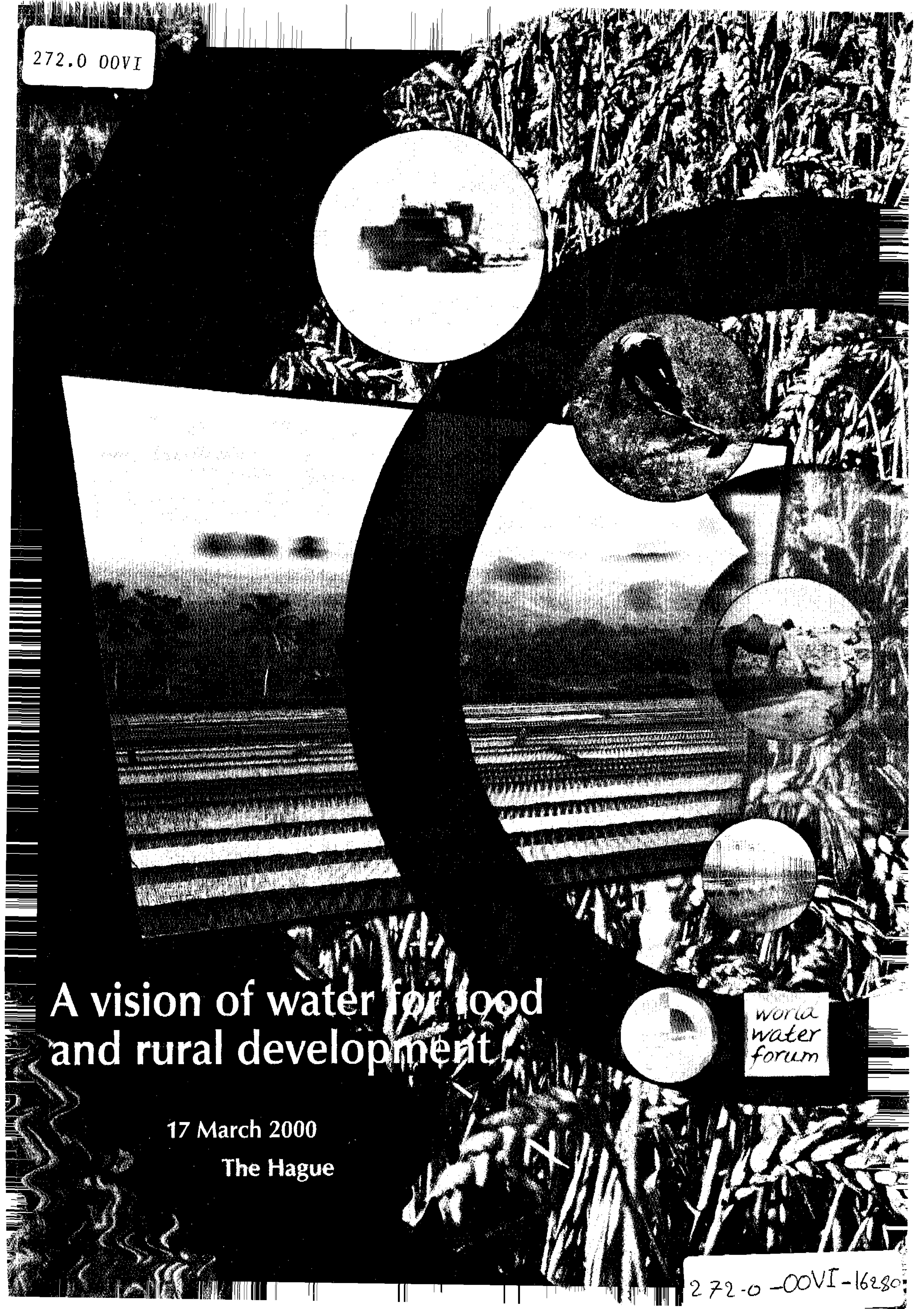

A vision of water for food and rural development

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A VISION OF
WATER FOR FOOD AND RURAL DEVELOPMENT

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Preface

This Vision of Water for Food and Rural Development is part of the Global Vision on Water, Life and the Environment in the 21st century. This vision document has been prepared in a consultative process in which numerous national and international institutes and organisations and hundreds of people all over the world have participated, providing inputs and comments on drafts. The World Bank has coordinated the process. Financial support has been primarily given by the Netherlands Directorate General for Development Cooperation (DGIS)

