted' state cutting back on education and public-sector employment. More and more

[1] *In an important new comparative historical analysis Scott (1998) puts the point somewhat differently; in his analysis science and technology became servants to the political project of high modernity in which a tiny political 'vanguard' saw itself as bettering the human race through imposing regularity upon the environment and landscape.*

children find themselves 'on the street', without education or family support (Richards, 1996a). HIV/AIDS only worsens this already difficult situation.

There are two implications, to be developed below. Social innovation will be needed to deal with the potential threat of increased alienation and social exclusion of rural youth as the HIV/AIDS crisis deepens. Second, ways will have to be found to re-focus the current debate about appropriate technologies for African agriculture on the needs of these potentially excluded young people.

8.3. HIV/AIDS as a problem in African agriculture

The link between ill health and under-performance in African agriculture is well established. I give two brief examples.

River Blindness (*onchocerciasis*) handicaps entire communities in West Africa, and over several generations empties otherwise fertile river valleys. The World Bank supported Onchocerciasis Control Program, spraying against the Black Fly vector, and parasite control in humans using the drug Ivermectin, has successfully opened thousands of square kilometers of River Blindness blighted terrain to agricultural resettlement.

Less dramatically, Richards (1986) shows that even minor health problems - sprains and cuts sustained in farming, for example - can have significant 'knock-on' effects if a member of a tightly-coordinated household labor group is incapacitated at any of a number of key points in the upland rice farming cultivation cycle in central Sierra Leone. If a man misses part of the planting ('ploughing') season or a woman is incapacitated during the weeding season consequences ramify throughout the rest of the farming cycle. Keeping the annual farm performance together despite such vicissitudes is a major preoccupation of upland rice farming households. A number of complementary planting, weeding and harvesting strategies (including planting topographic sequences with a range of niche-adapted rice types of varying durations) are deployed to minimize knock-on effects. Coping through labor sharing arrangements is also important. Labor cooperatives provide some degree of insurance against accidents and ill health (Richards, 1986).[1]

As Barnett *et al.* (1995) make clear, farming systems vary in their vulnerability to the challenge of HIV/AIDS.

Comparing West African grain systems (Richards, 1986; Hill, 1982; Watts, 1984) with eastern African banana/maize/root crop farming systems of the type found in rural regions with high levels of HIV seropositivity in NW Tanzania and southern Uganda (Barnett & Blaikie, 1992; Barnett *et al.*, 1995; Rugalema, 1998) it is clear that the east African systems are located towards the less sensitive end of the spectrum. Rugalema (1998) shows that although much labor that would otherwise be devoted to farm work is diverted into nursing an adult household member with AIDS-related sickness crop schedules are quite flexible, suggesting that food yield will remain more or less proportionate to effort invested.

[1] *However, it should be noted that labour cooperation arrangements only provide insurance against sickness where hazards are distributed randomly and are followed by full recovery; farmers with above average levels of illness or permanent disability are excluded.*

In highly sequence-dependent West African grain farming systems failure to complete key operations within the very narrow time 'window' available risks farm failure, and squandering all the labor invested earlier in the cycle. If HIV/AIDS begins to affect the kind of upland rice farming systems described by Richards (1986) it is possible that afflicted households will abandon upland rice production altogether in favor of small survival patches of 'garden' and dry-season wetland crops such as sweet potatoes.

Rugalema (1998) concludes that even in the relatively favorable agronomic conditions of Bukoba District (Tanzania) there is no coping with HIV/AIDS. The point about HIV/AIDS is that it attacks the mainstays of the household agricultural production system, and that there is no recovery. During the typical two years or so of AIDS-related sickness preceding death household food production drops sharply as large amounts of labor time are devoted to nursing the sufferer and to the search for health. Recovery of the household group from the death of an HIV/AIDS victim is hampered by the high levels of asset disposal involved in this ultimately futile search for health. There is also the strong possibility that the partner of the AIDS victim will also fall sick and die, pushing the survivors through a second cycle of labor diversion and asset disposal.

Rugalema (1998) shows that although it is possible at this stage that survivors will be absorbed into related household groups as widows and orphans definite categories of post-HIV/AIDS household are beginning to emerge in Bukoba District (*i.e.* households comprising children and elderly women, say, or outright 'orphan headed' households). The sociology of these unprecedented household groups remains to be more fully understood. Rugalema (1998) suggests that the normal pattern of absorbing orphans into related households is beginning to break down under the impact of so many HIV/AIDS related deaths, but it is also clear, locally, that lineage groups see land inheritance advantages in keeping orphans on the land to which they are entitled. Some of these orphan-headed households appear to be under some degree of supervision by the wider extended family.

8.4. HIV/AIDS is not like other crises

De Waal (1989) has argued that outsiders - humanitarian agencies, in particular - have misunderstood drought-famine crises in Africa. In local understanding famine is a period of hunger to be endured, even at some individual cost, and not an apocalyptic disaster threatening to end an entire way of life. That some people will die is accepted, and set against the wider understanding that the community will recover. Not all regions or households are affected equally. Communities with greater wealth differentiation sometimes do better in drought-famine recovery than more egalitarian communities - since the resources of the strong can be tapped to help the weak (*cf.* Richards, 1986).

HIV/AIDS is significantly different. The greatest impact is not felt by the weak. HIV/AIDS, in a sense, 'selects' for the strong - for the professional classes, for remittance earners and those in the best position to act as patrons to the young, for household breadwinners. This is a reflection of the strong connection between mobility and wealth generation in African society. HIV/AIDS is, in effect, a network disease, especially associated with urban nodes and major transport arteries.

Differentially attacking the wealthier more mobile stratum in rural society HIV/AIDS more rapidly depletes scarce reserves of rural capital. Households may economize on marginal members' search for health. But with HIV/AIDS it is often the male household head, with direct authority over asset disposal, who is sick. Relatively, no expense is spared to protect central breadwinners, even though in the end the search for health proves futile.

The depleted household must begin the struggle for post-AIDS survival with the cattle and other assets gone. Only the land remains. Rugalema (1998) reports that family opposition to land sales remains a healthy 'survival instinct' in areas of customary tenure, but it is an issue of concern what will happen to land in areas where tenure has been modernized.

The reduction to poverty of households otherwise among the wealthier segment of rural society has a number of agrarian consequences of potential general significance:

- it adds to the growing pool of free-floating young people without protection and sponsorship;
- it depletes scarce but essential pockets of rural capital formation that might otherwise have been directed towards various agro-technical improvements;
- it undermines the position of 'pillar' households who might otherwise have contributed to the kind of spontaneous recovery seen in the case of drought-famine disaster.

The general impact of HIV/AIDS is more akin to the wealth-corroding impact of war on rural society (Richards, 1996a), with the exception that war can be ended. HIV/AIDS seems sure to intensify in rural Africa over the foreseeable future.

8.5. HIV/AIDS and agrarian issues

This section will briefly discuss likely socio-cultural and political responses to the challenge posed by HIV/AIDS to African agrarian development.

The first point is to reiterate that asset disposal may extend to land if land tenure reform is pursued aggressively in rural regions at high risk of HIV/AIDS, with the consequence that household survivors may join the swelling ranks of a landless class, a phenomenon hitherto largely unknown in Africa. This implication deserves very careful precautionary consideration in policymaking debate at all levels (local, national and international).

Second, as the HIV/AIDS crisis matures, and people become more aware that AIDS-related sickness is irreversible, we may expect some cultural response directed towards the protection of collective, societal interest.

Anthropologists have long stressed that Western individualism is no natural condition but the complex outcome of a long process of cultural and political construction. From the neo-Durkheimian perspective of, for instance, Mary Douglas and others, there is no inevitable evolution of institutional cultures in the direction of individualism (Douglas, 1987).

From such a theoretical standpoint it is perfectly possible to anticipate that African communities will respond to the challenge of HIV/AIDS by developing new, or re-emphasizing older, modes of collective accountability embedded within local and informal institutions. This possibility is already explicit in Rugalema's (1998) findings concerning supervised orphan-headed households and the deep instinct to protect 'traditional' land entitlements from the AIDS-mortality asset disposal process. Not only may rural communities in Africa 'resist' ill-thought-out modernizations of agrarian institutions, but they may engage in a counter-creativity of their own based on elaboration of various 'collective' moralities.

Some of these may be rather negative in tone (*e.g.* renewed outbursts of witch-finding frenzy). Others, conceivably, may be socially progressive. The extent to which AIDS-sickness asset disposal is a wasteful dissipation of hard-won capital resources in expensive journeying back and forth for ultimately useless hospital treatment is already recognized in many communities, and local therapy enjoys a new lease of life and legitimacy. Some AIDS-afflicted heads of household may opt for parsimony of treatment, preferring to keep together the family asset base for the benefit of survivors. Whether such action becomes a social trend might depend on the degree of local commitment to respect for ancestors and concepts of ancestral blessing, still very strong in many parts of rural Africa (*cf.* Richards, 1996b).

Some indication of possible developments may be found in the medical anthropological literature covering the francophone central equatorial African zone. This is a region of fertility crisis and community extinction (Patterson, 1975) brought about by colonial concession company labor exploitation and the associated spread of venereal disease, and the literature of the region provides the best 'model' for thinking about social responses to HIV/AIDS. Here the idea of community involvement in sexual morality and management of disease is well established. Disastrous asset disposals may be stemmed by greater collective involvement of the extended family in disease management decision making and through the formation of new self-help therapeutic communities, perhaps drawing upon a stock of knowledge and experience from these earlier crises.

Now we turn to possible political responses at national level. The HIV/AIDS crisis in rural Africa will increase the numbers of dysfunctional, food-insecure, remnant households, and there will be a corresponding rise in numbers of young 'orphans', 'street children', 'educational drop-outs' and other categories of social excludees associated with family failure (*cf.* Richards, 1996a). The graph rises because of demographic pressure and economic failure, and household dissolution as a result of HIV/AIDS can only steepen the trend. It is one of the biggest challenges faced by African governments today.

Two highly problematic political responses to deal with these problems have emerged. The first is the tendency for African governments to institutionalize a begging bowl mentality to subsidize the feeding of political dependents, including the urban poor. Food aid even in famine conditions further undermines local agricultural capacity. De Waal (1997) argues that the unholy alliance between humanitarian agencies and neo-patrimonial African regimes is as unhealthy for democracy and human rights as it is for agricultural development. But it seems entirely likely that the HIV/AIDS crisis will be used to put additional pressure on donor organizations to 'feed the poor', and that African regimes will continue to build political legitimacy from their efforts to 'manage' these externally-funded resource flows.

The second trend is even more worrying. Unruly, foot-loose youth are recognized as a growing political 'problem' in many African countries. Increasingly, these alienated youths form their own political organizations, well beyond the boundaries of 'constitutional' politics or 'democratic' parties (Richards, 1998). Increasingly, they are stigmatized as 'drop-outs', 'vermin', 'drug addicts', 'bandits' and subject to draconian control measures.

Klein (1998) analyses the preoccupation of General Abacha in Nigeria with drug control as a way of building international support for his regime at the same time as putting down potential challenges from dissident youth movements such as the Delta separatist movement (MOSSOP) led by the late Ken Saro-Wiwa. The Kabbah regime in Sierra Leone uses similar language and tactics (not to mention troops supplied by Abacha) to deal with the threat of the dope-smoking jungle dropouts of the Revolutionary United Front (Richards, 1998).

But the more violent pressure is put on these shadowy movements the more determined they become, and a rallying point for increasing numbers of young people without jobs and educational prospects (Richards, 1998). There seems some prospect that young people spun off from HIV/AIDS-dissolved households might be drawn into such movements as they spread across Africa in response to the gathering youth crisis. Escalating violence against wild young radicals, sequestered in remote and marginal terrain, provides fertile grounds for the further spread of the rural HIV/AIDS epidemic. There is urgent need for far-reaching policy debate about this rampant youth crisis and on more constructive ways to respond to it than to copy Latin American right-wing vigilante death squads waging 'war' on hordes of street children.

8.6. HIV/AIDS and agro-technological development

Not before time, debate about agro-technical change in Africa has turned towards 'smart' (knowledge-intensive, labor and capital-economizing) solutions.

It is not currently economic to import fertilizer far inland for large-scale use on very low-fertility readily leached Sahelian soils under variable and marginal rainfall conditions. Perhaps for centuries farmers have taken careful note of micro-variations in soil type and elevation at field level, carefully matching these with seed types that perform well in drier or wetter conditions, and relying on a compensatory spread of results, depending on whether the year is drier or wetter than average (Brouwer & Bouma, 1997). Remote sensing and careful mapping with geo-positioning devices can sometimes expand the scope of these local adaptive measures and allow for the most effective precision use of whatever small amounts of fertilizer or manure are available for soil improvement.

In analogously 'smart' manner, participatory plant breeding programs (Eyzaguirre & Iwanaga, 1996) can overcome plant genetic bottlenecks to further adaptive experimentation by farmers at local level (one of the major results of the spread of a limited number of modern varieties into African agriculture during the Green Revolution may have been the enhancement of the genetic potential of local land races, by outcrossing with introduced varieties, so releasing potential for a further round of local adaptation, *cf.* Dennis, 1987). Some breeders now advocate crossing and selection strategies intended deliberately to support such trends. Others screen and select for the kinds of labor-management problems met with by poor farmers with uncertain labor supply (for durable pest resistance and weed competitiveness, rather than yield potential under ideal management conditions). Yet others are prepared to work on the myriad little-known crops that farmers in Africa make use of to supplement diet or to provide back-up in emergency.

A recent documentary project (Vietmeyer, 1996) uncovered evidence of more than 200 African food-crop plants little known to science. Africa has more indigenous domesticated grain crops than any other region in the world, yet it is normally represented as a 'blank' on maps of food crop domestication and biodiversity. The first task is to create a knowledge base and collect genetic resource. Then ways have to be found of applying scientific improvement to some of the more important of these potentially useful semi-domesticated or little known species.

Such a research focus is likely to be of direct potential benefit to HIV/AIDS afflicted households struggling to secure a basic basket of food with greatly reduced labor input. In the West African rice region, for example, farmers short of labor increasingly plant the little-known but locally-important grain *Digitaria exilis* ('hungry rice'), since it yields a crop in sometimes as little as sixty days on land too poor and weed-affected to sustain a crop of rice. To minimize weed competition on poor land farmers have similarly reverted to using African rice varieties (*Oryza glaberrima*) once thought to be approaching extinction (Richards, 1996b). Farmer selection on natural crosses between African and Asian rice have put into circulation a number of new hardy but higher-yielding hybrid types. Textbooks used to report that such crosses were impossible (Richards & Ruivenkamp, 1997). But art now imitates nature and farmer agency, and the West African Rice development Association has recently made available several African x Asian Rice crosses of great potential interest to war-affected farmers in Sierra Leone and Liberia because of their earliness combined with labor-saving hardiness.

Developments of this sort are likely to be of potential benefits to households adapting to labor losses as a result of HIV/AIDS. In Bukoba District Rugalema (1998) reports 'downshifting' of HIV/AIDS households away from banana and cash crops towards sweet potato and cassava, because of their greater hardiness and tolerance of some degree of neglect (*cf.* Fresco, 1986).

Sweet potato was once something of an 'orphan' crop in international research, but recognizing its global importance to poor, food-insecure, households, CIP-supported research by the UPWARD participatory research network in SE Asia has made considerable strides in understanding and releasing local bottlenecks associated with its cultivation by poor households under stressed circumstances (UPWARD, 1997).

Spreading the UPWARD approach to root and tuber research in HIV/AIDS affected rural districts of eastern and central Africa seems an obvious starting point for applied research intended to strengthen local food security.

It seems clear that African food security more generally, and the food security of HIV/AIDS afflicted households, in particular, will be better enhanced by adoption of the 'smart' emphasis in agro-technical research. The biggest obstacle to the further development of the 'smart' approach, undoubtedly, will be institutional problems resulting from the historical 'bias' of African research towards Green Revolution and other kinds of top-down and generalized solutions to technical improvement of African agriculture, compounded by the relative neglect of research in favor of extension and money-spinning integrated rural development. External donor support will be needed to revive the research sector and set a new course. But donor support for some years has favored NGO assistance at the expense of government-based activity, and NGOs have a general bias against long-term agro-technical research.

But other kinds of initiative are needed as well. Steps must be taken to address the youth crisis. If there were attractive options for rural youth some of the problem of urban dropout street children and outlaw criminal-political youth militias would be dealt with at source. It seems especially important to address the needs of HIV/AIDS orphans. Major reassessment of vocational education is needed, with an emphasis on rural income-generation opportunities and self-employment. Rugalema (1998) encountered HIV/AIDS orphans trying to develop market gardening opportunities. Cash flow for them was as important as food security. Such efforts will need to be supported by specific business skills training, credit supply and agro-technical research activity. The training and institutional support steps required may not be dissimilar to those proposed for dealing with the rehabilitation and social reintegration of under-age militia combatants in Africa's civil wars (Richards *et al.*, 1997), many of whom first became fighters because family support networks were destroyed by war (Peters & Richards, 1998a, 1998b).

8.7. Conclusion

It general, it will be noted that the impact of HIV/AIDS on rural households intensifies a number of already apparent adverse trends in African agriculture and agrarian development - notably shortage of labor and capital, lack of suitable agro-technical research, and the inability of African agriculture to attract and retain large numbers of young people with weak networks of family support. It follows that addressing these trends - through, for example, an emphasis on 'smart' innovation, or programs aimed at providing skills and start-up capital for socially excluded youth, will be good for HIV/AIDS management. HIV/AIDS underlines the need for agro-technical alternatives to the Green Revolution, for example, and this will require major institutional reform of agricultural research capacity. Within the framework of programs conceived with a broader remit than HIV/AIDS relief alone it is possible to envisage particular applications - *e.g.* research emphasis on food crops with low labor requirements and programming constraints, or start-up training for HIV/AIDS orphans - directed at amelioration of specific HIV/AIDS difficulties. In terms of agrarian issues it is important to recognize that HIV/AIDS is different from other kinds of crisis, where risks are spread more randomly, or where the weakest and most marginal members of society are the most likely to be affected, and where recovery is spontaneous. There is no recovery from the HIV/AIDS crisis, and it selects some of the strongest households. Possibly this will provoke a crisis of local community values and political self-confidence. Meanwhile, ill-thought-out and top-down modernization of agrarian institutions must be resisted in favor of support for long-term 'grass-roots' cultural and ethical innovation. Agencies might best assist HIV/AIDS affected rural communities by helping hold open suitable spaces for social agents to develop and enlarge their community perspective on agrarian aspects of the HIV/AIDS crisis, while carefully monitoring asset disposal, especially if and where this involves disposal of household or family land rights.

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9. Soil degradation: a threat to food security?

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9.1. Introduction

The soil is a very complex medium which displays a great diversity in physical appearance, in chemical processes, and in the flora and fauna present (bio-diversity).

The role of the soil is of vital importance to mankind and the maintenance of a healthy natural environment. The soil is a natural resource, which is not renewable in the short term and very expensive either to reclaim or to improve once it is eroded by water or wind, physically degraded or chemically depleted. It is our common duty to maintain this precious resource for the future, while at the same time to obtain the best benefit from its use now (Stoops & Cheverry, 1992).