The process started with the preparation of national vision documents by national experts and stakeholders, in many cases through the National Committees of the International Commission on Irrigation and Drainage (ICID) under the co-ordination of the Central Office of ICID. These national papers were synthesised through regional consultations organised by international organisations:

- West Africa region in Accra, Ghana by the Food and Agriculture Organisation of the United Nations (FAO)
- East and South Africa in Harare, Zimbabwe by the International Program for Technology Research in Irrigation and Drainage (IPTRID) and FAO
- Middle East and North Africa in Bari, Italy by a consortium of CEMAGREF, HR Wallingford and IPTRID
- Europe in Bratislava, Slovakia by the European Regional Working Group of ICID through the German Association for Water Resources and Land Improvement (DVWK)
- Central Asia in Tashkent, Uzbekistan by the International Institute of Land Reclamation and Improvement (ILRI)
- South Asia in New Delhi, India by Wageningen University
- East Asia in Kuala Lumpur, Malaysia by the Central Office of ICID
- The Americas in Montreal, Canada by the Brace Centre for Water Resources Management

Based on these regional consultations a first draft synthesis was prepared and presented to the World Commission on Water for the 21st Century during its meeting in Stockholm in August 1999. It was widely distributed for comments among the various participating organisations. The first draft was also presented and discussed at the ICID Congress in Granada, Spain in September, 1999. All comments received were considered in preparing the second draft of the document. This second draft was widely circulated among international agencies, national ICID Committees education and research institutes and NGO's. Their comments have been synthesised and incorporated in this final document.

Linkage with other water related issues was realised by including the developers of the *Water for People* and *Water and Nature* visions in the drafting committee for this vision.

The development of this vision document on water for food started with the use of available data and projections on food demand based on the IFPRI Vision 2020[1] and on water demand based on IWMI's research report on World Water Demand and Supply, 1990 to 2025[2]. The FAO Aquastat database and water availability figures from the World Resources Institute supplied important portions of the data used. In the course of the further development and completion of this document scenarios were developed by the Central Vision Unit using different sets of assumptions to suit the purpose of the World Water Vision. These different scenarios were simulated using IWMI's PODIUM model to match water availability and demand at country or regional level and IFPRI's IMPACT model to model food supply and demand projections. For comparison the outcomes of these simulations have been included as an Annex.

Acknowledgements

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Special acknowledgement is given to the contribution of David Molden and Sakthivadivel of IWMI for the "more crop per drop" section in Chapter 4, Linden Vincent of Wageningen University and Johm Soussan of Leeds University for Chapter 5 on Rural Development, and David Groenfeldt of The World Bank for Chapter 7 the Institutional Dimensions. Further we would like to thank all those that have taken time and effort to comment on the document and to Peter Hollanders of IHE Delft for collecting, processing and synthesising these comments.

Delft, February 2000

Paul van Hofwegen

Mark Svendsen

Executive Summary

This Vision of Water for Food and Rural Development is part of the Global Vision on Water, Life and the Environment in the 21st century. This vision document has been prepared in a consultative process in which numerous national and international institutes and organisations and hundreds of people all over the world have participated, providing inputs and comments on drafts. The process started with the preparation of national vision documents by national experts and stakeholders. These national papers were synthesised through eight regional consultations in West Africa, East and South Africa, Middle East and North Africa, Europe, Central Asia, South Asia, East Asia, and The Americas. Based on these regional consultations a draft Vision was prepared and widely distributed for comments among the various participating organisations. Linkage with other water related issues was realised by including the developers of the *Water for People* and *Water and Nature* visions in the drafting committee for this Vision. Our shared vision of water for food and rural development for 2025 is the following.

A Vision of Water for Food and Rural Development

At the heart of our vision of water for food and rural development is a world of healthy people with adequate nutrition and secure livelihoods. This endeavour encompasses both cultivators, and those who work in the agricultural and other economic sectors and purchase their food. Surrounding the people are other features of our vision:

- *vibrant rural communities comprising both young and old, living in security, with educational opportunities, social services, employment opportunities in and out of agriculture providing reliable access to food, good transportation and communication links with market and administrative centers and regional and world economies*
- *a healthy natural environment, with clean water in streams, lakes, rivers, and aquifers, and stable and diverse natural ecosystems*
- *opportunity for farmers and other rural residents to participate in the global rise in standards of living*
- *agriculture in rainfed, drained and irrigated areas, operating on a sustainable basis with an equitable access to resources in a fair price environment, using water efficiently*
- *women, men, and communities in reasonable control over their livelihoods and their resource base, supported by responsive public agencies*

Broad guiding principles

Three guiding principles give shape to our vision. The first of these is that all people have fundamental rights to sufficient water for drinking and sanitary purposes and to food. This is not to say that people should not have to pay for or work for water and food, but that society would have to be organised in such a way that these are accessible to all. Society must focus particularly on assuring this access for its weakest members – children and the poor. The second principle is that each generation has the moral obligation to preserve the global heritage for its successors. Inter-generational equity requires that today's food production should not reduce the capacity for future generations to produce food, by for example over exploiting and degrading water and land resources. The third principle is that people should have a voice in making decisions that affect them, including those related to water allocation and management. That voice must be shared by women and men. This means not only the devolution of decision making authority to the lowest appropriate level, but also ready access to information related to the decisions.

Driving forces of change

A number of powerful and pervasive forces will drive and direct change in all economic sectors over the coming decades. These forces are global in nature, though the extent of their impact will vary from region to region. These fundamental trends must taken into account in framing our vision and in making our choices.

The United Nations medium growth projections indicate that global population will expand from the present 6 billion to nearly 8 billion in 2025. More than 80% of these people will live in developing countries. This implies that with nearly the same water and land resource base, we must grow enough food for 2 billion more people and create jobs for those not engaged directly in agriculture, while supplying expanding domestic and industrial water use needs.

In 2025 about 84% of the population in industrialised countries and 56% of developing country residents will live in urban areas. Urbanisation will encourage dietary shifts to preferred cereals (rice and wheat) and higher meat consumption. Agricultural productivity (output per unit of labour) will tend to rise, along with yield per unit of land and per unit water, agricultural wages will go up, and farmers will rely more heavily on purchased inputs, better water management, and more mechanisation.

The world will experience continued rapid developments in the fields of information, communications, remote sensing, and biotechnology. Biotechnology will likely furnish seeds with higher yield potential, better resistance to drought, tolerance of saline water, and better pest and disease resistance. Market, weather, and other information will become more widely available, enhancing producers' ability to make sound management decisions. Irrigation and drainage agency management capabilities will also improve as a result of these technologies, allowing better service provision at lower cost.

Predictions of the Vision expert panel on Energy say that real costs of energy are likely to drop over the medium-term. This development will make a variety of practices, such as pressurised water application, pumping of ground and surface water, and reclamation of brackish and polluted water more attractive. On the other hand, it may encourage mining of groundwater reserves.

The drive toward market-based economies will lead to continuing reductions in subsidies in some countries and reduced implicit taxation of agriculture in others, providing new opportunities for low-cost producers. Farmers will change crop mixes more readily in response to shifting prices and costs and adopt new technologies, especially for producing higher-value crops. Farm sizes will stabilise or expand as rural non-farm employment opportunities expand. Trading in water and water rights will expand significantly and global trade in agricultural commodities will continue to grow. Regional trading blocks will strengthen, facilitating intra-regional trade. However, in areas of smallholder agriculture with uncompetitive farming systems, smallholders may fall back to subsistence agriculture or flee to urban areas.

Recognition of the power and worth of stakeholder participation will sustain movement in this direction at all levels, from the national to the community. In addition to its strong ethical basis, stakeholder participation can have practical importance in correcting failures and excesses in systems. Often this trend has accompanied trade liberalisation and a shift to market-based economic systems, but not always. When fully manifested, with mechanisms of accountability and transparency in place, this stakeholder particpation has the power to improve the functioning of resource allocation and management systems, and reduce costs of building, operating and maintaining water-related infrastructure.

Growing awareness of the importance of ecosystems to planetary health will generate pressure to improve the quality of return flows to rivers from all uses – municipal, industrial, and agricultural. It will also lead to demands for larger in-stream flows in many rivers to support ecosystems. Many changes will be accomplished through regulation and enforcement. Parallel commodity markets will emerge, with different price structures for genetically altered, traditional, and organically produced agricultural products.