One of the most intensively debated issues in projections on directions that agricultural policies should take over the next 25 years is the extent of land degradation and its effect on food production. While many argue that land degradation is a potential threat to global food production ("Arguments about the severity of global land and soil degradation, and the crises which humans are facing as a result of the shrinking productive natural resource base are convincing", Hurni, 1996) there are others who indicate that land degradation is over-estimated and relatively unimportant to global food production (Crosson, 1994).

There is a wealth of scientific literature, workshop proceedings and policy statements (*e.g.* Serageldin, 1995; Pinstrup-Andersen, 1995; Saouma, 1994) that link rapidly increasing world population, stagnant aggregate cereal output and the extent of soil degradation worldwide. These are central themes on the international and national agendas of policy-makers, decision-makers and agricultural research organizations.

The International Food Policy Research Institute (IFPRI) initiated in 1994 an initiative for "A 2020 Vision for Food, Agriculture and the Environment". This initiative aimed to develop a shared vision and a consensus for action on how to meet future world food needs while reducing poverty and protecting the environment. It grew out of a concern that the international community is setting priorities for addressing these problems based on incomplete information (IFPRI, 1995).

Each year global population increases by some 80 million people. The world population is estimated to rise to a total of 8.2 billion people by the year 2020. Cereal deficits in developing countries are projected to increase from 78 million metric tons in 1988 to 244 million tons in 2020 even under the most optimistic scenario, that food production will continue to grow at the same pace as it has since 1988 to the present, and that current levels of investment in agriculture by governments will be maintained (IFPRI, 1994).

In the past the demand for more food by increasing population was partly satisfied by opening up new land for agriculture and partly by intensified management of the land to obtain higher yields per unit land. Although world cereal production almost doubled between 1966 and 1990, the growth in aggregate cereal output started to decline after 1982, mainly as a result of a decline in quality and performance of irrigation systems, an inefficient use of fertilizers, a negative nutrient balance in most non-irrigated drylands in developing countries, increased losses from pests and diseases, and a deterioration of commodity prices, leading to reduced incentives to invest.

In much of Africa and also in most non-irrigated drylands in Asia and Latin America the "mining" of soil nutrients, often induced by poor socio-economic conditions, are pushing average yields into decline (Paarlberg, 1994). In response, farmers are trying to produce more food by extending their traditional low-input practices into forestland, or onto drier and more fragile pasturelands, or by shortening fallow-periods. As a consequence, fertile topsoil is washed away by the erosive forces of water, or blown away by wind. This so-called first generation of environmental problems leads not only to a negative nutrient balance, but also causes habitat destruction and loss of bio-diversity. Alternatively, it may also lead to positive off-site effects in *e.g.* valleys.

In OECD countries agricultural policies were guided by advances in sciences and technologies, focusing almost exclusively on production and financial efficiency (Dumanski & Smyth, 1993). As a result fewer farmers are producing more food on less land. However, excessive use of fertilizers and pesticides, and inadequate nutrient and animal waste containment has resulted in pollution of soil and water resources. This second generation of environmental problems not only caused a health hazard for increasing human and animal populations, but also lead to loss of bio-diversity and contamination of surface waters, including coastal waters and lakes.

In some of the economically more advanced developing countries, poorly managed yet high-input farming practices have also caused this so-called second generation of environmental problems. Excessive use of water in irrigated areas in the semi-arid and arid regions has led to waterlogging and secondary salinization. Acidification by atmospheric deposition of sulfide from coal mining industries is another form of land degradation, which may trigger a whole range of pollution processes.

9.2. The status of soil degradation

9.2.1. The GLASOD Project

Although soil degradation is generally recognized as a serious and widespread problem, its geographical distribution and total areas affected was only roughly known. Dregne (1986) stated that sweeping statements on the fact that soil erosion is undermining the future prosperity of mankind do not help planners who need to know where the problem is serious and where it is not.

Recognizing the need to obtain a better overview of the geographical distribution and the seriousness of human-induced soil degradation, the United Nations Environment Program (UNEP) commissioned the International Soil Reference and Information Centre (ISRIC), in 1988 to coordinate a worldwide program in cooperation with a large number of soil scientists throughout the world to produce, on the basis of incomplete existing knowledge, a scientifically credible global assessment of the status of human-induced soil degradation within the shortest possible time frame. This global study (GLASOD) was published as a world map at an average scale of 1:10 million and was complemented with statistics on the global and continental extent of the various types of soil degradation — water and wind erosion, chemical degradation and physical degradation — their degree and causative factors. GLASOD aroused worldwide interest and the results (Oldeman *et al.*, 1991, 1994a, b) have been widely cited in many policy papers (Scherr & Yadav, 1996; FAO, 1993, 1996) and reviewed in several scientific journals (Thomas, 1993; Young, 1993). Annex 1 illustrates some results of the GLASOD study.

While there is wide-spread evidence that soil losses resulting from erosion are far in excess of the natural rate of soil formation, the impact of such losses on crop yields or production has not been well-established in physical or economic terms, although there have been many attempts to do so (FAO, 1993).

Hurni (1996) states that science faces the challenge of assessing the impact of soil erosion by water and wind. To what extent is soil productivity affected? Economic estimates only focusing on production can be misleading because the underlying problem of soil degradation, its long-term irreversible consequences on soil productivity and the urgent need for action are under-estimated.

Crosson (1996) calculated the on-farm economic costs of soil erosion on a global level. Using data derived from GLASOD on lightly, moderately, and strongly degraded land in crops and permanent pastures and assuming percentage losses of productivity for each degradation category (5%, 18%, 50% respectively) he arrived at an average productivity loss on the total area of land in crops and permanent pastures of 4.8%. Even if higher loss percentages (15%, 35%, 75%) were used, the average worldwide productivity loss would not be higher than 8.9%. Using Crosson's approach, we separated cropland from permanent pastures and calculated these losses per continent. For Africa productivity losses on cropland would be 25% and for Central America even as high as 36.8% (see Table 9.1).

Table 9.1. Average percentage cumulative loss of productivity during post-second world war period as a result of human-induced soil degradation, worldwide and per continent. Loss is calculated by assignment of percentage productivity loss for the three degradation categories and the occurrence of degradation.

	Crop land	Pasture land	Crops and Pastures	(Crops and Pastures)
Percentage loss per degradation category (light, moderate, strong)	15, 35, 75	5, 18, 50	5, 18, 50	15, 35, 75
World	12.7	3.8	4.8	8.9
Africa	25.0	6.6	8.1	14.2
Asia	12.8	3.6	4.7	8.9
S. America	13.9	2.2	4.1	6.7
C. America	36.8	3.3	8.7	14.5
N. America	8.8	1.8	3.0	5.8
Europe	7.9	5.6	4.6	9.0
Oceania	3.2	1.1	1.2	3.2

Crosson (1997) concludes that nothing we could feasibly do to deal with degradation is going to contribute much to meeting future global demands for food! However, one may assume that if we do not deal with the causes of soil degradation, the areas now slightly degraded may become moderately degraded, areas now moderately degraded may become strongly degraded, while areas now strongly degraded may go out of production leading to higher, yield loss percentages.

There is an urgent need to better characterise the status of human-induced soil degradation and to prepare more detailed regional assessments, based on country-based inventories. The World Resources Institute, which assembled many of the GLASOD results in its World Resources Report 1992-1993 (WRI, 1992), indicated the critical need for further study to more accurately portray soil degradation problems at the national and local level.

9.2.2. The ASSOD Project

At FAO's 21st Regional Conference for Asia and the Pacific (New Delhi, 1992) it was recommended that FAO should find means to strengthen the collection and analysis on land degradation data in the Asian Pacific region. FAO's Asian Network of Problem Soils convened an expert consultation in 1993 (RAPA, 1994). This consultation, composed of 15 member countries in the region, recommended to prepare an Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia (ASSOD) at a scale of 1:5 million, based on refined and modified GLASOD methodology and using as a working template a physiographic map and database to be constructed along the lines of the internationally endorsed Soils and Terrain Digital Database (SOTER) approach (see also 9.4). UNEP commissioned the responsibility to coordinate and implement this study to ISRIC. The study was carried out in close cooperation with national resources institutions in the region (Van Lynden & Oldeman, 1997).

In 9.3 we will discuss the methodology followed in the Asian soil degradation study to relate in a qualitative approach the impact of human-induced soil degradation to the crop productivity, taking into account different management levels.

The qualitative approach used does not however give an indication on the future risks of soil degradation under certain management scenarios. In order to establish such a risk assessment using existing modeling techniques, it is essential to know the geographically referenced attributes of soil and terrain, of climatic parameters and information on land use. This information can be stored in a GIS-linked database. In 9.3 we will briefly discuss procedures to assess the impact of water erosion risk on food productivity using the internationally endorsed SOTER methodology (9.4).

9.3. The status of soil degradation and its impact on food productivity

Soil degradation was defined in GLASOD and ASSOD as a process that describes human-induced phenomena which lower the current and/or future capacity of the soil to support human life (Oldeman, 1988). These studies did not intend to indicate and delineate the instantaneous present and future rate of degradation processes and the potential hazards that may occur under human influence. They describe and delineate situations where the balance between climate aggressivity and the potential resistance of the land has been broken by human interventions.

In the GLASOD approach the degree to which the soil is degraded to its present status was related in a qualitative manner to the agricultural suitability of the soil, to its declined productivity, to its possibilities for restoration to full productivity and in relation to its original biotic functions. A light degree for example indicated that the soil had a somewhat reduced agricultural suitability, but was considered suitable in local farming systems. Restoration to full productivity was considered possible by slight adjustment of its land management. A moderate degree of degradation status was defined as a status of the soil with a greatly reduced productivity, but still suitable for use in local farming system. Major improvements were required to restore the soil to its original productive potential. A strong degree of degradation reflected a status of the soil, which had virtually lost its productive capacity. Major investments would be needed to rehabilitate the soil, often beyond the means of national governments in most developing countries. An extreme degree of soil degradation indicated that the soil was unreclaimable.

The GLASOD study (Oldeman *et al.*, 1991) revealed that 38% (or 749 million hectares) of the area affected by human-induced soil degradation was lightly degraded, 46% (or 910 million hectares) was moderately degraded, 15% (296 million hectares) was strongly degraded, while 9.3 million hectares (less than 1%) was extremely degraded on a world-wide basis.

Although the definitions used in the GLASOD approach were appropriate for the scale it was intended for, the severity of the soil degradation problem was not related to the management level. Crosson (1994) pointed out that according to GLASOD most of the mapping units in 6 states of the U.S.A. are moderately degraded, implying that the land suffered a greatly reduced agricultural productivity. However, in that region yields of the principle crops have been rising steadily over the last 40 years. Because of this apparent inconsistency with reality and being "unable to investigate whether there may be similar anomalies in other regions of the world between actual yield experience and severity of soil degradation", he concluded that real land degradation problems lie in the strongly or extremely degraded area.

Although Crosson's conclusions from the U.S.A. may be correct, he fails to recognize that the high level of management in the U.S.A. is not generally practiced in many of the developing countries. The GLASOD map indicates that worldwide about 45% of the degraded land is moderately degraded. If degradation of this non-renewable resource continues unabated for the next 25 years or so, these moderately degraded lands may become strongly degraded. The map therefore can strengthen the awareness of global policy-makers on the dangers of inappropriate land and soil management, which was the prime objective. It should however be recognized that GLASOD is indeed based on informed opinion and not on quantitative measures.

In the Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia (ASSOD), more emphasis was placed on the apparent impact of soil degradation on food productivity. Changes in soil and terrain properties such as loss of topsoil, development of rills and gullies, loss of nutrients, may reflect the occurrence and intensity of the process of soil degradation, but not necessarily the seriousness of its impact on food productivity. The removal of a 5 cm layer of topsoil may have a severe impact on a shallow soil with thin topsoil, but may not directly affect the productivity on a deep fertile soil. It would therefore be much better to use as criterion for soil degradation impact the relative changes of soil characteristics: the percentage of the total topsoil lost, the percentage of total nutrients and organic matter lost; the relative decrease in soil moisture holding capacity, the relative increase of the salinity of the soil, *etc.* It is obvious that this type of information only exists in experimental plots and micro-catchment study areas, while precise information for a region is lacking.

A significant complication in assessing productivity losses as a result of soil degradation processes is the variety of reasons that may lead to yield decline. Yield decline may be caused by a wide range of factors, such as erosion, fertility decline, improper management, drought or waterlogging, quality and quantity of inputs (like seeds, fertilizers), pests and diseases, and adverse weather conditions. It is therefore important to consider a medium or long-time period — 10 to 15 years — to level out aberrations resulting from fluctuations in weather patterns or pest and disease occurrences.

The assessment of yield reductions as a result of soil degradation is also complicated by the fact that over time farmers may apply increasing amounts of fertilizers both to substitute nutrients lost by topsoil erosion and to further enhance the natural fertility of the soil. They may improve tillage practices to improve the soil structure when compacted by heavy machinery, and grow improved varieties. Despite these ameliorating management practices, studies in the U.S.A. have shown a relationship between soil erosion and reduced yields on many soils (Batie, 1983). Despite technological innovations to improve the productivity of the soil the average rate of change in total productivity increases has declined from 2.2% annually during the 1950-1965 period to 1.8% annually during the 1965-1979 period in the U.S.A. Since soil degradation can be more or less hidden by the effects of various management practices, productivity changes should be assessed in relation to the amounts of inputs or level of management.

In ASSOD, the impact of human-induced soil degradation on productivity is therefore assessed in relation to the level of management. Five classes of soil degradation impact were defined (negligible, light, moderate, strong and extreme). The changes in productivity, ranging from a large increase, small increase, no increase, small decrease, large decrease, unproductive, are expressed in relative terms: the current average productivity compared to the average productivity in the non-degraded situation, or the inferred change in productivity over the last 10-15 years.

In summary, one can say that the degree of degradation reflects the intensity of the degradation process itself, whereas the impact considers the effect of that process. In areas with deep fertile soils the degree of soil erosion may be quite high, but the impact may only be light or even negligible. Note that negligible is thus not necessarily synonymous with "stable" land, which implies no degradation process. Table 9.2 shows how the impact of soil degradation on productivity is related to the changes in productivity and the management level.

If one indicates a small increase in productivity under a high level of management we may conclude that management improvements partly benefited yields and were partly needed to compensate the impact of degradation. Therefore the impact is light. If we find a small decrease in productivity under a high level of management, we may conclude that the management measures could not or only partly compensate the impact of soil degradation. Therefore the impact is strong. If a small decrease in productivity occurs under a medium level of management, we can say that the degradation impact was insufficiently compensated by improvement measures. The impact is moderate.

Table 9.2. Impact of human-induced soil degradation on changes in food productivity in relation to management level.

Level of productivity change	Level of management		
	High	Medium	Low
Large increase	negligible	not applicable	not applicable
Small increase	light	negligible	not applicable
No increase	moderate	light	negligible
Small decrease	strong	moderate	light
Large decrease	extreme	strong	moderate
Unproductive	extreme	extreme	strong/extreme

This methodology to assess the impact of soil degradation on food productivity in relation to management level was used in the ASSOD study. It should be noted that information on management level is subjective, and relates only to those areas where soil degradation has occurred. It appears that 38% of the land affected by human-induced soil degradation had a high level of management, 35% a medium level and 27% a low level. Table 9.3 indicates the percentage of areas within each management category in relation to the level of productivity changes.

Table 9.3. Areas affected by soil degradation in relation to changes in food productivity under different management levels for South and Southeast Asia

Level of productivity change	Level of management		
	High	Medium	Low
Large increase	18%	–	–
Small increase	46%	23%	–
No increase	22%	40%	12%
Small decrease	11%	22%	48%
Large decrease	3%	15%	28%
Unproductive	–	–	12%
Total (= 100%)	372 Mha	338 Mha	248 Mha

Source: Van Lynden & Oldeman (1997)

The total area, affected by human-induced soil degradation in South and Southeast Asia is equivalent to 46% of the total land area. From this affected area 18% showed a negligible impact on food productivity, 45% had a light impact, 13% a moderate impact, 13% a strong impact, while an extreme impact was observed on 1% of the affected land. Although this assessment is still qualitative and based on informed opinion, the results indicate that human-induced soil degradation is a serious problem and has a clear impact of food productivity. More details can be found in the technical report (Van Lynden & Oldeman, 1997) (see also 9.2.2).

9.4. Impact of water erosion risk on food productivity: the Soter approach

In 9.3 we have shown that soil degradation affects food productivity and is therefore a threat to food security. The GLASOD and ASSOD studies however only reflect the present status of human-induced soil degradation and its impact on food productivity related to productivity changes observed in the recent past. These studies also revealed that the process of water erosion is dominant on all continents (see also Appendix 1).

As indicated earlier under ASSOD, the impact of soil degradation on the functional properties of land and its productive capacity may differ between land units and/or soils. If the seriousness, and thus the need for soil conservation measures or for alternative land uses is to be made explicit, the initial productivity of a certain land use system must be known as well as the effect of soil degradation on this productive capacity (Driessen, 1986).

In order to assess future risks of soil degradation more precise and quantitative information is needed on the various soil and terrain attributes, on climatic variables, on present land use and vegetation cover. The International Society of Soil Science, FAO, UNEP and ISRIC have developed an internationally endorsed methodology for the systematic storage of detailed information on natural resources in such a way that this geographically referenced database — the Soils and Terrain Digital Database (SOTER) — can be assessed and combined in order to analyze each combination of land, water and land use within a country or region from the point of view of potential use, in relation to food requirements, environmental impact or conservation (Van Engelen & Wen, 1995). National SOTER databases have now been developed for a number of countries in Latin America, Africa, Europe and West Asia.

In the context of their Global Environmental Outlook (GEO) project, UNEP expressed the need for a quantitative assessment of the impact of soil erosion on food production. We will briefly indicate how the SOTER database and complementary data files on climate can be used to assess the impact of water erosion (in this case, loss of topsoil) on the productive capacity of the soil. More details can be found in the ISRIC study by Mantel & Van Engelen (1997). They used a so-called mixed qualitative/quantitative land evaluation approach. For the qualitative land evaluation an ALES-based model was used — SOTAL, developed by Mantel (1995). The risk of water erosion — SWEAP, developed by Van den Berg & Tempel (1995) — and the assessment of potential productivity — WOFOST, developed by Van Diepen *et al.* (1989) — were simulated using quantitative models. We will briefly describe the various steps involved in the assessment of the impact of water erosion risk on food productivity as used in a case study of Uruguay.

A qualitative model for physical land evaluation developed in ALES (Automated Land Evaluation System) (Rossiter, 1990) was linked to the SOTER database for Uruguay to assess the suitability for mechanized, low input wheat in Uruguay. The sufficiency of the land quality "availability of water" was determined separately with a water balance model. This resulted in a land suitability map for wheat. The non-suitable SOTER mapping units were excluded in further quantitative calculations.

In a simultaneous exercise the erosion risk under mechanized, low input wheat was calculated using the SOTER Water Erosion Assessment Program (SWEAP). In SWEAP two erosion risk models are defined in the model sub-system. In this study the Universal Soil Loss Equation (Wischmeyer & Smith, 1978) modified to handle SOTER data, was selected. Considering the scale of study (1:1 million) and the fact that the parametric model is not calibrated for the range of conditions as represented by the climatic and SOTER databases, it is not justifiable to present the results on an absolute scale as soil loss in tons per hectare. The results are therefore presented in qualitative terms (erosion hazards units). This allows for a comparison between the various areas within a country.

A crop simulation model — WOFOST — was used to calculate the potential yield of wheat under the present agro-ecological conditions of soil and climate. The potential yield (or constraint-free yield) reflects the 'bio-physical production ceiling' determined by the crop's genetic potential under ambient radiation and temperature regime. The water-limited yield calculations reflect the influence of limited or excessive water supply. The water supply to the plant is determined by the water buffering capacity of the soil and only indirectly by the forcing variable: rainfall. Changes in crop yield as a function of water availability due to altered hydraulic characteristics as a consequence of erosion are (in this study) a consequence of texture shifts and change in rootable depth. The QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) methodology was used to calculate nutrient-limited yield as a function of the availability of macronutrients (Smaling & Jansen, 1993).

The soil erosion risk as calculated for the mapping units in Uruguay were then used as a basis for a simulated soil loss over a period of 20 years. In this study no account is taken of the possibility that soil deposition occurs in some units. This simplification is justified when the objective is to study the impact of erosion on crop productivity under different agro-ecological settings. In this manner topsoil losses ranging from 0 to 50 cm over a 20-year period were established for the dominant soils in the mapping units and new WOFOST input files were created to calculate water-limited and nutrient-limited yields.

Comparisons of the water-limited yield now and after 20 years erosion show the modeled impact of erosion on crop yields. Not only does this give a possibility to calculate the yield decline as a result of water erosion at national level, more importantly perhaps it gives a spatial impression where soil erosion shows the highest impact. This information can be useful for national land use planning agencies.

The results of this study can be complemented with some statistical trends. The qualitative land suitability evaluation indicates that 53% of Uruguay is not considered suitable for mechanized low-input wheat. Further quantitative assessments were therefore based on the remaining 47% of the country (12% highly suitable; 32% moderately suitable; 3% marginally suitable).

Erosion risk under mechanized low input wheat cultivation was low on one percent of the remaining area, medium on 15%, high on 57% and very high on 26%. In this study six yield classes were defined. For each yield class the areas were calculated under constraint-free conditions, nutrient-limited yields before and after erosion and water-limited yields before and after 20 years erosion. Table 9.4 shows the results.

Table 9.4. Trends in wheat yield under constraint free, nutrient limited (before and after erosion) and water-limited (before and after erosion) conditions expressed as a percentage of the total suitable area for mechanised low-input wheat (Uruguay).

Conditions	Yield classes (in ton/ha)					
	0-0.5	0.5-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0
Constraint-free			30	31	31	9
Nutrient-limited	1	1	34	34	21	8
Nutrient-limited after erosion	4	-	34	43	9	8
Water-limited	7	20	43	16	13	2
Water-limited after erosion	28	27	42	1	1	1

It can be concluded that the nutrient-limited yield potential is not significantly different from the constraint-free yield, and that the nutrient-limited yield on the generally fertile and organic matter rich soils is little affected by topsoil erosion. The water-limited yield on the other hand is significantly different from the constraint-free yield and the water-limited yield is strongly affected by topsoil erosion. If we set the total wheat production under constraint-free conditions at 100 percent, then the nutrient-limited yield is reduced to 93% before erosion and to 86% after 20 years of erosion. The water-limited yield before erosion is 65% of the constraint-free yield before erosion and is reduced to only 16% after 20 years erosion.

9.5. Conclusions

Soil degradation is occurring over vast areas. As a consequence of increased population pressure and the scarcity of unreclaimed land, physically and socio-economically suitable for cultivation, there will be increasing pressure on all sectors of society to utilize the existing cultivated areas as efficiently as possible and on a sustainable basis. While it may be true that it is economically not interesting to reclaim already strongly degraded land, it appears essential that all available mechanisms be set in motion to prevent further degradation of the land and to protect the land, which is not yet affected by soil degradation.

The Science Academies Summit (Madras, July 1996) developed an agenda for future action to be adopted by world leaders at the World Food Summit in Rome in November 1996 (IFPRI, 1996). They urged world leaders to revert the global trend of disinvestment in agricultural research and development, convinced that such shortsighted policy can only have tragic results. "Meeting the challenge of increasing food availability now and in the future demands equal focus on production systems and on the larger issues of access to food". They stress among other that a national natural resources conservation and enhancement strategy will be fundamental to a national food security system. "High priority must go to combating desertification and deforestation and to restoring degraded land".

In the preceding sections we have indicated how rapidly our natural resource base has been degraded in the last decades. We have attempted to illustrate how soil degradation affects food security and what might happen if soil degradation processes continue uninterrupted. It is our duty to communicate our concerns on soil degradation and its impact on food production to all stakeholders; international and national policy-makers; international and national agricultural research organizations; non-government organizations (NGOs); agricultural extension services; and last but not least, the farmers who cultivate the soils. There is a great demand for well-documented soil information to better understand and quantify the impact of soil conditions and human-induced alterations of these soil conditions on biomass production. A comprehensive project proposal for the development of an Asian Land Resources Information System has been developed in close cooperation with IBSRAM and national agricultural research systems in the Asian countries.

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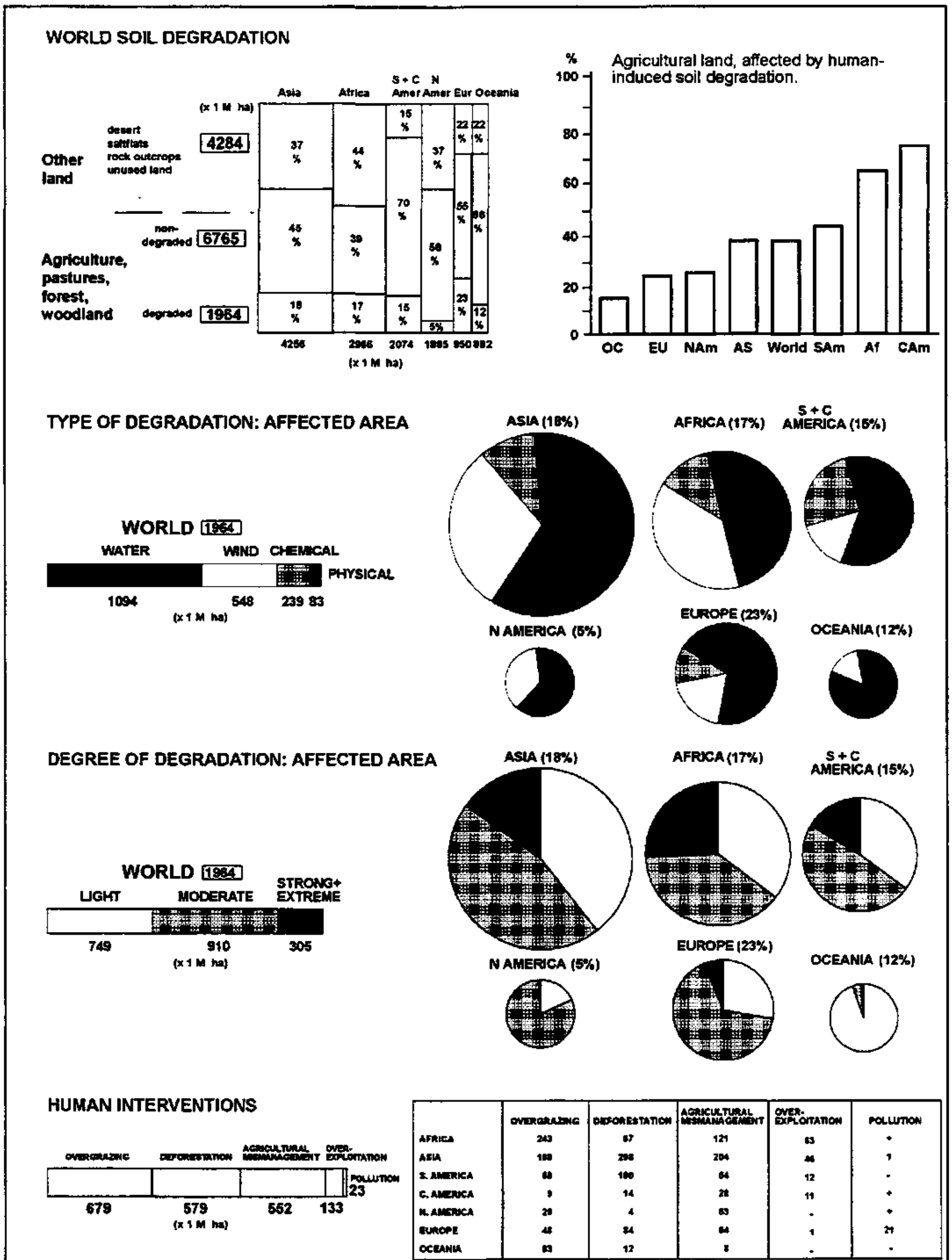
Appendix 9.1. Global extent of the status of human-induced soil degradation



	OVERGRAZING	DEFORESTATION	AGRICULTURAL MISMANAGEMENT	OVER-EXPLOITATION	POLLUTION
AFRICA	243	67	121	63	+
ASIA	189	298	204	46	1
S. AMERICA	68	100	64	12	-
C. AMERICA	9	14	28	11	+
N. AMERICA	29	4	63	-	+
EUROPE	48	84	64	1	21
OCEANIA	83	12	8	-	-

(All data from GLASOD, 1991)

10. Water availability

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10.1. Introduction

Water has no color, no smell, and no taste. Water is refreshing and revitalizing. Being one of the simplest chemical compounds, water plays a critical role in sustaining life on our blue planet that is covered for 70% with water. Water is essential to all life, all ecosystems and all human activity. Wisely used, water means health, harvests, prosperity and ecological abundance for the people and nations on earth. Badly managed, or out of control, water brings poverty, disease, floods, erosion, salinization, waterlogging, silting, environmental degradation and human conflict (WWC, 1998). At the fundamental level water has only two uses, sustaining the ecosystem and serving as a natural resource to mankind. All other uses are part of these. When water is not in use to serve human needs, it sustains ecological functions. So there exists nothing like 'available water' nor something like 'surplus water'. These are man made concepts. All water is already 'in use'. Water can only be reallocated between different species/users.

10.2. Water on earth

The total amount of water stored in the global hydrosphere is estimated at approximately 1.4 billion km^3, a quantity beyond the comprehension of most humans. However, about 97.5% is seawater or brackish, while three-quarters of the remaining 2.5% is locked in ice caps (Table 10.1). Fresh water represents 0.26% of the total water mass on the earth surface and only 0.007% if we discount the ice at the poles and the groundwater resources. This scarce resource must be seen as part of the common heritage of humankind. Only this small fraction of water is regularly renewed by rain and snow and is therefore available on a sustainable basis. With an availability of 7,300 m^3 per person and an average consumption of less than 800 m^3 per person there seems no reason to discuss water issues or water scarcity. In theory there is enough water to support a population many times larger than the present one and water may not be a limiting factor to food security. Unfortunately, however, this supply is not distributed evenly as illustrated by the large extent of arid and semi- arid regions.

This world's fresh water resource water is not increasing, and barring some major breakthrough such as very low-cost desalinization, is unlikely to increase. Pollution even decreases the usable or re-usable portion of the resource. Today desalinization of salt and brackish water is technologically mature, but energy intensive and expensive. Desalinization provides just one-thousandth of present world water use. At a cost between \$1-\$8 per cubic meter, compared to \$0.01-\$0.05 per cubic meter paid by farmers in the US and to about \$0.30 paid by urban users. Desalinization, therefore is a realistic perspective only in water-poor and energy-rich regions, such as the Middle East. Unless for high valued domestic and processing uses in urbanized areas in coastal zones it is unlikely that oceans will become a supplier of fresh water in the decades to come. In other regions, in particular where water is scarce, energy choices will be limited too; where energy is expensive, opportunities for improving and expanding water supplies will be limited in particular (Gleick, 1997). The greater occurrence of groundwater indicates its potential for future water supply but aquifers can be used sustainably only temporarily in excess of replenishment rates. The same is true for rivers and lakes. The annual precipitation on the world's land areas is the only source of water with long term sustainability to supply for green and blue water.

Table 10.1. World's water resources.

Oceans	1360	10^6 km^3
Ice caps	26	10^6 km^3
Groundwater resources (< 4000 m)	10.5	10^6 km^3
Rivers and lakes	0.126	10^6 km^3
Runoff (annually)	47000	km^3
Runoff (inhabited areas only)	39000	km^3

Source: Cox, 1987.

10.2.1. Water availability

Annual precipitation brings about 119,000 km^3 to the land area of the earth. Evaporation from land bodies is about 72,000 km^3, so that some 47,000 km^3 yr^{-1} falls renewed as fresh water to the earth land surface. Each year, about 40,000 km^3 water runs of the land areas into the sea. The amount of water to be allocated economically for human purposes is estimated to be about 13,500 km^3 yr^{-1}, including 2000 km^3 of groundwater. Actual abstractions, which cover all withdrawals from the source including both surface- and groundwater are estimated to be 4,000 km^3 or 30%. Consumption, which covers all water that is irredeemably consumed in the relevant process (crop evapotranspiration, cooling tower evapotranspiration) is about 60% of total abstraction or 2,440 km^3.

At global level there seems to be no scarcity of water even if use would double. However, due to spatial variation, both in supply and demand, serious shortages may develop at national or regional levels (Table 10.2). The per capita water availability differs enormously between continents. Africa presents about the world average. Asia's per capita water availability is only half and South America about 6 times the world average. Within the same continent differences between regions are even greater. With respect to the population increase in Asia and Africa the present situation will worsen.

Table 10.2. Per capita fresh water availability in 1980.

Continent	Water availability (1,000 m^3 yr^{-1})
Europe	4.6
North and Central America	21.3
Africa	9.4
Asia	5.1
South America	48.8
Australia	64.0
World	8.6

10.2.2. Regional water scarcity

We can distinguish three types of water scarcity:

- *Natural water scarcity*: this is the scarcity related to aridity, implying scarcity of soil water with restrictions for potential rainfed production;
- *Demographic water scarcity*: the available water per capita;
- *Technical water scarcity*: the ratio of withdrawal-to-availability as an indicator of the difficulty to meet increasing water needs by further water resources development.

In dry climates the natural water scarcity implies problems for rainfed agriculture which have to be eliminated by water conservation, storage or water supplies from rivers or lakes.
Natural scarcity can be aggravated by demographic and/or technical scarcity.

Bjorklund and Falkenmark (1997) analyzed data from Shiklomanov on water availability and use. The world was regionalized in 26 different internally rather homogeneous regions. The 26 regions tend to concentrate in five clusters:

Group A: *North Africa, West and South Asia*
High use to resource ratio, high population pressure, moderate withdrawals per capita. Dry climates.

Group B: *USA, Central Asia, Kazachstan, and Caucasus*
High use to resource ratio, moderate to low population pressure, high withdrawal per person. Temperate climate.

Group C: *Central and Southern Europe, former Soviet Union, South East Asia, and North China*
Moderate levels in all respects, good potentials in terms of unused water. Mixed climates.

Group D: *Northern Europe, North America, South America, and Central Africa*
Water rich regions with low water needs; high potentials in terms of unused water.

Group E: *Dry parts of sub-Saharan Africa*
Dry climate, erratic precipitation, moderate population pressure, use to resource remains low due to lack of irrigation Theoretical high potential in terms of unused water, but water is difficult to mobilize.

Attempts have been made to correlate the need for active planning for water management and the level of water demand. If demand is less than 5% of the total runoff few water problems occur and there is little need for water management activities. Water supply commonly will become a significant problem when demand is in the range of 10 to 20% of total runoff and need arises for water planning. If demands exceed 20% of total runoff, severe water management problems can be expected that require active planning and investments in infrastructure. Under these conditions water may become a limiting factor in economic development (Bjorklund & Falkenmark, 1997). Where global water consumption (2,440 m^3) is about 6% of total runoff (40,000 m^3), abstraction (4,000 m^3) is 30% of the potential that can be made available economically (Table 10.3). So, at global level, water may already be a limiting factor in economic development, in particular in arid and semi- arid regions.

Table 10.3. Estimated water abstraction and consumption (km^3).

Use/Purpose	Abstraction	Consumption
Domestic	350	60
Industry	800	380
Agriculture	2,850	2,000
Total	4,000	2,440

Source: WWC (1998).

Total renewable supplies have been estimated to be adequate to meet the needs of five to ten times the existing population (Postel, 1984). Land use and landcover and their demands for water and food are governed by the size of the global population. United Nations projections of world population indicate an inevitable further growth of world population. World population increases will be by 80 million persons per year and will not decline before 2015. All future world population growth will be in developing countries. Most of these countries are in arid and semi arid regions. By 2050 Africa has to feed 1,300 million people in addition to the 700 million currently. In Asia population increased between 1950 and 1995 with about 2,000 million persons and has to accommodate an additional 2,000 million persons by 2050. Nigeria and Ethiopia will have the largest population increase in Africa. In Asia population growth will continue to be large in China and Indonesia, but India and Pakistan will out-grow them. As a reference, Pakistan's population in 2050 will have a larger population than all countries of West and Southern Europe combined, and Nigeria will have twice the total population of Western Europe.

10.2.3. Land cover and land use

About 90% of the earth land surface is covered by some sort of vegetation (Table 10.4). The remaining is covered by snow or ice. Some 55% of the land surface is covered by cultivated lands and pastures, and built-up areas. Cultivated land, including irrigated agriculture, is only 10% where pastures contribute 44%. These categories represent action on land use affecting land cover. Land cover is constantly changing, as a result not only of seasonal climate variations but also of human activity. The past centuries have been marked by massive land use conversion: the change from one category, natural ecosystems, generally forests and savannas, to agriculture and pastures (Fresco, 1994).

Table 10.4. Land cover categories.

Covers	Area (10^6 km^2)	Area (%)
Snow/ice	15	10
Cultivated	15	10
Pastures	65	44
Forest, *etc.*	45	30
Wetlands	6	4
Built-up areas	2	1.5

Source: Fresco, 1994

As fewer and fewer areas of natural ecosystems are left, and protection and wise use of the remaining is strongly advocated, the future will be of one where changes in land cover have to be within the broad category of arable lands. In some regions these may be reconverted to 'man- made nature areas', when land is taken out of production. But by far the most important land cover change appears to be the intensification of land use through better management of production factors, including water management.

Of the 10% of land brought under cultivation (1,451 million hectares), about 83% is under rainfed agriculture and 17% under irrigation (Table 10.5). So, irrigated agriculture is only about 2% of the earth landcover. Irrigated land however, provides 40% of the world's food. In the developing countries about 60% of rice and wheat is produced on irrigated land. Average yield per irrigated hectare is 2.2 times the yield of rainfed agriculture. Between the mid-1960's and the mid-1980's, irrigation accounted for more than half of the increase of global food production. Of all the water taken from rivers, lakes, streams and aquifers in developing countries almost 80% is used for irrigated agriculture.

Table 10.5. Arable and permanently cropped area per (sub)continent (10^6 ha).