The gradual warming of the earth, 1.0 °C in the past 50 years, is leading to glacial recession, declining snow cover, and rising sea levels. Some scientists claim that precipitation patterns will alter, reducing water availability in some regions and increasing it in others. Increased variability in precipitation patterns will accompany this shift with a huge impact on both irrigated and non-irrigated agriculture. Precipitation patterns will include a greater proportion of extreme events, leading to higher and more frequent flooding and lower dry season flows in rivers. More intense rainfall will lead to increased erosion and higher sedimentation rates in reservoirs and canals. The value of past investments in water control facilities will be reduced where reservoirs no longer fill and irrigation canals do not run full.

Food Demand to 2025

The human food supply comprises three principal sources – agricultural crops, livestock, and fisheries. In terms of total tonnage, crop agriculture accounts for more than three-quarters of food consumed (77.5%), with livestock (15.9%) and fishery products (6.6%) making up the balance. At its most basic level, the need for food depends on the number of people on the planet. Global population is expected to expand over the next 25 years, at a rate of 1.5% during 2005 - 2010 but steadily decreasing thereafter. As a result, demand for food will increase over this period, but at a slowing rate. The composition of the demand will also change. As incomes rise and urbanisation continues its rapid advance, preferences shift, first from maize and coarse grains to rice, and then from rice to wheat. There is an accompanying shift in growth from cereals to meat and fish as income levels rise further. Increased demand for meat leads in turn to strong demand by producers for maize and other coarse grains as animal feed. Demand for food grows at 1.3% per year in response to population growth and rising incomes. Demand for animal products rises at a much more rapid rate. Composition of the cereal demand will shift to maize and wheat from the previous emphasis on wheat and rice. Cereal prices remain roughly stable in constant value terms. Other crops remain locally important.

During the coming quarter-century, rates of cereal yield increase are expected to decline further, averaging 1.0% for all cereals worldwide. Yield growth will provide almost all of the production increases, with global cereal area expanding at a rate of just 0.25% annually. More than half of the growth in area will be in Sub-Saharan Africa, where crop yields are very low.

Water for Food

Growing more food requires more water. This fact is simple and inescapable, whether production is rainfed or irrigated. Water supplies used in agriculture will have to be augmented by an additional 15 to 20% over the next 25 years, even under favourable assumptions regarding improvements in irrigation efficiency and agronomic potential to meet food requirements. This amounts to an additional 0.6% to 0.7% of water supply per year. Some of this additional water can come from water harvesting on rainfed land in arid and semi-arid regions, especially in Northern Africa and Western Asia, and development of small-scale water sources such as dambos or shallow aquifers in Central and Southern Africa. These are preferred solutions for they operate in areas where poverty is extensive, water extremely scarce, and population growth rates high. There is also scope here for introducing simple yield-increasing, water-saving technologies such as manually operated pumps and bucket-drip systems. Better agronomic practices, such as mulching, can also save water, which can be used to improve productivity of rainfed areas and expand irrigated or partially-irrigated area.

There are limits though to how much additional water such practices can make available. The largest share of an increased water supply for agriculture must come from new practices and investments, which operate on a larger scale. These include improved water management practices both on farms and in delivery systems, comprising new technology, reforms in management institutions, and more rational pricing policies. Reducing waste loads in return flows from both agricultural, municipal and industrial users, can also make a contribution to improving the available supply of water for all uses, including agriculture.

Development of new storage capacity will also be required, both to replace capacity lost to sedimentation and to save water lost during flood flows for use during times of scarcity. New storage can either be surface storage in small or large reservoirs or groundwater storage and will generally serve a variety of users. The challenge is to find ways to increase groundwater storage to make new water available during dry seasons, but also to reverse the draw-downs, which are taking place currently. New techniques and institutional mechanisms to enhance recharge of groundwater aquifers are urgently needed.

New surface reservoirs are a subject of much debate and controversy as their collateral impacts on local society and the environment may be considerable. Some of these impacts are inundation of land, resettlement of people, and disturbance of the river ecosystems and fish migration routes. In addition, surface reservoirs are subject to sedimentation and water losses through evaporation. However, reservoirs may perform functions that are difficult to replace by other means.

Rural development and food security

The foundation of rural livelihoods is food security, which at national and household level can be achieved by a combination of local production, secured imports, and effective food distribution systems. Self-sufficiency, on the other hand, is achieved only if all food needs are met through domestic supplies. Several factors are limiting the option of a number of countries to be food self-sufficient. Many of these stem from rapidly growing populations, which reduce per capita water and land availability and increase municipal demands on already scarce water resources. Inefficient farming systems and higher returns to labour in industries also cause shifts from self-sufficiency to partial reliance on food imports.