Continent	Total arable area	Irrigated	% Irrigated
Africa	186	13	7.0
Asia	473	159	33.6
South America	105	10	9.5
World	1451	249	17.2

Source: FAO, 1995.

10.3. The arid developing world

There are many types of arid regions that are distinguishable by degree of aridity, human history, vegetal cover and other. The degree of aridity depends on the relative importance of the supply of water by precipitation and the loss of water by evaporation and transpiration (Dresch, 1982). The limit for arid regions is where rainfall represents half of potential evapotranspiration. The UNESCO map of arid regions (UNESCO, 1977) identified four zones: hyper-arid, arid, semi-arid and dry subhumid. The last category permits rainfed agriculture when interannual rainfall variability is less than 25%. The arid zones represent 37% of the earth land surface or about 48.53 10^6 km^2 (Table 10.6).

The arid world is a fragile environment, in which numerous plants and other species are at the limits of their distribution. The natural environment also seems to limit human presence. In fact, most arid regions have a low population density. Traditional rural resources have severe limitations. The question of water resources is most vital in arid countries. Rainfed cultivation is irregular, even in areas with adequate rainfall: irrigated agriculture is strictly dependent upon water supplies. The arid world has a low carrying capacity for both pastoralists and cultivators. Food production and food security are at risk. Yet, in some parts of the arid world, like in the valleys of the Nile and the Indus, human presence is abundant in megacities of the Old World as of today's world. Moreover, in many countries in the arid region population growth is rapid.

Table 10.6. Aridity zones by continental region (10^3 km^2).

	Hyper-arid	Arid	Semi-arid	Total
Africa	6720	5035	5138	16893
Asia	2773	6257	6934	15964
Australasia		3030	3090	6120
Europe		110	1052	1162
North America	31	815	4194	5040
South America	257	445	2645	3347
Total	9781	15692	23053	48527
% of Earth's land area	7.52	12.06	17.72	37.30

Source: UNEP (1992).

The Hyper arid zone covers largely the Saharan, Arabian and Gobi deserts with only local population concentrations except where water is externally sourced as in the Nile Delta. The Arid zone covers 12.1% of the land surface. Asia and Africa have large arid zones. Here pastoralism is dependent on mobility or the use of groundwater resources. Cultivation is dependent upon irrigation. Semi-arid zones occur in all continents and cover 17.7% of the land surface. Pastoralism and cultivation are both vulnerable but still dependent upon water supplies.

Population distribution and urbanization in arid and, in future also in semi-arid regions, is confined to water supplies from groundwater or external origin. Where the arid regions cover 37% of the land surface, they sustain only 15% of the world population or 840 million people of which 94% live in developing countries. In arid regions the most extensive form of land use - if any - is livestock raising, nomadic in the traditional form from Mauritania to Mongolia, and ranching as the modern form in the arid regions of the United States, Argentina, South Africa and Australia. Traditional rain-fed agriculture occurs in the Maghreb, the Sahel, India and northeast Brasil. Modern rain-fed agriculture, dry farming is practiced in Australia, Central Asia and the United States.

Irrigated agriculture is only a fraction of the land use in arid regions, 2-3%, but sustains a large part of the population. High population concentrations in arid regions correspond with irrigated zones along the major rivers Nile, Tigris, Euphrates, Aral Sea basin rivers, Colorado and others.

10.3.1. Urbanization and industrialization

Rapid urbanization and industrialization are placing unprecedented pressures on water supply and quality. Between 1950 and 1990, the number of cities with populations of more than 1 million nearly quadrupled from 78 to 290, adding some 650 million urban people. In the next few years, half the world's population will live in cities. By the year 2025, 90% of population growth will have taken place in urban areas, increasing the demand for water of suitable quality for domestic, municipal and industrial use, and for treatment of waste. Today in the developed world, industry uses between 40 and 80% of total water withdrawals. Comparable figures for developing countries are 2-5%. This figure can be expected to grow significantly. Greater industrial use will also lead to more problems of water quality.

Income growth will also put pressure on household water use, because the rich use more water than the poor. In view of this trends, proactive measures for managing the demand for water will be as critical as investments in new infrastructure (Serageldin, 1997).

10.3.2. World food projections

Computation of the potential for food production in the world has been the topic of many studies. Buringh *et al.* (1975) estimated the maximum world food production under optimal agricultural conditions to be enough to feed at least 30 billion people. Recent studies (Luyten, 1995) confirmed that potential global food production could be 10 to 20 times the current global production of 4 billion ton depending on high or low external inputs to the agricultural production system. This potential global self-sufficiency does only imply global food-security if worldwide transports of food from surplus to deficit regions will occur. Will deficit regions have a buying capacity? The potential global production levels will only be attainable if all fresh water available will be allocated to irrigated agriculture. The share of irrigated agriculture, now 17%, has to increase to 50% independent from the type of agricultural production system. This will require large investments.

Differences among regions are very large. South America has a huge potential as soils are suitable and water abundant. Northern and Southern Africa and Western Asia have low values due to poor soils and limited fresh water resources. The latter regions with highest increase in population and food demands will continue to be regions of risks with regard to regional food security and dependent on imports.

While using all fresh water available to irrigated agriculture can be questioned, continued pollution of groundwater with nitrate seems to be unavoidable and again raises questions about the long term sustainability of the production system with regard to the quantity and quality of fresh water as an external input to the production system.

Last but not least, whether the projections of global or regional self-sufficiency can be realized is depending very much on the ability of countries and farming communities to apply in a strategic framework the measures to create the enabling environment for the introduction and implementation of infrastructure and farming and trade systems. A coping capability is needed in terms of economic, technical and knowledge capacity. The most important external input would be capacity building through human resources development and institutional development. Other constraints such as social and cultural barriers make it doubtful that achieving food security will become reality in some regions, perhaps even in the 21st century.

There have been several attempts to evaluate the status of water resources on a worldwide basis. The most recent is the 'Comprehensive Assessment of the Freshwater Resources of the World', published in 1997 by WMO. The report gives global projections of water demand for the year 2025 at three levels related to different scenarios. In the scenario with the lowest impact on global water withdrawals, the total global abstraction has to increase with some 10% to 4,500 $km^3 yr^{-1}$. In the scenario with most impact on water resources abstraction will be in order of 5,500 $km^3 yr^{-1}$. An increase of some 40%. The abstraction level of 5,500 $km^3 yr^{-1}$ amounts to 40% of the 13,500 km^3 deemed to be economically available. Table 10.7 gives the breakdown by sectors.

Table 10.7. Projections of global annual water abstraction ($km^3 yr^{-1}$).

Use/Purpose	1998	2025
Domestic	350	600
Industry	800	1400
Agriculture	2850	3500
Total	4000	5500

Source: WWC (1998).

Projections of water supply and demand for individual countries can only be achieved from detailed studies. Most developed countries have carried out studies of this type, but these studies are rare in developing countries.

The Mediterranean 'Blue Plan' assembles the results of a number of separate country studies by riparian states into a regional framework. Scenarios were prepared for projections to the reference years 1990, 2010, and 2025 (Table 10.8). The total water abstraction for a population of about 400 million was in 1990 some 276 billions of $m^3 yr^{-1}$ (bcm). For the year 2025 different scenarios show the effect of:

a. no increase in water abstraction: to meet the growing demands of different sectors water will be reallocated from agriculture to other users. The water allocated to agriculture will decrease with 10-20%.
b. increase of water abstraction to 430 bcm yr^{-1} (60%). The additional water (154 bcm) will be allocated to non-agricultural sectors 60%. The water allocated to agriculture will increase with 40%.

In both scenarios it is unlikely that irrigated production areas will expand.

Table 10.8. Mediterranean water consumption forecasts by different sectors (billions of $m^3 yr^{-1}$, bcm).

		Domestic	Agriculture	Industry	Energy
1990	276	13	64	10	13
2025	high 430	14	56	12	14
2025	low 272	15	58	13	14

10.4. Food security

Food security is defined as a state of affairs where all people at all times have access to safe and nutritious food to maintain a healthy and active life. Food insecurity at the household level is most often associated with food shortages as a result of crop failure due to failing rainfall or agricultural pests. However, for those who live in urban areas, and in future the majority of world population will live in urban areas, food shortages are associated with unemployment and lack of income. Therefore, food security at household level should be seen as the necessary resources to buy food. Only in the case of the self-sustaining farmer food security can be seen as the necessity to produce the household food according to the household needs. Therefore food insecurity is dominantly linked to lack of income rather than lack of water.

Food self-reliance at country or region level is ensured trough a combination of food production and food import. However, countries with low incomes and a weak trading position may be unable to buy in the international market the food needed to ensure every citizen is adequately fed. Here again food security is predominantly linked to income rather than the ability to produce the food or the lack of water.

In countries where water for agricultural production is becoming a scarce resource one should decide to allocate water to other uses than irrigated agriculture, uses that provide a higher valued domestic or industrial product and more benefits to the majority of the (urbanized) population in the long run by improving employment, household income and the countries ability to import food from the world market.

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11. Impacts of climate change on agriculture

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Abstract

Climate change will have important impacts on agricultural production. It is widely recognized that these impacts depend on a variety of factors, such as temperature change, precipitation, weather extremes and direct physical impacts such as hurricanes and floods. In addition, the CO_2 fertilization effect plays an important role. As a result of sea level rise, much land may be lost in coastal areas, reducing the area of arable land. This paper summarizes some of the impacts of climate change on the agricultural sector and pays attention to adaptation strategies in the agricultural sector.

11.1. Introduction

The results of research on the impact of the enhanced greenhouse effect on agriculture are ambiguous, despite large research efforts in the past decade. All impacts strongly depend on the adaptability of the farmers, and on the reaction of markets and politics (Tol *et al.*, 1995). Together with the costs of sea level rise the effects on agriculture are probably the most studied aspects of the enhanced greenhouse effect. Much of this research concentrates on productivity or output aspects and does not include the impact of changing prices. Price effects are crucial, however, for the economic valuation of agricultural damage (Fankhauser, 1995). Elevated CO_2 may lead to more carbon stored in the vegetation. Through an increased root growth it may lead to an elevated carbon pool in the soil, too. This clearly illustrates that mutual relations exist between climate change and the agricultural sector. The consequences for the total carbon balance may be considerable.

11.2. Impacts of climate change on agriculture

The estimates of the costs to agriculture in Table 11.1 are based on a study by Kane *et al.* (1992) which includes price effects, but neglects managerial responses as well as the effect of CO_2-fertilization. Working with two scenarios, Kane *et al.* analyzed the impact of climate change on crop yields, data which are then fed into a 'world food model' to analyze the effects on world agricultural markets. Welfare changes (measured as changes in producer and consumer surplus) can occur in two ways: firstly by a change in a region's agricultural output due to different climate conditions, and secondly by a change in world prices. The welfare effects (as percentage of GDP) for the two scenarios considered in the study are reproduced in Table 11.1. Absolute values for the year 1988 are based on average figures from the two scenarios.

Table 11.1. Costs to Agriculture (2×CO_2 - 10^9 US $ 1988).

	Range of welfare change (% GDP[a])	Average welfare change ($10^9$$[b])
EU	-0.400 .. -0.019	-0.9666
USA	-0.310 .. +0.005	-0.7392
Former-USSR	-0.520 .. +0.032	-0.6185
CHINA	-5.480 .. +1.280	-0.7812
OECD	-0.316 .. -0.018[c]	-2.3130
WORLD	**-0.470 .. +0.010**	**-3.9141**

[a] Range from the two scenarios of Kane *et al.*, 1992.
[b] For former-USSR the result is based on GNP rather than GDP.
[c] Average over several subregions.
Source: Fankhauser, 1995.

The results are significantly negative for all regions, but the discrepancies between the two scenarios are considerable. This is particularly the case for China, where impacts range from a loss of more than 5% to benefits of over 1% of GDP, and to a lesser extent for the former USSR. It should be emphasized, however, that particularly the 'upper bound' case is quite optimistic, compared to *e.g.* Rosenzweig & Parry (1994). It assumes non-negative yield effects in most regions. The first scenario assumes negative yield effects even for northern regions such as Canada and the former USSR, and is more within the Rosenzweig & Parry range.
Rosenzweig and Parry (1994) base their results on three of the older equilibrium General Circulation Model (GCM) experiments. Impact on yields for wheat, rice, maize and soybeans is calculated for some sixty sites in 18 countries, for three modes of adaptation, *i.e.* no adaptation (1), minor shifts (2) and major shifts (3) in behavior. For the rest of the world, yield changes are interpolated in an unreported fashion. Table 11.2 contains the nine world regions of Tol (1995) in the Climate Framework for Uncertainty, Negotiation and Distribution called FUND. Based on this, yield changes are then assessed per country, and these are also fed into a 'world food model' called the Basic Linked System, leading to impact on production levels, prices, and the number of people at risk from hunger. The Basic Linked System does not provide feedback to the yield models. In real life, the crop choice depends on market considerations. Change in crop is a powerful form of adaptation, but, as any other form of adaptation, little is known of the driving processes. How fast farmers will adapt, and under which circumstance adaptation will be successful is a crucial but largely unknown determinant of the damage costs. Cropping practices including crop rotation, tillage practices and nutrient management are quite effective in combating or reversing deleterious effects (IPCC, 1996, Chapter 13, p. 1). Scientific studies will tend to overestimate the damage if no adaptation is assumed (see Table 11.3). This bias is sometimes called the 'dumb-farmer scenario' to suggest that it omits a variety of the adaptations that farmers customarily make in response to changing economic and environmental conditions. Omitted variables are the effect of extremes and ranges in climatic variables as well as the effect of changes in irrigation. Another bias arises in the production-function approach, because it fails to allow for economic substitution as conditions change (Mendelsohn *et al.*, 1995). Newer studies increasingly emphasize also other (non-climate change) stress factors, and the need for integrated assessment of damages. The rate of change may be equally important, as are the speed of adaptation and restoration.

Table 11.2. Agricultural Yield Changes ($2\times CO_2$ - % of Gross Agricultural Product)[a,g,h].

model[b]	UKMO			GISS			GFDL			avg.	avg.	diff.
Scenario[c]	1	2	3	1	2	3	1	2	3	2+3[d]	1[e]	avg.[f]
region:												
OECD-A	-20.0	-5.0	-5.0	-5.0	+10.0	+10.0	-5.0	+10.0	+10.0	+5.00	-10.0	-15.0
OECD-E	+5.0	+5.0	+5.0	+10.0	+10.0	+10.0	-5.0	-5.0	-5.0	+3.33	+3.33	0.00
OECD-P	+7.5	+7.5	+7.5	+7.5	+7.5	+7.5	+7.5	+7.5	+7.5	+7.50	+7.50	0.00
CEE&SU	-7.5	-7.5	-7.5	+22.5	+22.5	+22.5	+7.5	+7.5	+7.5	+7.50	+7.50	0.00
M-E	-22.5	-22.5	-7.5	-7.5	-7.5	+7.5	-7.5	-7.5	+7.5	-5.00	-12.50	-7.50
L-A	-22.5	-22.5	-8.5	-15.0	-15.0	-1.0	-10.0	-10.0	+4.0	-8.83	-15.83	-7.00
S&SEA	-20.0	-20.0	-10.0	-10.0	-10.0	0.0	-10.0	-10.0	0.0	-8.83	-13.33	-4.50
CPA	-7.5	+7.5	+7.5	+7.5	+22.5	+22.5	+7.5	+22.5	+22.5	+17.5	+2.50	-15.00
AFR	-20.0	-20.0	-20.0	-7.5	-7.5	+7.5	-15.0	-15.0	0.0	-6.67	-14.17	-7.50

[a] After Rosenzweig *et al.* (1993); *cf.* also Fischer *et al.* (1993); Rosenzweig & Parry (1994); Reilly (1994).
[b] The climate change scenarios used are the equilibrium $2\times CO_2$ experiments according to the General Circulation Models of the United Kingdom Meteorological Office (UKMO), the Goddard Institute for Space Studies (GISS) and Geophysical Fluid Dynamics Laboratory (GFDL).
[c] The scenarios concern no adaptation (1), minor shifts (2) and major shifts (3) in behavior.
[d] The average of adaptation scenarios 1 and 2 over the three models.
[e] The average of no adaptation scenario over the three models.
[f] The difference between the averages described under notes d and e.
[g] The costs due to a changed climate correspond to the yield losses associated with the average over the three models and the two adaptation strategies. The costs due to a changing climate correspond to the difference between this average and the average over the three models without adaptation.
[h] The source can be criticized for two reasons: (i) the climate sensitivity of all three models is above the IPCC consensus best guess, and (ii) the carbon fertilization effect is based on too high assumptions for the atmospheric concentration of carbon dioxide (Cline, personal communication). As the effects of this are unclear to Tol, but of opposite sign, they are supposed to cancel out.
Source: Tol, 1995.

Moreover, changes in socio-economic vulnerability are as important as the actual shape of the damage function. In addition to adaptation, vulnerability will change exogenously to climate change (Fankhauser & Tol, 1995). In Rosenzweig & Parry (1994) physical production potential is the driving force for agricultural production. Land use change is excluded from adaptation. Climate change scenarios near the high end of the IPCC range of doubled-CO_2 warming exerted (in most cases) a slight-to-moderate negative effect on simulated world cereal production, even when the beneficial direct effects of CO_2, farm-level adaptations and future technological yield improvements were taken into account. The only scenario that increased global cereal production was one involving major, and possible costly, changes in agricultural systems, for example, installation of irrigation. Climate change was found to increase the disparities in cereal production between developed and developing countries (Table 11.3). Whereas production in the developed world benefited from climate change, production in developing nations declined. Adaptation at the farm-level did little to reduce the disparities with the developing world suffering the losses. Cereal prices and thus the population at risk from hunger, increased despite adaptation. The number of people at risk of hunger is estimated at

640 million or 6% of the total population in 2060 (compared to 530 million in 1990, 10% of total current population). The largest negative changes in cereal production occur in developing regions, though the extent of decreased production varies greatly by country depending on the projected climate. Price increases resulting from climate-induced decreases in yield are estimated to range between 24-145%. These increases in price affect the number of people at risk of hunger. Their estimated number increases 1% for each 2-2.5% increase in prices (depending on climate change scenario). People at risk of hunger increase by 10% to almost 60% in the scenarios tested, resulting in an estimated increase of between 60 million and 350 million people in this condition (above the reference scenario projection of 640 million) by 2060. Even a high level of farm-level adaptation in the agricultural sector did not entirely prevent such negative effects (Rosenzweig & Parry, 1994).

Table 11.3. Economic effects of 3 GCM equilibrium scenarios (10^6 US $ 1989).

	With CO_2 & Adaptation			With CO_2, No Adaptation			No CO_2, No Adaptation		
Region\GCMa	GISS	GFDL	UKMO	GISS	GFDL	UKMO	GISS	GFDl	UKMO
Developing									
<$500/cap.	-210	-2573	-14588	-2070	-5322	-19827	-56692	-66110	-121083
$500-$2000/cap.	-429	-2927	-10669	-1797	-5135	-15010	-26171	-27839	-48095
>$2000/cap	-603	-534	-1021	-818	-878	-328	-6661	-4351	-3870
Eastern Europe	2423	-125	-4875	1885	-2048	-10959	-12494	-28854	-57471
OECD	5822	25	-6470	2674	-3644	-15101	-13453	-21485	-17606
TOTAL	**7003**	**-6135**	**-37623**	**-126**	**-17028**	**-61225**	**-115471**	**-148640**	**-248124**

a GISS = Goddard Institute for Space Studies; GFDL = Geophysical Fluid Dynamics Laboratory; UKMO = General Circulation Models of the United Kingdom Meteorological Office.