The IMPACT model predicts that cereal imports from developed to developing countries will increase by 140% between 1993 and 2020. However some countries which are not self-sufficient will not have sufficient exports to generate the foreign exchange required to purchase the required food. And individuals may not have the cash to purchase food for themselves and their families, even though it is available in the market. Currently, more than 1.3 billion people are absolutely poor, with incomes of a dollar a day or less per person, while another 2 billion people are only marginally better off.

Thus, it will be very difficult to find a substitute for agriculture-based rural development programs in a number of countries, many of which lie in Sub-Saharan Africa, West Asia and North Africa. These programs must focus on increasing agricultural productivity (labour and water), under both rainfed and irrigated regimes where other medium-term options are not really available. The central role of female farmers in much of this agriculture must be better recognised and rights (to water for example) and representation redefined to encompass them. Domestic development priorities, international assistance programs, and international trade agreements will have to acknowledge the centrality of agriculture-based development in these circumstances and support it in their policies and strategies.

Our vision is not only to ensure food security, but also to ensure security of livelihoods through new and more responsive approaches to developing water resources. Water projects can bring many positive changes to the lives of poor people by reducing poverty, improving health and well-being, and by empowering individuals and groups to act to improve their lives. Rural development requires that rural residents be empowered to manage and direct their own growth and development. This requires decision-making authority and at least a share of control over development resources to the local level. The pulling back by many state agencies from day-to-day water management will bring new roles for civil society. User associations are formed to run irrigation systems, and new multi-stakeholder catchment committees influence water management practices and water allocations. These new civil water associations can protect the interests of poor producers and engage them in other collective actions to improve their livelihoods.

A strategy to realise the Vision

The proposed strategy to realise the Vision focuses on improving food security and rural livelihoods by increasing the productivity of water (more crop and value per drop) and improving the access to food and water while reducing negative impacts of food production on the environment. These efforts are to be accompanied by supportive international trade arrangements, the development of adequate institutions and the necessary infrastructure.

To realise the Vision, choices will have to be made by many primary organisations and groups. A shared understanding of the problems and their consequences, solutions, and the interconnections and tradeoffs among them are crucial if actions are to focus on common objectives. The starting point must be the creation of a common awareness and understanding among current and future decision-makers around the world. This must be done in schools, in the media, and in workshops, meetings, and conferences. Then those that are affected must make the choices and appropriate actions must be taken in the areas of economic policy and trade, investment, infrastructure, institutional reform, research, and capacity building.

Institutions and capacity building

In all the regional consultations a reform and strengthening of the water managing institutions was called for to improve water management and to develop accurate and reliable water availability and water use data for future planning and management. These institutions should be embedded in a system of integrated water management with empowered multi-stakeholder basin organisations managing surface and groundwater. This is to be underpinned by systems of water rights that recognise existing registered users, safeguards existing unregistered uses, enhances the water access of poor and disadvantaged groups, and allows a minimum flow for basic needs and development of irrigation.

Reform of irrigation and drainage management institutions and other institutions involved in water management is to be directed towards people and service orientated, user-controlled and self-financing organisations with transparent decision making procedures and effective accountability mechanisms in place.

Sufficient qualified and skilled people are needed to develop and manage these organisations and institutions. Moreover, the envisaged people and service orientation may require changes in attitudes and skills of staff and management processes. Motivated staff with sufficient knowledge and skills has to be developed through education, training and human resources management. This involves further development of local capacity for education and training on water and food production for professionals and researchers, facilitating the exchange of knowledge between local users, technicians and professional water managers and establishment or strengthening of linkages between education institutions and water research organisations.

Attractive career development programs are needed for water-related professionals to ensure and retain sufficient capacity and capability for planning, regulation and policing related to water resources use and management. Preference is to be given to women professionals to improve their participation in water management, particularly at higher levels of governance and management

Investments in infrastructure and investments policies

Investment policies should be directed towards improvement of the productivity of water and sustainability of water resources based on participation of all stakeholders, including the women and the poor. The investment programs should respond to the key principles of subsidiarity, participation, accountability and transparency and foster the development of accountable, transparent and representative institutions within an integrated water resource development and management context.

Investments are needed to meet the demand for food, to improve the productivity and development of water and to improve the livelihood of rural people. These include the development of water resources to enable community based irrigated agriculture, particularly in Sub-Saharan Africa, modernisation of irrigation and drainage systems in existing schemes and replacement and augmentation of water storage capacity in reservoirs and groundwater basins particularly in water scarce countries. Moderate investment in new surface storage is necessary to replace storage lost to siltation (1%) and add new capacity (0.5%), giving a net increase in storage for food production over 25 years of 13%. Groundwater recharge programs are to be initiated to help stem decline in groundwater tables. Environmental regulation and parallel investments in municipal and industrial waste treatment are needed to improve the quality of river water, reducing dilution requirements and increasing available supply. Some of this additional supply is allocated to environment, some to municipal withdrawals (most of which will become return flow to rivers), and the remainder to irrigated agriculture. The result will be an average annual increase in irrigated area of around 0.7%.

Moreover, investments are needed in drainage and reclamation of degraded irrigated land, restoration of eroded lands and provision of flood protection and drainage of frequently inundated areas to improve rural livelihoods and secure or improve food production.

Investments in rural infrastructure and decentralised industrial development policies are needed to create improved rural living conditions and rural jobs. In high-yield agricultural areas, much of this development will be in agro-processing industries. This takes employment pressure off agriculture and allows some increases in labour productivity and expanded operational holding size. In low-yield agricultural areas, productivity increases and off-farm income to farm families helps pay for cereal imports.

The role of the private sector needs to be expanded and transformed if our vision is to be achieved. This includes the stimulation of public-private partnerships to finance rural infrastructure, investments in labour-intensive industry in rural areas and the provision of agricultural support services. Reforms in water and power pricing and irrigation management will lead to financially stable operation and maintenance and together with public capital cost-sharing, induce private sector interest in development and management of existing or new irrigation and drainage.

International water management

Many countries share international rivers and river basins. In all the regional consultations the desire of better international cooperation to improve the management of such basins was expressed. This involves negotiation of water-sharing agreements on international rivers and establishment of river basin organisations to share information and to coordinate sustainable development and management of the rivers and their watersheds.

Trade

Global trade is a key element of the Vision. To achieve adequate nutritional levels, food must be accessible and affordable. Therefore, trade arrangements should be developed that encourage water scarce regions to produce and export high-value crops and import water intensive staple crops. Trade regimes are also critical to building a food secure world, and must make special provisions for those countries not yet able to compete in world markets for their food supply. The economic implications are to be evaluated of long-term imports of "virtual water", i.e. trade in food grains, in food deficit countries and regions. International trade regimes are to be further developed, which promote socially equitable production and distribution of food, and support agriculture-based rural development initiatives in low-income resource-poor countries. Some farmers in water-short regions will then be able to shift to higher value crops, enhancing value of output per unit water, and allowing purchase of imported cereals. Much area under higher value crops will shift to micro-irrigation, boosting yields and saving water.

Research

An increase in the overall research support is required for the development of new or situation adapted technologies focussing on the improvement of water productivity in irrigated and rainfed areas that maximise both water productivity and poverty alleviation impacts. This should be accompanied by research on further development of institutions which are important for management, operation and maintenance. Biotechnology research is required to maintain or increase crop yield levels. Private sector genetic research supports growth in tradable cereal and horticultural crop yields. Public funding is required on locally important crops not likely to attract private sector interest such as coarse grains and tubers and improvement of drought resistance and salinity tolerance of major cereals. This would have to include the research on impact of development and use of genetically modified crops.

The improvement of water quality of agricultural return flows requires the development of affordable and effective technologies including lower-impact pesticides and herbicides (including biological agents) and feed for livestock. Strategies have to be developed to attain worldwide phase-outs of more persistent agricultural chemicals.

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1 Introduction

From a distance, the earth is the water planet. Three-quarters covered with water, it looks, as one Apollo astronaut put it, like a "blue marble" against the black velvet backdrop of space. From that lunar distance, the earth appears today much as it did one hundred, or one thousand years ago, the brown, green, and white continents outlined against the seas.