Source: IPCC, 1996, Chapter 13, p. 27.

Several studies (Nordhaus, 1991; Titus, 1992; Nordhaus, 1994; Fankhauser, 1995) have estimated the damage costs of agriculture in the US due to climate change. These scientists have respectively damage costs of 1.0, 1.0 and 0.6 billion dollars. The latest estimates of Tol (1996) are 10.6 billion dollars in OECD-A and with the 15.2 billion dollars of Cline (1992) this scientist has the highest damage costs for agriculture in OECD-A. Table 11.4 summarizes the regional impact assessment of Tol (1996). For the OECD-E, OECD-P, CEE&fSU and S&SEA there are some benefits to gain for agriculture. A recent study by Mendelsohn *et al.* (1995) shows a significantly lower estimated impact of global warming on U.S. agriculture than the traditional production-function approach and, in one case, suggests that, even without CO_2 fertilization, global warming may have economic benefits for agriculture.

Some general implications for the US agricultural sector can be drawn. First, because of possible changes in domestic and foreign production under a GFDL (see Table 11.3) climate, the role of the United States in agricultural export markets may change. Second, patterns of agriculture in the United States are likely to shift as a result of changes in regional crop yields and in crop irrigation requirements. Third, concern for future agricultural impacts on important natural resources, especially land and water, seems to be justified (Adams *et al.*, 1990). In the European Union various climate change scenarios appear to yield considerable different changes in yield both for each location and for the EU as a whole (Wolf & Van Diepen, 1995).[1] Other recent studies on this topic are: Bumb (1995), Darwin *et al.* (1995), Oram & Hojjati (1995), Rötter *et al.* (1995), Mendelsohn (1996), Mendelsohn *et al.* (1996), Reilly (1996).

Table 11.4. Costs to Agriculture ($2\times CO_2$ - 10^9 US $ 1988)[a].

OECD-A	10.6	CPA	-3.2
OECD-E	-6.0	AFR	11.4
OECD-P	-6.1	OECD	-1.5
CEE&fSU	-23.2	nOECD	29.7
ME	7.6	North	-24.7
LA	13.1	South	52.9
S&SEA	23.9	World	28.2

[a] The impact of a 2.5 °C warming at a pace of 0.04 °C, accompanied with a sea level rise of 50 cm, an increase of 25% in hurricane activity, a 10% increase in winter precipitation, and a 6% increase in storm intensity in the extratropics.

Source: Tol, 1996.

11.3. Forestry

Many of the world's forests are amongst the last ecosystems on Earth that remain relatively undisturbed by human influences. Especially in the tropics, they harbor the majority of the world's biodiversity. As such, they are indispensable, self-maintaining repositories of genetic resources. Forests are of great socio-economic importance as a source of timber, fiber for pulp for paper making, fuel and for many non-wood forest products. Forests are also of special economic and spiritual importance to many indigenous people. As components of climatic system forests play a major role in the present and projected future global carbon budget. They also influence ground temperatures, evapotranspiration, surface roughness, cloud formation, and precipitation (IPCC, 1996, Chapter 1, p. 2). Roughly one-third of the world's land surface is covered by forests or woodlands (IPCC, 1990). The extent to which this area will be affected by climate change depends on various factors like, for example, the species and age of trees, possibilities for forests to migrate and the quality of forest management. The impact of global warming on wood production is therefore ambiguous. The IPCC (1996) assumes that although net primary productivity may increase, the standing biomass may not increase. Regional impacts will be strongly influenced by the extent to which forest zones can shift northwards. Sedjo & Solomon (1989) used the Holdridge Life Zone classification to estimate that as a consequence of $2\times CO_2$ the worldwide forest area could reduce by about 6%. Temperate and boreal forests would decline more, by about 16%, whereas tropical forest areas would expand by some 9%. These figures form the basis of the estimates in Table 11.5. Adjusted to 2.5 °C warming they

[1] *Tol et al. (1995) make the following observation: In abstracto the damage costs of climate change are based on limited, parly outdated information, inconsistent combination of models, uncontrolled up- and downscaling, gross inter- and extrapolation, and non-expert interpretation*

correspond to changes of -3.5, -9.6 and 5.2%, respectively. Further underlying assumptions are as follows. Forest and woodland area statistics can be found in FAO (1991). Based on Sedjo & Solomon and World Resources Institute (1992) it was assumed that 40% (42% according to IPCC, 1996, Chapter 13, p. 14) of all forest areas are tropical, and that no tropical forests can be found in the OECD, the ex-USSR, and China. That is, in the five regions EU, US, China, ex-USSR and OECD forest areas uniformly decrease by 9.6%. Studies by Fankhauser, Cline & Titus estimate damage cost on forests in the United States due to climate change on respectively 1.0, 2.9 and 38.0 billion dollars (Tol *et al.*, 1995). For the world as a whole the picture is mixed. 40% of all forest areas (those in the tropics) are growing; the remaining 60% are decreasing.

Table 11.5. Damage to the forestry sector (100 km^2 and 10^6 US $, 1988).

	Loss in forest area (100 km^2)	Forestry loss (10^6 US $)
EU	52	104
USA	282	564
Ex-USSR	908	363
CHINA	121	24
OECD	901	1,801
WORLD	**1,235**	**2,005**
temperate	2,169	2,284
tropical	-934	-279

Source: Fankhauser, 1995.

Internationally, the shift toward tropical, and away from boreal and temperate, forests suggests that most developing countries would experience relatively less forest loss than would the mid- to high-latitude countries (Cline, 1992). Table 11.5 shows the reduction in forest areas implied by these assumptions. More recent estimates can be found in IPCC (1996, Chapter 15, p. 7). The forest area of ecosystems projected by BIOME (IPCC, 1996, Chapter 15, p. 7) for present and for the year at which climate reflects a doubling of greenhouse gases is shown in Table 11.6. Note that estimated present forested areas and modeled present forested areas are similar except for a serious discrepancy in the tropics. There, the differences are in both definition and in model capability. The major pattern to emerge from comparison of all four climate scenarios with modeled present area is a moderate increase in area occupied by tropical forests, a strong increase in area occupied by mid-latitude temperate forests, and a similarly severe decline in area occupied by boreal forests. Table 11.7 presents forested areas in tropical, temperate and boreal zones, projected by IMAGE (IPCC, 1996, Chapter 15, p. 7) at 1990, 2000, 2020 and 2050.

Table 11.6. Global, tropical, temperate and boreal-forested areas in 10^6 km^2 under different future climate scenarios, projected by BIOME 1.0 Model.

	Present Area		Area				Difference (%)			
	Est.*	Modeled	GFDL	GISS	OSU	UKMO	GFDL	GISS	OSU	KMO
Tropical Forests	17.6	36.8	40.6	42.9	41.3	41.4	11	16	13	13
Temperate Forests	10.4	10.6	15.7	15.7	13.3	16.1	48	49	25	52
Boreal forests	13.7	16.7	8.4	11.5	13.5	9.1	-50	-31	-20	-46
All Global Forests	41.7	64.1	64.7	70.1	68.1	66.6	1	9	6	4

* From Dixon *et al.*, 1994;

- From Solomon *et al.*, 1993.

Source: IPCC, 1996, Chapter 15, p. 7.

Table 11.7. Tropical, temperate, boreal and total global forested areas in 10^6 km^2 under a single, future climate and land use scenario generated by IPCC and projected by IMAGE 2.0 Model.

	Area of Forest				% Difference in Area		
	1990	2000	2020	2050	2000	2020	2050
Tropical Forests	27.6	25.0	21.0	14.4	-9	-24	-48
Temperate Forests	5.4	4.1	4.9	5.3	-24	-9	-2
Boreal Forests	13.8	14.3	15.2	15.3	4	10	11
All Global forests	**46.8**	**43.4**	**41.1**	**35.0**	**-7**	**-12**	**-25**

Source: IPCC, 1996, Chapter 15, p. 7.

The areas of tropical, temperate and boreal forests estimated for the present by the two models differ substantially. The differences appear to arise from a much larger agricultural area calculated in IMAGE than in BIOME. BIOME indicates a total global increase in forested area from 1 to 9%, IMAGE calculates a decline of 25%. The value of forests in the US was estimated by Titus (1992) as \$11,000-\$37,000 km^{-2}, based on observed differences in land values before and after logging. This figure is roughly in line with the ratio of income from the forest sector relative to forest area in countries with comparatively small forest areas like Germany or France. It is, however, more than an order of magnitude too large for a country with wide forest areas, such as Canada. A very small number of countries report forestry income in their national income statistics. Yet, from there Fankhauser (1995) deduced an average forest value of about \$2,000 km^{-2}. The value in the middle income countries is assumed to be \$400 km^{-2} and in low-income countries \$200 km^{-2}. The resulting forestry loss is also reported in Table 11.5. In the short term, timber supplies from all zones can be readily assured in intensively managed forests. Unfortunately, past intensive management, especially fire suppression and tree selection at species and intra-specific levels, has created forests that may now be more vulnerable to fire, pests and pathogens (Schowalter & Filip, 1993). Other scientists dispute this conclusion. Given the current degree of uncertainty over future climates and the subsequent response of forests ecosystems, adaptation strategies (those enacted to minimize forest damage from changing environment) entail greater degrees of risk than do mitigation measures (those enacted to reduce the rate or magnitude of the environmental changes) (IPCC, 1996, Chapter 15, p. 19). The figures are inexact in several ways. First, they are based on an equilibrium assessment of $2\times CO_2$ damage, *i.e.* after enough time has passed for forests to migrate or adjust. It has been pointed out by Cline (1992) that the slow adjustment speed of forest systems may cause a temporary decline in forested area over 200-300 years, before a new equilibrium is reached. The estimates would in this respect be too optimistic. On the other hand they neglect the managerial response from the forestry industry, which may help to ease both transitional and equilibrium losses. On a conceptual level it should be noted that the approach used here is only an approximation of the exact welfare changes to producers and consumers. A more accurate analysis would have to be based on a general equilibrium assessment, which allows for price changes as well as trade effects.

11.4. Discussion

The agricultural sector is facing many challenges in the coming decades. Soil erosion and declining soil fertility as a result of overexploitaiton are manifest in many areas of the world. At the same time, the growing world population needs larger quantities of agricultural products and rapid growth of the demand for animal protein in developing countries will increase the need for arable land to produce animal fodder. In this context the additional impacts of climate change on the agricultural sector definitely pose challenges, either because of the potential threats or the new opportunities. Detailed analysis of the impacts of climate change on the agricultural sector requires detailed and regionalized climate scenarios, based on down scaling of the results of Global Circulation Models.

To what extent the agricultural sector will adapt to climate change depends on the flexibility and the quality of agricultural management in the various regions in the world. In most developed countries we can expect that technologies and crops will rapidly be adjusted to the changing circumstances, offering scope for higher productivity on the basis of higher temperatures, more precipitation and CO_2 fertilization for the relevant crops.

The dispersion of pests will also change as a result of climate change, affecting yields and the need for additional plant protection. Finally, the agricultural sector may not only be influenced by the effects of climate change, but also by the policy measures to mitigate climate change. Energy taxes, or increased production of biomass may have an important impact on land use and prices of land, thus affecting the agricultural sector. Although model calculations shed some light on the aggregated impacts of climate change and climate change policies on the agricultural sector, it will be extremely difficult to assess the final outcome of so many counteracting forces. This explains that a large variety of estimates of the impacts of climate change on the agricultural sector exists and the final outcome will only be known in a number of decades, when the actual impacts become evident.

11.5. Conclusions

The impacts of climate change on the agricultural sector will be the result of a number of counteracting forces. Positive impacts may result from higher temperatures, more precipitation and CO_2 fertilization. Negative impacts are the result of weather extremes, land losses because of sea level rise, desertification, serious droughts and flooding. Global circulation models have so far not yet provided detailed regionalized information on temperature and precipitation that

allows scientifically justified detailed estimates of the impact of climate change on agriculture. However, a large number of studies exist that try to provide an impression of what can be expected as a result of doubling CO_2 concentrations.
The impacts that are reported in this paper depend highly on the assumptions of adaptive behavior in the agricultural sector. If technologies and crops are selected according to the newly prevailing climatic circumstances, the negative impacts can be largely reduced and positive impacts can be reinforced. Some areas where agriculture at present is not successful will have new opportunities. Other areas may suffer from drought, desertification and or flooding.

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12. Striving for food security in vulnerable rural regions: The case of semi-arid West Africa

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Summary

This paper deals with food security of poor rural households in vulnerable regions. The resource base that provides their food entitlements is weak: they face unfavorable agro-climatic conditions, scarcity of fertile soils and a lack of viable economic opportunities. Consequently, survival is usually a major element in their livelihood strategies. We will focus on two issues: food security strategies and characteristics of the food and related (agricultural inputs, labor, land, capital) markets. We stress the complex nature of food security problems in the semi-arid regions in West Africa. Food security policies, which do not take into account this complexity, are bound to fail. These policies can consist of strategies of the government and non-governmental organizations. Such policies may improve transport services; help to set up insurance and other market institutions; support initiatives of the rural population to introduce, for instance, agricultural methods of low external inputs and improved methods of water and soil management; strengthen cooperative farmers' associations; create credit facilities to farmers and traders.

12.1. Introduction

This paper discusses some constraints and opportunities for the rural poor in semi-arid West Africa to achieve food security[1]. Poverty at household level is a major problem in the rural areas of this region. Food entitlements are scarce and fluctuate heavily from one year to another. In bad years most rural households are 'deficit producers' and their failure to earn sufficient off-farm income makes them to live below the poverty line[2]. They are food insecure, *i.e.* they run a high risk of not having access to enough food for a healthy life. For example, the FAO estimated that 37% of the population in Sub-Saharan Africa were chronically undernourished in the period

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[1] In accordance with Sanders et al. (1996) we define the semi-arid region as the area with mean annual rainfall between 500 and 1000 mm (which corresponds approximately to an average growing period of 90 to 179 days). Limited annual and highly variable rainfall severely limits agricultural production in these regions, together with low soil fertility levels. Cropping systems are dominated by millet and sorghum cultivation.

[2] Country assessments of poverty have been undertaken during the last decade, with technical and financial assistance of the World Bank. Sijm (1997) discusses some results of these studies for Ghana, Tanzania, Mali and Malawi. Respectively 36%, 55%, 47% and 51% of the population in these countries live below the poverty line. It is also shown that the rural population is relatively over-represented in this group. In a recent critical review of 23 poverty assessment reports of Sub Sahara countries (Hanmer et al., 1996) it has been concluded that more than 75 per cent of the poor live in rural areas in all but two of the countries.

1988-1990[1]. Their vulnerability is the result of unfavorable agro-climatic conditions, scarcity of fertile soils, lack of viable economic opportunities and incidentally major social and political disruptions. Livelihood strategies are therefore mainly characterized by survival.

Assessment of food (in)security and of perspectives to improve food entitlements requires a multidisciplinary approach as it depends on biophysical, socio-economic and political systems in a large sense. Production and exchange of food depend not only on food requirements and on the quality and quantity of production factors at the disposal of households or rural communities, but also on cultural values, political stability and economic opportunities. It is not our intention to provide a complete list of factors that determine food security. This paper focuses on two issues related to production and exchange decisions of the rural poor: their food security strategies and some characteristics of the food, agricultural inputs, land, labor and capital markets. We want to stress the complex nature of food security problems in the semi-arid regions of West Africa. No blueprint exists to provide a solution for these problems. On the contrary, food security policies should be based on careful assessments of the constraints and the perspectives of rural development, taking into account the spatial and temporal dimensions of local food systems and inter-household differences with respect to food entitlements. This paper does not plead to postpone action, but to defer from ineffective top-down approaches. It emphasizes the different levels of policy-making, and the need to involve stakeholders (farmers, traders, project officials, extension agents, *etc.*). Finally, it nuances the regularly acclaimed recipe of 'market liberalization' to improve food security in these regions. To which extent the private market can indeed contribute to food security is one of the crucial questions for the next decade.

In 12.2 of this paper the concept of food security is discussed (food security, food entitlements, chronic and transitory food insecurity). Section 12.3 focuses on strategies of the rural poor to earn a livelihood from the resource base at their disposal (production for self-sufficiency, non-farm income and transfers). Section 12.4 presents the rural market as an allocation mechanism (arbitrage, imperfect information, incomplete markets, thin markets, markets and famines). Subsequently some local initiatives to improve the food situation are discussed. In 12.6 we discuss briefly the perspectives of sustainable agricultural intensification. Finally some conclusions for food security policy are drawn.

12.2. Food security; some notions introduced

Food Security is defined in the World Bank report on Poverty and Hunger as follows: 'Access by all people at all times to enough food for an active and healthy life' (World Bank, 1986). Enough food is defined on the basis of a minimum consumption norm: a standard for the minimum average daily per capita energy intake[2]. This nowadays widely accepted definition of food security contains at least two crucial elements:

- the availability of food on the household level, through own production and marketing channels (*e.g.* buying on the local market);

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[1] FAO has defined chronically undernourished people as "those people with food energy consumption averaged over a year inadequate to support more than light activity and maintain body weight". This definition excludes productive manual labour (see FAO/WHO, 1992 and Sijm, 1997, p. 67, for further discussion of this standard).

[2] FAO uses the 1.54 Basic Metabolic Rate (BMR) as a minimum standard (see FAO/WHO 1992). The factor 1.54 allows only for light activity. It is the energy expenditure of an individual while in a fasting state and lying at complete rest. The standard used by the World Bank (1986) is a minimum energy intake of 2070 or 1840 calories per capita per day (respectively 90% and 80% of FAO/WHO minimum requirements).

- the accessibility of food for individual households, resulting from exchange entitlements.

Food Security and Food Entitlement

During the 1970s, when serious concern arose with regard to cereal imbalances in Sahel countries, the term food security was hardly used at all. It certainly did not have the connotation of food shortages at the household or individual level, which it has today. Food security had a supply-oriented meaning. Its assessment was usually based on a comparison between national food needs over the season (year) based on the standard developed by FAO/WHO (see footnote 4) for minimal food requirements per adult, and a national estimate of net food availability. Efforts of food donors and governments focused on the national food supply and in particular on the establishment of security stocks.

Evaluations of food policies have shown that aggregated food-availability statistics are quite uninformative about the causes of hunger. Except for civil wars and during years of extreme drought, availability of food (on the national level) is not the constraining factor for household food security. However, a large part of the rural households in the vulnerable regions of semi-arid West Africa is chronically food insecure (FAO/WHO, 1992). Sen (1981) stressed the importance of accessibility to food for consumers, not at an aggregated level but at the household or individual level. A household has several 'entitlements' at its disposal, which can be used to produce or buy goods and services. The bundle of entitlements consists of various components and varies among households: income from employment; the assets owned; the food produced for home consumption. If a farmer loses his crop due to some calamity like a drought, he loses entitlements. The same loss of entitlements occurs when he loses his job. Although good harvests attenuate the threat of food insecurity for many of the poor, it does not necessarily provide all of them with the required food entitlements.