Draw closer though, and, if one could travel in time, a number of changes would be visible between the turning of the last century and the new one. Most obvious would probably be the loss of forest cover over large portions of Asia and South America, balanced to a modest extent by the return of forests to eastern North America. In South America and in Asia much of the conversion has been to cropland. A sizeable share of Asian cropland today is green nearly year round, where previously it was brown between the monsoons. In the dryer zones in western North America, and across the Arabian Peninsula, the brown landscape is dotted with large green circles where centre pivot irrigation machines water lush crops in the desert. In Africa, the Sahara desert has crept visibly to the south. Not seen but present nonetheless is the lost diversity of plant and animal species in many of these areas.

Other human artefacts are also visible in 2000, which were not present in such profusion a century earlier. Linear features stretching across the landscape mark the tremendous growth in infrastructure which now supports societies – railroads, highways, power and communication lines, and canals. New lakes are visible where rivers have been dammed, while other natural lakes and inland seas have shrunk. Invisible are a profusion of newer communication technologies based on radio waves, satellites, and fibre-optic cables.

Sprawling urban concentrations dot all of the continents, except Antarctica, where earlier there was but a handful. At night, seen from space, cities and entire continents, particularly North America and Europe, literally glow. Not visible is the slight but continuing increase in global temperature resulting from the release of sequestered carbon. However polar icecaps and Himalyan glaciers are visably smaller, portraying an ominous uncertainty for future generations.

Stepping down on the surface, a tremendous diversity among people and their habitats is evident, along with huge discrepancies in their standards of living. In some places, women and children travel long distances to fetch water, while others simply open a tap. Some people spend nearly all of their waking hours growing food for their families. Others work in large buildings and need to spend only a few minutes of each workday to earn enough to buy their groceries. Well-watered fields producing 8 or 9 tons of grain per hectare contrast with dry and barren fields that produce only a few hundred kilograms per hectare.

Many of the human alterations of the planet's face have connections with its fresh water supply. Deforestation has altered the hydrologic cycle, reducing water storage in forest soils and evapotranspiration while increasing rainfall, runoff and flooding. Dams reduce flooding and even out river flows over time while increasing evaporation into the atmosphere and changing local ecological systems and patterns of human settlement. Expanded agriculture, especially irrigated dry season agriculture, increases evapotranspiration and shortens soil-drying cycles. Dams and canals also redistribute water geographically, sometimes shifting it hundreds of kilometers from its original course. Drainage networks reduce water logging and soil surface evaporation while increasing the discharges to downstream water bodies increasing the risk of flooding. Major urban centers draw large quantities of water from rivers and underground aquifers, purify it, transport it to millions of points of use, and recollect it in vastly degraded form for treatment and disposal. Industries and power plants also draw large quantities of water, most of which is returned to rivers and streams, though often at lower quality.

Water now flows in new places and patterns, and is often of poorer quality, affecting myriad natural ecosystems – a subject of great and growing concern. Moreover, water supplies in rivers and aquifers are, in many cases, not adequate to support expansion of irrigated agriculture, growth of urban areas, establishment of new industries, and the maintenance of ecosystems critical to our planet's health. Despite the abundance of earthly water, less than 1% of the total is available as renewable fresh water. We are faced with critical choices among these competing demands for water, and how wisely we choose will affect the welfare of billions, both now and in the future.

In Chapter 2 we begin our consideration of the future by imagining the world of 2025 as it could be. This vision, distilled from many regional consultations and discussions, is then used to guide our more analytic exploration of the actions, which are needed to move toward our envisaged world. Twenty-five years is almost certainly too short a time for such a vision to be fully realised. It does point the direction we wish to take, however, and allows us to gage our progress en route.

In Chapter 3 we look at the demands in 2025 for food and the water necessary to achieve adequate nutritional levels around the globe. These demand projections are based on recent work done by FAO, IFPRI and IWMI and much of their texts are incorporated in this chapter.

In Chapter 4 the possibilities to meet these demands are explored. These possibilities comprise the increase in yields in rainfed and irrigated agriculture, improvement of water productivity to make more water available for other uses or expansion of cropped areas, additional development of water resources and improvement of food security through imports.

Each of these possibilities has its positive or negative impact on individual farmers and rural communities. They are the food producers, they are basically the guardians of our land and water resources and they also deserve a proper livelihood. Therefore, rural development can not be separated from food production. Especially the poor and the vulnerable groups in many rural areas might be seriously affected by the possible interventions to improve global food security. These aspects are dealt with in Chapter 5.