Chronic and transitory food insecurity

The World Bank (1986) introduced a distinction between chronic and transitory food insecurity. Chronic food insecurity refers to a persistent inadequate diet caused by the inability to acquire food; transitory food insecurity refers to a temporary decline in a household's access to enough food. It results from a major shock in food production or household income - and in its worst form it produces hunger: famines. Although both types of food insecurity are linked and not always easy to distinguish, this classification has important consequences for the policy instruments to be developed (Drèze & Sen, 1989). In the context of famine prevention the crucial need for timely intervention often calls for a calculated reliance on relief agencies to supplement existing distributional mechanisms. Combating chronic hunger requires quite different and more permanent actions at the household level as we will see later.

12.3. Food security strategies of the rural poor

The food entitlements of the rural poor differ among individual households and from one zone to another. Rainfall, population density and infrastructure vary considerably within the semi-arid region of West Africa, and determine both major constraints and options for rural development. Food entitlements differ also between households of the same sub-region. Kinship relations, and the domestic development cycle of farm-households were - and still are - important factors which explain differences. Processes of individualization further increase the differences in food entitlements between households[1]. The following two examples serve to illustrate the wide variety of situations.

- In the northern areas of the semi-arid region of West Africa (***sahelo-sudanian zone***), food entitlements of households are largely based on livestock, and millet-cultivation. Millet is cultivated on small plots, which receive relatively large doses of organic manure. Average levels of food crop production of the (semi-)nomadic population in these regions are well below subsistence requirements. Livestock production depends on the fluctuating availabilities of fodder and water resources in the dry season (especially after a bad rainfall year). In bad years, animal densities are reduced through strategies of destocking (sales of animals) and by increased movements of herds to the southern regions. Besides, income from petty trade, non-livestock trade, artisanal (weaving, making of baskets, *etc.*) and other local non-farming activities and seasonal migration is used to buy additional food crops. Many households have developed important networks to diversify their sources of income (*cf.* Reardon & Matlon, 1989). The resulting set of food entitlements makes them food secure. However, the mobility of the pastoralists and their herds becomes increasingly constrained, as both human and animal densities rise in the southern areas[2].
- In the ***densely populated areas of the sudanian zone*** (700-900 mm), as for instance on the Central Plateau in Burkina Faso, food entitlements are predominantly based on food crop production (millet, sorghum, maize). In normal years, food production is generally sufficient to meet subsistence requirements. However, in the most vulnerable areas or in bad years, poverty is widespread and household food security is seriously threatened. Revenues from cash-crop production, livestock sales and local non-farm activities (*e.g.* processing) are generally insufficient to provide the required food entitlements. Agricultural productivity is very low in these regions. Present yield levels are obtained largely at the expense of the fertility of land. Fallow periods are shortened or have disappeared, and agriculture is extended into marginal areas (rangelands) without sufficient measures to restore soil nutrient levels. Animal husbandry is very much constrained by the limited availability of fodder resources (decrease of rangeland area, limited availability and competitive use of crop residues) and labor.

Food security strategies depend on the local situation farmers are facing. They also differ from one year to another. Strategies are characterized by rationing and destocking of animal herds in 'bad' years; in better years, farmers invest in food security stocks, livestock and other activities (*e.g.* Toulmin, 1995, Gué, 1996). Over time, food security strategies have changed, among others as a consequence of increasing population pressure on land. In the densely populated zones of the Central Plateau of Burkina Faso over the years several distinct phases can be distinguished:

Shifting cultivation: the traditional agricultural system of shifting cultivation, based on the natural regeneration and maintenance of the original vegetation (fallow periods of 10 to 15 years, after 3 to 5 years of cultivation).

- ***Expansion of cultivated areas***: the growth of the rural population causes an extension of cultivated areas in "virgin" areas and, more and more, a decrease of fallow periods, thus creating an agricultural system based on (semi-)permanent cultivation with relatively short periods of fallow, next to some permanently cultivated fields. The increased cultivation of

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[1] *The process of individualisation refers both to a weakening of the socio-economic ties between households of the same extended family (clan, hamshed), as to the weakening of customary family authorities (see e.g. Kohler, 1971, Marchal, 1983). Migration, increased market-integration, and the persistence of a 'survival'-economy are often claimed to be the dominant forces behind these processes of individualisation.*

[2] *Another factor is the development of horticulture on the low-lying soils around dams and water reservoirs (carried out immediately after the rainy season).*

cash crops (cotton in colonial times, groundnuts thereafter) also induced an increase in area cultivated per active member (see Hart, 1982).

- ***Extensification of cropping practices***: as the fertilization measures (fallow, organic manure) and intercropping and rotation patterns are not sufficient to compensate for the extraction of nutrients from the cultivated soils, soil fertility declines. In order to cope with the decrease of soil fertility levels, more land (in terms of ha/active member of the household) is cultivated, often at the expense of more intensive methods of land preparation, sowing and weeding. This extensification of cropping systems (*cf.* Marchal, 1983) is only aggravating the phenomena of soil degradation, and contributes also to an increased competition between cropping and livestock systems, and in particular between sedentary farmers and (semi-)nomadic pastoralists.
- ***Marginalization, migration and farmers' initiatives***: the decrease of labor productivity (as a consequence of soil degradation, and the scarcity of new arable lands) stimulates farmers to look for other opportunities to invest their own labor: livestock, non-farming activities[1] and migration. The diversification of revenues is an important strategy to balance crop production deficits. However, since the local possibilities to diversify are very limited, a large and growing number of households becomes increasingly dependent on revenues from seasonal migration and income transfers from migrated parents. A large number of households finds itself in such a situation, having less and less access to sufficient food. Some of them, in particular the younger heads of a farm-household, take the decision to emigrate to higher potential zones in the sub-humid regions; others try, often with the help of extension services or rural development projects, to increase agricultural production and to restore soil fertility through the adoption of soil and water conservation methods.

Not all these changes in food security strategies were directly related to just rural population density. Some other important factors are: the progress of Islamic religion, climatic cycles ('good' rainfall years in the '60s, droughts in the early '70s and '80s) and the influences of colonial and post-colonial policies. Moreover, changing food security strategies themselves affect rural society, the organization of labor, the intra-household division of relationships and the inter-household economic relationships, and tend to induce further changes. Seasonal migration, which is part of the food security strategies of a large number of households in the semi-arid region, is a good example of this. Its effects go far beyond the short-term food security situation of these farm-households, as it strongly influences 'traditional' relationships in the rural areas from which they migrated (Mabogunje, 1990).

Gender relations are of particular interest here. It is difficult to generalize about the evolution of gender relations, as there are large differences from one region, class or ethnic group to another. However, in almost all regions of semi-arid West-Africa, women have - often successfully - tried to diversify their incomes, through animal husbandry, horticulture, trade (vegetables, *etc.*), with only one major exception: seasonal migration. These new sources of income are needed to counterbalance the decrease of crop production from their small individual fields[2]. These individual plots are often the less fertile fields of the farm, and yield-levels have dropped dramatically on these plots. In some regions the crops cultivated on the

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[1] *Non-cropping activities have been important in every different phase described here. However, livestock-production and other important income-earning activities (such as trade) were in the first phases only allowed on a limited scale. Capital accumulation through these kind of activities was often restricted to some households with substantial status. Nowadays, a growing number of households and individuals are practising livestock and trade to counterbalance decreasing and variable crop harvests.*

[2] *Peulh-women are the major exception here. Generally they do not cultivate, not even on the 'common' fields of their husbands.*

individual plots have changed too, from cash-crops (groundnuts) and sauce-plants, to cereals; different reasons may explain for this change: a decreasing ratio of the producer-prices for cash-crops and the consumer-prices for cereals and/or an increase of women's responsibilities to provide food for the family from their own individual granaries.

12.4. Food allocation by the market

Many policy-makers and researchers tend to view sedentary rural households in the semi-arid tropics as almost exclusively dependent on their own cereal production to ensure household food security. Rural markets are seen as primary markets that drain surpluses to urban deficit markets. Various recent research results have undermined this view and show that many farm households are net buyers of substantial food quantities (see Reardon *et al.*, 1989 and 1992). Revenues from livestock and non-farm activities provide an important part of the necessary food entitlements for the rural population. Despite the growing importance of markets for the distribution of food, a major limitation should be stressed. The market is only operational if consumers have sufficient purchasing power. Implicitly, market advocates presuppose that consumers have the food entitlements at their disposal, which ignores the problem that many households lack these assets.

The rural economies are increasingly monetized and nowadays food markets play a crucial role in food distribution. Petty trade and processing activities are an important income source for many women. Remuneration is often low, but it is attractive when no other opportunities exist. Properly functioning markets will serve both the producers at the one end of the marketing chain and the consumers at the other end; market failures or missing markets will affect opportunities for producers, as well as food availability for consumers. Opinions on the functioning of food markets have shifted over the years. During the 1960s the debate stressed "market failures", in line with the desire of newly independent states to plan economic development. Subsequently, interventionist policies were developed to correct for these failures. However, the 1970s have shown that many of the so-called "market failures" were only replaced by "government failures". In line with these experiences, structural adjustment policies in the 1980s and 1990s advocated market liberalization, which put to an end the interventionist policies of many governments. However, several market imperfections persist.

Seasonal and spatial arbitrage with imperfect information
Food production is not synchrone with food consumption. In the semi-arid areas of West Africa, producers have only one harvest a year, while consumption is continuous. Moreover, harvests are regularly threatened by climatic hazards. This seasonal aspect may cause substantial price fluctuations, as storage costs (due to storage losses and to capital needed to finance the stock) are important and information on local supply and demand conditions is imperfect. Efficient temporal arbitrage is important for food security. However, most traders operate with very small funds while most farmers have little withholding capacity (Saul, 1987). Imperfect credit and insurance markets and imperfect information hamper the functioning of seasonal arbitrage.

In the same vein, we observe that the place of food production often does not correspond to the place of food consumption. Moreover, after a bad year production in neighboring regions will be affected as well (Snijders *et al.*, 1988) and arbitrage over long distances may be necessary to provision consumers. Consequently, efficient spatial arbitrage is crucial for the food system. As described above, the food chain is complex as many food producers are constrained by variable seasonal agro-ecological conditions and appear to be net food buyers. This implies that local supply and demand conditions vary between years and within years. Adequate information on local market conditions is a prerequisite for successful traders, but difficult to obtain in most of these countries as the telecommunication infrastructure is imperfect and information depends on personal networks of individual traders.

On a perfect market, "(....) prices convey information from households to firms concerning what consumers want, and from firms to households about the resource costs associated with consuming each commodity" (Stiglitz, 1994). However, one of the major constraints which hampers the functioning of the rural markets is imperfect information on the potential market opportunities. Traders are reluctant to share their information with competitors. Due to the seasonality in production, the cereal trade is a volatile business. Some information simply does not exist due to uncertainty in the production process. Other sources of information may exist but are not always accessible for all traders and farmers. Moreover, official regulations are not transparent and their implementation arbitrary. The existence of oligopolistic markets often seems to be based on the possibility for certain wholesalers to detain specific information. In practice we observe that traders stick to their individual marketing networks which are nested in particular geographical regions.

Thin markets

The thinness of the food market is another feature that explains the high costs related to market transactions. Most producers are peasants who are to a high degree self-sufficient with regard to cereals and are incidentally buying/selling their deficit/surplus in the market. The grain stock is perceived as a liquid source that may be used for urgently needed household necessities. The problem for the market is that most of these transactions concern small and highly variable quantities, scattered all over the country's territory. This fragmented structure inflates transaction costs: the assembly of cereals becomes a labor-intensive activity. The average retailers' turnover, per market day, is often less than 100 kg, while the major group of small-scale wholesalers may collect at most 1000 kg. The development of a personal network of trade agents and farmers may provide traders the necessary information on potential suppliers. However, the elaboration of such a network presupposes the availability of sufficient working capital and takes time, which constitutes an entry barrier for potential competitors.

In order to evade the high transaction costs, farmers may increase the number of non-market transactions and consequently aggravate the thinness of the market. Cereals can be exchanged within the family and some services and goods can be paid in kind. Matthews (1986) formulated this problem as follows: "Family production tends to make for high production costs because it restricts exploitation of scale economies and may create mismatches between talents and occupation. On the other hand it tends to reduce transaction costs, because if instead you have a lot of dealing with strangers you have to devote more resources to checking up on their personal characteristics and safeguarding yourself against opportunism". If transaction costs are high, it will decrease the competitiveness of farmers and, consequently, they may decide to withdraw from the market (see de Janvry *et al.*, 1991). The food security of farmers that do not have other food entitlements will be at stake if production falls short. This situation is quite common for the farmers in densely populated areas of the sudanian zone as mentioned in 12.3.

Markets and Famines

Various authors, who have studied food insecurity and hunger situations, have particularly discussed the relationship between famines and markets (Ravallion, 1987; Drèze & Sen, 1989). They have documented situations where market failures, thin markets and missing food markets have made hunger and famines more severe. Markets work badly during famines when scarcities are exacerbated by panic buying and excess hoarding. The food insecurity is aggravated by the seasonality of food production, which makes that food demand is highest during the hungry season, whereas the availability of food stocks is at its lowest level. Consequently, governments should be alert and in drought prone areas policies are necessary to attenuate the problem of transitory food-insecurity.

Missing or incomplete markets
In all countries in sub-Saharan Africa, the set of commodity markets is highly incomplete. Imperfections in three related commodity markets, providing essential services for cereal trade, hamper the functioning of the food market and increase the transaction costs:

- Transport services are only limitedly available. A small group of large-scale wholesalers have their own transport facilities, but the majority of small-scale traders depend on public transport facilities, which are mainly oriented toward the urban centers. During rainy seasons large rural areas may even become inaccessible. Consequently, the transport of commodities is less flexible than required for optimal trade flows.
- Credit facilities constrain the commercial activities of traders and farmers, in particular the storage function. The formal financial sector does not provide credit for trade activities and even if credit facilities do exist, most traders and farmers lack the necessary collateral (see Zeller *et al.*, 1997).
- Finally, an insurance and futures market accessible to individual traders and farmers almost does not exist. Hedging against price fluctuations is impossible. Only recently some experiences can be observed (see below). However, the institutional structure necessary to guarantee the enforcement of contracts between individuals is weak, often resulting in the non-existence of this market.

12.5. Alternative local initiatives to improve the food situation

During the last 20 years a growing number of farmers have taken new and promising initiatives to master the situation again. These activities include among others:

- activities on the farm-household level: improvement of strategies to reduce risks of low yields by careful choice of different varieties and of intercropping and rotation patterns, and by timely land-preparation and sowing; adoption of low external input methods to restore soil fertility and water management methods to improve hydrological capacities of soils; use of animal draught power for land preparation and weeding; agroforestry and the integration of animal husbandry and crop production; investments in non-farming activities (trade, processing);
- 'collective activities' by farmers' groups: village cooperatives working together on the construction of small water-reservoirs, anti-erosive measures and horticulture; exchange of information between farmer groups; education and information activities; establishment of cereal banks with the aim of building up reserve stocks to strengthen food security in the village and to improve the local distribution and marketing system.

They have taken up the twofold challenge: survival in the "hungry season" and the transformation towards a more sustainable agrarian system. Some of these initiatives are almost entirely based on strategies of 'self-reliance'. However, others do rely directly or indirectly on market-exchanges. These initiatives can be individual or collective; the latter, often structured by 'new' forms of agrarian institutions, aim to improve access to product- and factor-markets (in particular food, finance and inputs) for some group of relatively 'isolated' farmers. Cereal banks are a good example of the latter. They substitute to a certain extent for market-exchanges, but at the same time they play a key-role in improving access of farmers to rural markets.

Cereal Banks

Cereal banks are a type of organization that may challenge the existing market structure (Saul, 1987; Yonli, 1997). They concern a communal village organization that coordinates the marketing and storage of cereals. In general, cereals are bought in harvest time and sold during the lean season to members of the community. The idea behind this structure is that farmers in the rural areas are obliged to sell a part of their production just after the harvest in order to settle debts and other financial obligations. The same farmers have to buy during the lean season to supplement the cereal deficit. Put differently, they sell low and buy high. The difference between these prices may be important when farmers in the dry regions are concerned. In these regions cereals have to be imported over large distances. Rural population density is low, meaning that the market is thin. Large-scale traders are not interested in provisioning these regions, and supply may even be lacking. Under these circumstances a farmers' organization (cereal bank) may be useful; there are opportunities to beat the market. However, it should be noted that many cereal banks, established during the last decade, failed. Often, the objectives were too ambitious and organizational problems were frequent.

Cereal auction market (futures market)

A more recent initiative in Burkina Faso is interesting in this respect: the development of a cereal auction market. In 1991 the auction started as an experiment, with the aim to facilitate the exchange between farmers' organizations, in particular cereal banks. Nowadays also private traders are participating in this market. Yonli (1997) indicates that the auction facilitates the functioning of cereal banks as it may provide the structure to link directly surplus and deficit cereal banks and, consequently, limit transaction costs. Moreover, the auction may introduce a futures cereal market as contracts can be concluded for delivery at a certain time, which may result in an effective instrument to protect farmers against price changes.

12.6. Perspectives of sustainable agricultural intensification

The initiatives of the rural populations in the semi-arid regions of West Africa to increase agricultural productivity are almost exclusively based on new or improved methods of low-external-input agriculture. The importance of these methods is not contested here, often they succeed to increase applications of organic manure, and to fine-tune low-cost technologies to fight erosion, to improve the use of crop residues, *etc.* (Prudencio, 1983; Dugué, 1989; Rochette, 1989). However, the margins to increase agricultural productivity in the longer run without the increased use of 'external' inputs are small (Maatman *et al.*, 1996, 1998). Agricultural production systems based on an efficient combination of low-cost water conservation methods and modest applications of chemical fertilizers (rock phosphate, imported complex fertilizers) seem to be the only realistic option to increase agricultural productivity substantially, and to maintain - or even to restore - soil fertility (*e.g.* Sanders, 1996). The adoption of 'external' inputs, and in particular of chemical fertilizers, gives rise to considerable financial risks. These financial risks are determined by:

- the prices farmers have to pay for the 'external' inputs;
- the availability of credits to buy 'external' inputs;

- the agricultural technology - and knowledge about technological options;
- the prices farmers receive for their agricultural produces.

Most farmers in the semi-arid regions are unwilling to buy 'external' inputs, as a consequence of uncertain supply, the absence of local credit systems and -last but not least - unfavorable and fluctuating price/value ratios. We recall that non-market exchange of labor, land, capital and agricultural produces by means of socio-familial networks are predominant characteristics of these farm-households, as is their dependence on low cost agricultural methods and the production for self-sufficiency. Some actions that may decrease the financial risks are:

- fine-tuning of technological options (optimal choices of chemical fertilization according to climatic zone, soil type, and crops cultivated, complementary measures of soil fertility management and of water harvesting) through research and extension;
- improving the accessibility, both geographically and financially, of 'external' inputs, for example through the development of infrastructure (roads, facilitation of storage, transport and marketing of inputs) and of appropriate credit systems;
- development of market outlets for agricultural commodities and the reduction of transaction costs.

Decisions about the adoption of chemical fertilizers ultimately depend on the comparison of costs and benefits with other economic opportunities of the farm-household. These alternative options include investments in other local non-cropping sectors, (seasonal) migration and 'insurance' strategies to cope with crop production risks and to decrease food insecurity (security stocks of cereals, animal stocks, social relations).

Land use rights and the importance of farmers' organizations

The adoption of alternative methods of soil fertility management depend to a large extent on the degree of control individual farm-households exercise on the lands they cultivate, *i.e.* on the system of land-use rights. Land-use rights can differ much between households, and even between different fields of the same farm-household. When land-use rights are very insecure, this may prevent the farmer to invest in soil fertility improvement (for example the plantation of trees, application of chemical fertilization). Such investments may be forbidden, or they may not be profitable in the very short term. Land-use rights are in particular insecure for young farm-households, for 'immigrated' farmers, for pastoralists who have settled down at the border of a village, and for women within the farm-household. Systems of land-use rights are sometimes very complex, especially in the densely populated areas. Moreover, processes of individualization have decreased the authority of the traditional land-chiefs ("chefs de terre"). The development of 'alternative' social structures of land-use management, reinforcing the responsabilization of rural populations to manage their own natural resources (also with respect to the rangelands, the use of forest lands, and of water resources) are important conditions for every sustainable rural development. The question of farmer organization is also of particular importance in the context of imperfect markets. Cooperation between farmers may improve their accessibility to marketing networks as we have already discussed in 12.5.

12.7. Consequences for food security policy

Experiences with food policies in the last decades provide ample evidence that market failures and government failures persist. The policy challenge with regard to the food market is to develop a structure that minimizes the transaction costs and maximizes food security at the household level. The government remains to be an important actor in the market. It regulates markets and reinforces the rules. Nevertheless, food security cannot be "planned", even if policies are decentralized and executed by regional and (sub)regional government agencies. The market proved to be an important instrument to regulate food distribution and in particular the individual strategies of farmers and traders. However, we also stressed that market incentives can fail. We conclude that civil organizations at the intermediate level may provide a solution for some of the mentioned food distribution problems (*e.g.* farmers' organizations for cereal banks and rural credit, the distribution of land rights and the implementation of soil conservation techniques)

In our view, there is a strong need for flexible 'learning' and decentralized approaches to rural development. Such approaches imply that decisions can be fine-tuned to the specific circumstances of the region, and - more important - that these can be negotiated thoroughly with all different stakeholders: farmers, traders, project officials, extension agents, *etc.* Several lessons can be drawn from this paper with regard to food security policies:

- The constraints and options for the rural populations are very diverse. Food security policies should take this heterogeneity of situations into account. One way of dealing with this kind of heterogeneity is to opt for a "multipurpose enabling approach" (de Janvry & Sadoulet, 1993). Such an enabling approach should include "education, training, health, infrastructure, the promotion of grass-roots organizations, responsive research institutions and increasing options for women, youth, ethnic groups and low castes" (ibid., 43-44). However, some choices have to be made and should be based on a careful assessment of the constraints and potential of different (sub-)regions, and of different types of farm-households (ethnic groups, sedentary farmers/ pastoralists, "immigrant" and local inhabitants, *etc.*). For example, in the most northern zones of the semi-arid regions agricultural intensification seems not to be the best option, investments should focus on livestock development, rangeland management, non-farming incomes and should support migration. In the more southern areas, intensification of agriculture could be an option. However, in terms of labor and financing some investments seem necessary here - at least in the most densely populated areas - to restore soil fertility levels in order to decrease production risks, and by that also the financial risks of applying 'external inputs'.
- Perfect markets do not exist - not in the semi-arid regions of West Africa, nor elsewhere. They are a theoretical construction. Transaction costs are particularly high in the semi-arid regions of West Africa. There are good reasons why markets 'fail' in semi-arid West Africa. Farming systems striving for self-sufficiency (based on family labor, non-market exchange and management of land and other natural resources through kinship relations) can be more efficient than, or supplement, market institutions. The challenge therefore is to deal with both market and non-market exchange in food security policies: 1) to improve the market-structure where possible and adequate (in particular with respect to food and other agricultural commodities, inputs and credits); 2) to stimulate the development of grass-roots organizations, in order to improve the functioning of 'agrarian institutions' (village platforms to manage the natural resources, farmer groups to increase knowledge of agricultural techniques, cereal banks to improve distribution of food, solidarity groups to increase the accessibility of credits, *etc.*)
- Processes of social and economic change seldomly have only winners. Some specific policies are needed to target those groups who may become marginalized (pastoralists who have recently settled at the border of a village, without proper land-use rights; other "immigrated" households with insecure land-use rights, (young) households with not enough land, *etc.*).

Finally we conclude that the perspectives remain bleak, even when government policies intervene in the best possible way. Households in the semi-arid regions of West Africa already face considerable risk of food shortages and environmental degradation severely threatens the prospects in the longer run. Demographic growth is another puzzling factor, it may aggravate environmental degradation, but it might also increase the perspectives for market development, and open up new economic opportunities. One thing is clear, there is no easy way out. The perspectives depend on the creativeness and perseverance of the rural populations. Food security policies, which improve market infrastructure and facilitate the development of efficient agrarian institutions in these regions, play an important role, but should not be overrated. More could and should be done to help farmers in these regions to break through the vicious circle of poverty, overexploitation of natural resources and environmental degradation:

First, as we have stated above, sustainable rural development in these regions requires considerable investments - at least in the short term - to stop the degradation of natural resources and to restore degraded soils (at least when we accept that mass-migration to the sub-humid guinean zones is not a realistic option[1]). Public investments seem necessary to help farmers improving their soils.

Second, food security and rural development in the semi-arid regions crucially depend on economic progress on a larger (geographic) scale, and in particular on industrial development and agricultural intensification in the 'higher-potential' sub-humid regions. Both industrial development and agricultural intensification in the better-endowed sub-humid regions create additional (non-local) income-earning opportunities. This could stimulate seasonal and permanent migration from the semi-arid regions, and hence lead to higher non-cropping incomes and to less environmental pressure. Moreover, industrial development could stimulate farmers to intensify agricultural- and non-agricultural production, to increase the marketing of food crops and/or other commodities and to buy inputs ("growth-linkages").

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[1] *Which does not exclude the idea of stimulating migration, e.g. from the northern sudanian zones to the better endowed southern regions.*

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13. The role of Asia in world food security

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13.1. Introduction

The World food situation in the coming decades depends to a large extent on the changes in Asia. When food security cannot be guaranteed in that continent world food security is in jeopardy. It is for that reason that I will concentrate in this contribution on food production, food supply and food security in Asia. I refrain from a description of the development of food production in a historical context. It is well known that during the last millennium food production in all places of the world has increased considerably. In the last centennial worldwide the food production increased six fold, whereas the world population increased five fold. Changes in diet, mainly the enormous increase in consumption of animal proteins, have caused a larger increase in demand than when the elementary food requirements were just fulfilled with a vegetarian diet.

On a world scale food production can meet the increasing demand (FAO, 1993; WRR, 1994). There are sufficient possibilities to increase food production at various places through increased land productivity. The differences between various regions is dramatic (WRR, 1994). In Latin America a self-sufficiency ratio of more than 26 is possible, whereas East and South Asia are just beyond a self-sufficiency ration of one. This self-sufficiency ratio is based on an analysis of the potentials of food production in agro-ecological terms in various places of the world, in relation to the demographic development in these parts of the world projected for the year 2040. The potentials are determined by the prevailing climate, the conditions of the soil and the characteristics of the crops. The demand for food is dictated by the demographic development and the prevailing diet. The calculations of potentials are based on simulation studies with crop growth models and geographic information concerning soil, climate and water availability. The figure is theoretical but it demonstrates the wide variation in self-sufficiency ration in various part of the world. It is due to the ratio between number of people per km^2 and the amount of (potential) arable land that the big variation in self-sufficiency ration is so wide.

In fact the situation at present is a very mixed one. On the one hand Europe (including Northwest, South and East Europe) has ample opportunity to feed its population. There is a surplus of land, in North and South America the surplus of land is even larger. All types of government policy (set aside change of land use) in North America and to a much lesser extent in Europe, are oriented to a decrease of cultivated land. In Africa and East and South Asia that situation is considerably different. In Africa the spiral of unsustainability (Rabbinge, 1994) has to be broken. Land security is there in theory not a problem, but lack of inputs causes very low land productivity. Assuming optimum conditions that are considered for potential calculations, the possibilities of self-sufficiency of all African nations, even when population increase takes place according to the highest population growth scenario of the United Nations, is possible, but it requires an enormous change in land use and agriculture. Several proposals to stimulate agricultural development in Africa have been developed (FAO, 1995). They basically have all in common that agrotechnological changes using external inputs to upgrade and restore the many outmined soils and extensive land use change are needed to reach the envisaged development. At some places in Africa such changes occur but it is very modest in relation to the enormous change that is needed. Nevertheless, the world food situation does not depend so much on those changes in Africa. Within the continent the lack of improvements will have dramatic effects, but on a world scale Africa is in principle not the key problem. That seems to conflict with observations of IFPRI (1995) and FAO (Alexandratos, 1995), but as the absolute size of the population and the relative small room for maneuvering in Asia is so very important, it is especially in this continent that food security should be achieved. The world food situation in the 21st century will be dominated by the changes that occur in Asia.

13.2. The food situation in Asia

About two third of the world population is living in Asia and the demand for food is enormous. This is the first reason for Asia's major effect on the world's food situation. The demographic development in absolute terms, and in relative terms the increasing contribution to the world's population, will have major consequences for the food security in that part of the world. The growth rate in South and East Asia was decreasing from 1.9 to 1.3% during the last decade, but in absolute numbers that means still an increase at least 300 up to 800 million people in that part of the world by 2025.

More impressive than the absolute population numbers is the population density expressed in numbers per km^2 cultivated arable land. The density in many provinces of China is 10 to 20 fold the density in various member states of the European Union. This means that the population density in the majority of the provinces and states of Asia is such that the availability of arable land per capita is less than 500 m^2. The increase in total productivity is only possible through a higher production per ha. During the last decade there was a considerable economic growth in nearly all countries of Asia. The present economic crisis has reduced the growth figures but the big trend is still one of a considerable increase. The higher income per capita is affecting the consumption pattern. These diet changes, characterized by a much higher consumption of animal proteins such as eggs, wheat, cheese and especially meat does affect the need for increased plant production considerably. Per kg of beef some 8 kg of grains are necessary. The diet changes are in these areas of the world more demanding for the primary production than the present changes in population numbers (Penning de Vries *et al.*, 1995).

Most good agricultural land in Asia is situated in coastal zones or close to rivers and very often places where megacities develop. As a result the area of agricultural land is decreasing especially at those places. Industrial development and urbanization require extensive land areas and these are normally found in the close neighborhood where agriculture is removed. Substantial expansion of agricultural land to meet the increasing demand for food is therefore not possible. The amount of land use for industry, urbanization or infrastructure is still relatively limited but the places where this well endowed land is situated makes the impact of this decrease in agricultural land in terms of total production more than proportional. That is another reason for a threatening shortage in regional or local food production in Asia.

To feed the Asians the surplus of land in Europe and America could play an important role. However, that will be limited in relative, although big in absolute terms. It will be limited for three reasons:

1. A structural food production and export from USA and Europe to Asia presumes sufficient money to pay for it. That is a sweeping assumption.
2. The distribution of the food and its allocation requires an enormous transport and distribution system. The logistics of a substantial part of the food supply from abroad is even in physical terms nearly impossible. When 10% of the rice demand of China is covered by imports this is more than 50% of the world rice market and it requires a train of the length from Amsterdam to New Delhi.
3. The structural dependence on food imports may create political imbalance and cause geopolitical instabilities.

These reasons once more underline the importance of aiming at self sufficiency at regional level. That is of course not always possible and an open world market may help to adjust and compensate for shortages that may occur due to disasters, reduced yields due to apparent exogenous effects, such as a year of very bad weather.

The reasons mentioned above all lead to one conclusion. The food production in Asia has to increase considerably during the coming decades and is crucial for the world food situation. With less land, less water and optimal balanced production systems that make ample use of preventive and biological control methods, an increasing number of mouths with more demanding diets have to be fed. To guarantee good natural resource management at field, cropping system, farm and ecoregional level, dramatic shifts in agriculture are needed.

13.3. Possibilities for food production in Asia

When China imported in 1995 and 1996 substantial amounts of rice and wheat from various places in the world, some observers saw this as a symptom of structural shortages in the years to come. The response of the Chinese authorities was such that the increase of food production has been regained. Imports are less than before, but the question remains whether various Asian countries will have the possibilities to produce sufficient food for their growing population. Studies on the availability of good agricultural land and best agricultural practice demonstrate that this is possible (Luyten *et al.*, 1997). However, at some places that requires dramatic shifts from present to other land use and considerable change in agricultural technologies. There is in Asia no room for an agriculture that does not make optimal use of the land and external inputs and resources. Good environmental practice and agricultural practice requires an intensive and higher productive agriculture.

It is for that reason that a movement away from productivity, technology and adverse to inputs and use of external resources is so dangerous. The possibilities to feed the Asian population numbers with an organic farming system are absent. Bans on artificial nitrogen fertilizers will especially in this part of the world cause immediate structural shortages of food. A reduction of the number of mouths to be fed with some two billion is then necessary whereas the trend is of course still an increase. The adagium 'think globally act locally' does not imply that external inputs should be banned but used in a rational, intelligent and diligent way. That way leads to high effectivity and efficiency and the best use of all resources.

This type of agriculture with innovations at systems level is currently developed at many places around the world. It makes use of the best knowledge and insight at process level that helps to improve agrotechnological practices and it stimulates better land use. It is a combination of Integrated Pest Management, Integrated Water and Nutrient Management and Precision agriculture. That advanced high technological agriculture is productive, efficient in use of natural resources and stimulates ecological continuity at all levels, field, farm and region.

The tendency to neglect agriculture (World Bank studies) in part of Asia is a very dangerous one. The fragility of food self-sufficiency is demonstrated through the recent experiences in China, Indonesia and the Philippines. Investment in agricultural innovations and research, guidance of markets and amplification of public-private partnerships in this sector are needed to achieve the increase of food production in general and more specifically rice with some 50% before 2025. That seems a mission impossible, but it is not so when the right attitude and dynamics are promoted.

Steps to be taken involve a revolution of agricultural systems. The decrease of labor in agriculture due to expected considerable changes in labor and land productivity and the related changes in the society will have to be guided by a combined public/private investment program. The need for democratic institutions is increasing. The change in the attitude towards market requires a reengineering of the rural society and this is probably the most important change in Asia in the coming decade.

13.4. Conclusions

1. The role of Asia in world food security is vital and cannot be underestimated.

2. The only way to ensure food production in the future is increase of production per hectare. Expansion of agricultural area is only very limited possible and the changes of diet that take place cannot be stopped. Population control is needed and will help but requires much effort. In fact, the increase in income and elementary conditions of welfare are the best factors to affect population control.

3. The room for locally oriented agriculture that makes only very limited use of external inputs and that is based on organic farming principles is very limited. It would be very dangerous for Asia to go in that direction. Increased productivity requires external inputs, sophisticated technological and maximum use of ecological principles but bans on inputs or particular technologies will be counter productive.

4. All principles of high technology agriculture have to be implemented. That includes the best of precision agriculture, ecoregional approaches, integrated nutrient, water and pest management. A true production ecological approach will be the best guarantee for achieving the multiple goals of food security, protection of the environment and having room/space for other activities.

5. The role of America and Europe to feed the Asians is and will be limited in the future. It would be unwise and physically impossible to rely on major structural food transports from these continents to Asia.

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14. Investing in the proper functioning of markets

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Abstract

For developing countries that suffer from a food security problem, the slogan "trade no aid" is now more relevant than ever. First, aid flows have been stagnating, and there are many competitors for aid funds: countries from the former Eastern block, South East Asia bail-outs and there is much pressure to use the funds for peace-keeping operations and commercial investments. In fact, developing countries have increasingly recognized the importance of private foreign investment, though many of them have by now experienced the disadvantages of accepting footloose foreign capital. Secondly, the alternative of autarky has become less viable than ever, as virtually no country can develop without imports of oil, chemicals, pharmaceuticals, or computer software on the global market. Finally, there is general recognition that it is impossible to address the hunger problem exclusively by means of targeted aid to the poor, not only because of the vast sums of money this would require, but also because of the problems created by aid-dependence itself. In short, as emphasized in the Rome Declaration of '96, food security policy is primarily a matter of eliminating existing barriers to private initiative on domestic and international markets, while both national governments and international institutions are primarily seen as providers of an "enabling environment" for the proper functioning of these markets. The paper argues that past shifts in development paradigms in general and food security policies in particular, reflect the trend in ongoing debates in economics (macro/micro) and philosophy (positivism/postmodernism). It reviews some of these shifts, and sketches broad areas of consensus around the theme indicated in the title.

14.1. Introduction

The organizers of this seminar series were thinking truly big when they asked the speakers of the present session to answer the question "How to achieve food security?", no more, no less. It can safely be presumed that at this stage of the seminar series, after thirteen lectures on the subject, this audience has no need for any further clarification of the concept of food security itself. This enables us to postulate that achieving food security largely means achieving absence of food insecurity which in turn has become synonymous to eliminating poverty, and thus to successful development. Food security is a useful concept, because it maintains a clear focus on poverty and vulnerable groups, as well as on the various threats to human welfare in general, be it environmental degradation or political disorders, thus pointing to existing and potential problems. However, the concept gives no indication whatsoever about the ways to resolve these problems and it is the other part of the question, "How to achieve ...?" that makes it so immense, as it raises three underlying issues: "Food security for whom?", "Food security by whom?" and

[1] *The author thanks Ben Sonneveld for comments on an earlier draft.*

finally "How?". With respect to the first, let us agree that we mean food security for all, now and in the future. The second and third questions are far more difficult to answer. In other words who are the actors that should see to it that poverty is eliminated and how should they proceed?

This paper starts with some remarks about past shifts in the prevailing development paradigms that are in the general perspectives on answering to these two questions. Next, it describes a perspective on policies at the national and the international level, and concludes with a brief discussion of possible implications of these policies for food security related research.

14.2. Past shifts in the development paradigm

Over the past decades, development paradigms have undergone many changes. Table 14.1 shows some of the poles in between which they have been drifting. One might argue that tensions existed mainly between overall approaches that aim at strengthening the economic performance of the whole population on the one hand, and targeted approaches that try to help the individual in need on the other (see also Keyzer, 1998a).

Table 14.1. The dialectics of development paradigms.

Coordination	Participation
Discipline	Democracy
Conditionality	Ownership
Innovation	Respect of traditions
Shocks	Gradualism
Growth	Equity
Infrastructure	Micro-credit
Trade	Aid

To the outsider, these shifts might convey an impression of lacking orientation and effectiveness, as if the field was more driven by its failures than by its successes.

Adjustment to failures

Indeed, one might argue that the agenda of priorities both in research and in practical policies is largely controlled by donor agencies, which need to be convinced, time and again, of the positive and significant returns from their contributions. These agencies tend to focus on situations where the needs are great and the crisis is deep. Those are often situations where accepted paradigms have failed and where radical change is called for, and in fact the issue of food insecurity itself tends to be raised in this context of crisis and famine. In addition, the returns from aid should be visible, and this is more easily achieved in micro-approaches through a video of a happy fisherman who just received a new boat, than through a modest participation in a major multilaterally financed project, that might put local vegetation at risk.

Macro - micro debate

Yet there is a growing understanding that development assistance cannot help the whole population in an equitable way if it is fully oriented to the individual. At the same time economists have, in the context of the macro-micro debate, come to recognize that macro-economic growth should be such that it also benefits the poor and reduces their food insecurity, even if the rich gain more.

From positivism to postmodernism

There is, however, another aspect that deserves mentioning, which the research community in the field of food security and development might not sufficiently be aware of. It relates to the strong impact of past and ongoing philosophical debates on what is generally perceived as common wisdom. These debates have themselves been strongly affected by real world events, such as the collapse of communism and other great ideologies, but they were also influenced by deeper and long-term undercurrents in science. In a nutshell, one might argue that mainstream positivism, with its attempt at describing the world in full so as to control it better, has over the past decade or two lost much ground to the post-modernism of writers such as Rorty (1991) who emphasize community and consensus building. The post-modernists think that the description will always be so imperfect that control is unreliable, and, furthermore, that this illusion of controllability has proven dangerous as it was often misused to justify despotism and terror. Post-modernist like to search for consensus and this naturally leads to dialectic processes, and to a relativistic attitude with respect to ideologies.

14.3. Policies at national level: three lessons learned

Yet this variability in policy stance does not mean that it is impossible to learn any lesson from past experiences. At this point and at the risk of oversimplification, let us try to summarize these lessons. There will be four. The first, highly post-modernist one is the following.

Lesson 1: **The worst food security crises are due less to wrong choice of economic paradigm than to failures of political system.**

Oppression, chaos and wars disrupt the food security and human well being more than any misguided policy can ever do with a government that maintains law and order. Cambodia, China in 70's, Guatemala, Haiti, Soviet-Union prior to '89 and present-day Russia and Sudan are only some of the many examples. In positive terms, a national government can make a fundamental contribution to food security by fulfilling its minimal task of providing law and order. We only mention law and order, since the evidence unfortunately does not warrant the direct conclusion that grassroot democracy and respect of human rights, are closely correlated with successful development (Srinivasan, 1997).

Lesson 2: **No country can solve its food security problem by foreign aid or domestic redistribution alone. Successful countries tend to have a long-term government commitment to development, with a pluriform and shifting policy emphasis.**

Usually, in successful countries the policy has been inward looking and hardware-oriented at the start of the development process and has gradually shifted its emphasis to human development, democracy and export orientation. Successful governments assume an active role in economic planning, where they provide more central guidance than the adepts of the free market economy might wish, but where they maintain a pluriform and economy-wide perspective that is not kept hostage by sectoral interests, and leaves ample room for private initiative. Prominent examples are, in random order, and in spite of current financial crises in some of these countries, Chile, present-day China, South Korea, Malaysia, Singapore, the state of Punjab in India and, finally, Taiwan.

***Lesson 3*: Employment is the key factor.**

Notwithstanding the gains than can be achieved through improved food habits and hygiene, there is virtually a general consensus that malnutrition is primarily due to poverty, and that poverty alleviation is intimately linked to unemployment, since redistribution of assets or aid cannot solve the problem. Indeed, successful countries tend to concentrate their efforts on achieving steady growth in remunerative employment. They maintain social safety nets of some sort, often in the form of ration card systems, in the explicit understanding that this does more than avoiding hardship and maintaining social stability, since it also contributes to labor productivity. Malnutrition is both cause and consequence of poverty, as higher food consumption enables the worker to become more active.

As a corollary to this lesson, one may notice that agricultural growth is, by itself, not the solution, since agriculture generally offers little growth in income and even less in employment. Clearly, this is not to argue that agricultural growth is irrelevant. Most food insecure people in developing countries currently live in rural areas, and lack the skills for securing remunerative non-agricultural employment. Consequently, it is important to improve their opportunities to work in agriculture. Nonetheless, it is very difficult to achieve sustained growth in yields of more than three per cent, and even more difficult to combine this with a growth in employment. Therefore, unless there is ample unused land available for cultivation, elementary arithmetic already indicates that countries with a population growth in excess of two per cent per annum, can hardly rely on agriculture in their attempts to reach food security through adequate employment. In addition, the expansion of agricultural production is only feasible if the up- and downstream sectors develop in parallel, and this necessitates substantial investments outside agriculture.

Clearly, in the long run a developing country cannot afford to solve its poverty problems solely by creation of artificial jobs in the public sector. Employment policies should be sustainable, which means that it should primarily be obtained in the private sector, and naturally leads to the final and central lesson:

***Lesson 4*: Invest in proper functioning of markets.**

For developing countries that suffer from a food security problem, the slogan "trade no aid" is now more relevant than ever. First, aid flows have been stagnating, and there are many competitors for aid funds: countries from the former Eastern block, South East Asia bail-outs and there is much pressure to use the funds for peace-keeping operations and commercial investments. In fact, developing countries have increasingly recognized the importance of private foreign investment, though many of them have by now experienced the disadvantages of accepting footloose foreign capital. Secondly, the alternative of autarky has never been less viable than at present, as virtually no country can develop without imports of oil, chemicals, pharmaceuticals, or computer software on the global market. Finally, there is general recognition that it is impossible to address the hunger problem exclusively by means of targeted aid to the poor, not only because of the vast sums of money this would require, but also because of the problems created by aid-dependence itself. In short, as emphasized in the Rome Declaration of '96, food security policy is primarily a matter of eliminating existing barriers to private initiative on domestic and international markets, while both national governments, international institutions and the world community at large are primarily seen as providers of an "enabling environment" for the proper functioning of these markets.

The practical implications of these principles were already touched upon. A food security policy cannot rely on markets unless these exist. If there are no means of transporting goods from one place to the other, local markets can be flourishing, but supply shocks due to, say, crop failures in specific regions, cannot be cushioned by commodity trade between these markets, there is no scope for specialization, and the local supply is constrained by local demand, and vice versa. Thus, infrastructural development is essential if market integration is to be achieved. A discussion of this and the many other requirements for the proper functioning of markets obviously falls beyond the scope of this paper. These requirements include protection of property rights, through a well functioning police and judiciary system. They also include good access to information about prevailing market conditions, and hence assured freedom and sufficient reach of news media. The system for grading of commodities should be reliable and its inspectors should know chalk from cheese. In addition, state and other monopolies should be avoided to the extent possible. Finally, government should be providing guidance to the process of technological innovation and of expansion of physical and social infrastructure.

In short, for markets to function, the national government should invest significant resources in their creation and upkeeping and maintain a very active presence. Clearly, many developing countries are far from reaching this ideal but their resolve to achieve it should be clear and outspoken. Incidentally, these policies do not imply that international trade should be liberalized overnight, and even less that all controls on capital flows should be lifted. As long as market imperfections persist, government should fight them and at the same time take corrective actions. All this is well known by now and well accepted in international circles. However, it raises the question as to the role that is left for development assistance beyond the provision of funds that should help well-intentioned national governments fulfill their mandate. This is the question to which we now turn.

14.4. Enabling global environment: an agenda

Being a friend

It is not possible to consider the future of development assistance, without touching upon the basic question as to why people in developed countries are willing to provide any assistance at all. Over the years, many non-altruistic motives have been suggested, ranging from the promotion of commercial interests through subsidized export credits, to the absolution of past guilt. Be this as it may, a development assistance policy that purely bases itself on non-altruistic motives has no long term future as public expenditure category, for the simple reason that the tax-payer would eventually become unwilling to keep on subsidizing exports in this way. Moreover, the World Trade Organization (WTO) would start denouncing these exports as unfair trading practices. As to the guilt argument, it also requires credibility to be effective. In short, developing assistance has at the very least to look altruistic to be sustainable from the donor side.

In fact, opinion polls tend to indicate that most people in Europe are not indifferent to the hunger and poverty in the world but, in the era of individualism and competition, they care more about themselves and next of kin. Moreover, the past record convincingly shows that aid and self-sacrifice would not solve the problem. Consequently, one should not count on significant increases in aid disbursement in the near future, except in dramatic emergency situations.
Here again the shift to a postmodernist worldview should be recognized as a long-term and lasting trend. For development assistance, it means abandoning the "control" approach to the hunger problem. Such an approach builds on the morality of paternalism, which means "Being like a father", or "Do what a father would do" and sometimes also "Do what The Father would

like us to do". In contrast, the postmodernist view calls for a more secular approach, characterized by a sense of community (Rorty, 1991), where "being a good friend" is what counts.

This good friend is critical, fair, respectful of mutual differences and of privacy. He or she helps out occasionally, gives advice when asked, and mediates in international conflicts and negotiations. In international relations, a good friend is there for the people, not for the president of a country in need. He is not a Big Brother, neither is he a Rich Uncle. He does not engage in strategic games where the enemy of his enemy becomes a friend. He does not discriminate, and keeps his distances, he is not the old pall, the very very best friend. Finally, he may expect a sign of appreciation once in a while.

The friend's agenda

Now let us try to make this notion of friendship somewhat more operational. The basic message so far has been that, since food security cannot be achieved by financial aid and redistribution alone, to address the problem, it becomes necessary to use the energies of the market mechanism. National governments should therefore invest in the proper functioning of markets, while keeping the other three lessons at the forefront of their policy agenda: maintain law and order in a civil society, maintain a coherent development perspective and ensure sustained growth in employment.

However, when it comes to achieving fair international relations, there is not much that disbursement of official development aid can achieve. Here the best and most friendly help a donor country can give is to create a level playing field. This part of the argument has several ramifications that were discussed elsewhere (Keyzer, 1997, LNV-BZ, 1996) and will only be summarized briefly.

First, it is clear that developing countries should have access to the markets of developed countries, to enable them to sell their produce, and buy the necessary imports from the proceeds. The current policies of the EU, which only grants preferential access to a selected group of countries is highly deficient in this respect (Kuster, 1998). The upcoming round of WTO negotiations should emphasize the point that free trade means more than a reduction of export subsidies. The key element in free trade is free access for imports. Export subsidies will then adjust automatically. The current proposals for agricultural reform of the EU presented in the context of Agenda 2000 and the views of the EU for a new Lomé Convention do not augur well in this respect.

Secondly, there should be free competition. The poorest developing countries will not gain from GATT/WTO rounds of trade liberalization if the reductions in tariffs are gradually being replaced by increases in monopoly margins. As recognized in the conclusions of an Inter-governmental forum on food security that was organized by the European Commission in December last year, it is very important that competition be safeguarded in areas such a seeds, pharmaceuticals, equipment for electricity plants, computer software and airplanes. While most developed countries currently pursue an active anti-trust policy on their own markets, there is so far no organization that fulfills this task at the international level (Keyzer, 1998b, CEC-Solagral, 1998, Keyzer & Merbis, 1997)

Thirdly, it should be recognized that constraints on labor migration amount to protecting the trade in services. While developed countries currently stress the importance of liberalization of this type of trade within the WTO, they only open their borders to political refugees and refuse economic migrants. This is an anomaly that deserves serious attention. It seems unlikely that a densely populated country, such as Bangladesh, will ever, within the confines of its national borders, be able to secure remunerative employment to everyone. It is admittedly utopic to expect a return to the conditions of relatively free migration that prevailed in the past, when for instance major segments of the Irish population had the opportunity of moving to the United States. Yet the issue needs to be tabled time and again, if only to highlight the current inequality in opportunities, and enforce concessions on other subjects.

One of these subjects might be the implementation of international environmental policies, the fourth subject to be mentioned. Few will dispute the basic principle that the atmosphere is the common property of all and that polluters should pay every owner for the resources they use. Yet the current practice in implementing global warming policies is a different one. Polluters in developed countries receive quota in proportion to their emissions in a given base year and are only required to compensate others to the extent that they exceed these quota. Moreover, the individual in a developing country will in general not see much of these payments.

This leads us to our fifth and final point, which starts from the observation that international markets function on the basis of private initiative, as opposed to inter-state trade. At the same time, all negotiations and dispute settlements on the above mentioned subjects are between nations. The individual trader has no way of denouncing inappropriate implementation of rules, other than through the long and tortuous channels of the bureaucracy of his own country, which might, if they so wish, eventually issue a formal complaint. This usually is a hopeless path to follow, especially for a small trader. The channels are too long and often the own government will prefer to maintain good diplomatic relations with the foreign countries concerned. These difficulties could to some extent be circumvented if foreign individuals were granted access to civil courts in developed countries where they could file complaints against states or companies that violate existing regulations. Clearly, many traders will lack the financial means for starting such proceedings, but recognition of the principle is by itself important, as it reflects the sincere will to create a level playing field (LNV-BZ,1996).

14.5. Implications for food security related research

To the specialized agronomist, the discussion so far might seem rather abstract. Therefore, let us conclude with a few remarks on the implications for food security related research, starting with the general observation that changes in research priorities over time seem to reflect shifts in paradigm of the type listed earlier (Table 14.1). This seems unavoidable as these priorities are to a large extent governed by the prevailing concerns of the funding agencies.

We argue that applied researchers, while showing willingness to meet the challenges of the day, should not follow too closely the fluctuating concerns of the political arena, as this could lead to an erratic type of research that addresses topical issues but shows no real progress. The dilemma can be resolved if research methods rely on theoretical frameworks that are sufficiently flexible to accommodate shifts in emphasis without requiring major re-orientations. Moreover, the researcher should know where the own contribution fits within the overall picture and be aware of paradigm shifts in the past, as this will allow him to anticipate the necessary modifications and extensions of his tools and knowledge base.

This suggests an organizational structure that partitions the subject into thematic fields. Table 14.2 gives an impression of how these fields are defined at SOW-VU. Within each field, researchers can develop specialized expertise but applied projects often require inputs from more than one thematic field.

Table 14.2. Thematic fields at SOW-VU.

Thematic field	*Agronomy*
International:	
WTO, CAP, Kyoto,	
the friend's agenda	
National:	
public investment allocations	
taxation, trade policies, ...	resource base
Household:	
human development	extension
institutional constraints	
vulnerable groups	
Spatial:	
land development	yield functions
infrastructural projects	land, water
diffusion of pollutants	hydrology

The main challenge is to seek integration across themes while respecting the integrity of the disciplines concerned, and maintaining the social and spatial diversity in higher levels of analysis.

14.6. References

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15. Closing presentation

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This is the end of the seminar series on Food Security at different scales: issues, challenges and opportunities. When I invited speakers to this series, I got a lot of comments and suggestions to improve the set-up. Socio-economists thought that the series were too technical, while the more technical scientists wondered why it had to be so broad. Now, I think that we know that solutions to the problem of food security can neither be too broad, nor too technical. Even in this series with 15 presentations, we have not exhaustively discussed the issues, challenges and opportunities on food security. This however, was a good start to shape the discussion and to identify researchable issues.

Briefly, a couple of major issues that were identified I would like to mention. Food security concerns the production, distribution, access and quality of food. The geographical and temporal scales, and both participatory bottom-up and top-down analyses turned out to be important.

It need not argued anymore that enough **food** can be **produced** in the world at the global level, but this does not mean that it will happen just like that. An increasing amount of food will have to be produced on the same agricultural area, which will result in increased pressure on the natural resource base. Much attention will be needed therefore on sustainable agricultural production systems, considering variability and risk in production.

Regions, countries and individuals need not be self-sufficient in food, as long as they can be self-reliant. That means that enough **income** should be generated either in- or outside agriculture. The loss of labor from agriculture should for instance not be seen as a threat, but more as a way to make agricultural more productive in terms of labor and inputs.

Access to food should be improved at all scales, but probably most at the micro level. That is, good extension and information is needed to create awareness on how to prevent malnutrition, by choosing **nutritious** food, once income allows it, and by balanced proportional distribution of food among family members.

Developments should be studied at different **scales** in a comprehensive integrated manner. Related to the **geographical** scale, the interactions between developments at the global and local scale are very important to understand. Local effort to increase, say the meat production in West Africa, will not be successful if global developments, like the dumping of meat on the world market, cut down the required conditions of good prices. While participatory bottom-up approaches are needed, top-down approaches to reveal broader and general developments, opportunities and limitations at higher levels should not be rejected. This aspect has also been emphasized in the declaration of the World Food Summit.
Another scale concerns the **temporal** aspects of development. Poverty driven decisions at lower levels to assure food supply at the short term may jeopardize long-term sustainable

developments. Both situations need attention, and creative solutions may be needed to realize a phase of transition.

Some **major international** developments are currently taking place, which will have strong impact on food security in developing nations.
Liberalization is expected to be beneficial for food consumers around the world and ultimately put an end to subsidized over-production in the North, reducing dumping of food. But then, the formation of **monopolies** may become a real problem. During this series, a number of other shortcomings of liberalization have been identified. A liberal market is not expected to reach the **poorest** of the poor, those who are most severely under-nourished. Also, a liberal market system may not protect our **natural resource base**, as long as these resources are not well priced or privately owned. Many poor live in so-called **marginal regions**. These are not exactly the regions that are likely to benefit from liberalized markets. If these regions are not developed, instability and disintegration of societies may be the result. Another issue that needs attention is unequal conditions of departure in negotiations on liberalization, generally unfavorable for poorer countries. Also, market forces may not trigger investment at the right time. Prices increase when demand has exceeded supply. The problem of shortage has then already occurred.
Although direct impact of *global climate change* on agricultural production may be still under discussion and investigation, political measures to reduce emission of gasses at world level, like suggested on the climate conference in Kyoto, also will have strong impact on developments in relation to food security. What gains can be obtained from measures like joint implementation, emission trade, clean development mechanism, technology transfer, *etc.*? Will an additional flow of capital towards the developing countries improve food security? Are the measures a crowbar to create access of multinationals and western companies into developing nations?

These are some of the major issues that have come up. If you have missed any, and I am sure that this list is far from complete, please submit that in writing. This overview indicates that answers to these questions can only be found by comprehensive analyses, requiring joint forces from the various disciplines involved. Collaborative efforts are needed among scientists within the Wageningen University and Research Centre, but also with other scientists of universities and institutes in and outside the Netherlands, in interaction with stakeholders, be it politicians, extension service, farmers, NGO's , private organizations, *etc.*

This series has set the stage for further discussion and should be followed up. The presentations will be published and we will work on a Wageningen platform on food security. All this should accelerate and streamline collaborative efforts on the desire to realize food security for at least one billion people.

I would like to thank all the speakers, chairpersons, and participants for their contribution in these series. Also on behalf of the research schools Production Ecology, Wageningen Institute for Animal Science and the Mansholt Institute, the institute for Agrobiology and Soil Fertility, the Program "North-South" of DLO and DGIS. I have assured that the liquid intake of the speakers and of all of us is secured; just outside there are some drinks, to stimulate an informal get-together and to get the discussion and collaborations going. Please keep actively participating in these initiatives.

Thank you for your interest.