Improved productivity of water - more crop and more value per drop – can only be achieved if the water users, water managing agencies and their governments are capable of developing and implementing the necessary policies and strategies. In many countries important reforms are underway and still much reform is to be implemented. The role of the institutions and the necessary conditions for effective, and accountable management are discussed in Chapter 6.

The interventions to achieve the vision will differ from region to region and country to country. Spatial variability of rainfall and runoff patterns makes it difficult to get acceptable generalisations for a world-wide vision. Also, differences in economic development, culture and traditions make region based strategies necessary. Therefore in Chapter 7 of this vision document special attention has been given to the regional variations in global perspective but more in regional context.

This document concludes in Chapter 8 with proposals for actions at international and national level to achieve the Vision.

2 The Vision

2.1 Vision Statement

A vision gives us something to aspire to. It helps us crystallise what it is we want the future to be. Our shared vision of water for food and rural development as presented below, is not an impossible dream. It is feasible, but it does not become reality by itself. In fact, a vision often runs counter to worrisome trends and tendencies in our current experience. Achieving a vision therefore requires concerted and sustained efforts aimed at guiding events in the directions we choose.

A Vision of Water for Food and Rural Development

At the heart of our vision of water for food and rural development is a world of healthy people with adequate nutrition and secure livelihoods. This endeavour encompasses both cultivators, and those who work in the agricultural and other economic sectors and purchase their food. Surrounding the people are other features of our vision.

- *vibrant rural communities comprising both young and old, living in security, with educational opportunities, social services, employment opportunities in and out of agriculture providing reliable access to food, good transportation and communication links with market and administrative centers and regional and world economies*
- *a healthy natural environment, with clean water in streams, lakes, rivers, and aquifers, and stable and diverse natural ecosystems*
- *opportunity for farmers and other rural residents to participate in the global rise in standards of living*
- *agriculture in rainfed, drained and irrigated areas, operating on a sustainable basis with an equitable access to resources in a fair price environment, using water efficiently*
- *women, men, and communities in reasonable control over their livelihoods and their resource base, supported by responsive public agencies*

2.2 Broad Guiding Principles

Three guiding principles give shape to our vision. *The first principle* is that all people have fundamental rights to sufficient water for drinking and sanitary purposes and to food. This is not to say that people should not have to pay for, or work for water and food, but that society would have to be organised in such a way that these are accessible to all. The crucial role of water in meeting these basic needs, and the needs of the environment and other economic activities, means that society must ultimately create the rules that govern access to and use of water. Since it is clearly impractical for everyone to produce their own food, the challenge today is to devise mechanisms that provide either direct access to land and water, or effective access to these through the economic system. Society must focus particularly on assuring this access for its weakest members – the poor.

The second principle is that each generation has the moral obligation to preserve the global heritage for its successors. Inter-generation equity requires that today's food production should not reduce the capacity for future generations to produce food, by for example over exploiting and degrading water and land resources.

The third principle is that people, men and women, should have a voice in making decisions that affect them, including those related to water allocation and management. This means not only devolution of decision making authority to the lowest appropriate level, but also ready access to information related to the decisions. It also means giving a voice to the hitherto excluded. This requires decision making and management processes that are transparent, where managers are accountable for their decisions to those affected.

2.3 Driving Forces of Change

A number of powerful and pervasive forces will drive and direct change in all economic sectors over the coming decades. These forces are global in nature, though the extent of their impact will vary from region to region. If the vision shows us where we want to go, and the basic principles help to guide our way, these driving forces are the powerful currents that will push us on the journey. A realistic vision of the future must take them into account.

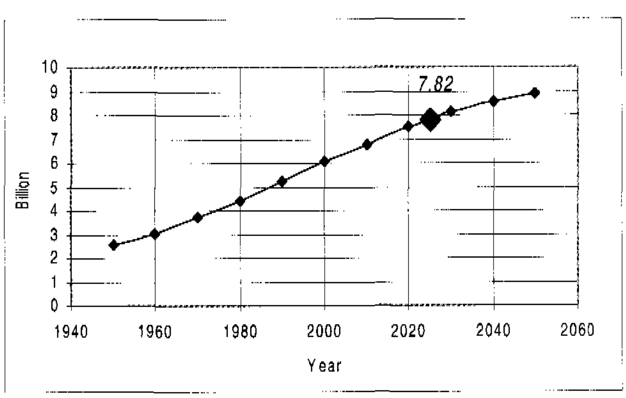

Figure 1 Global medium projection population growth 1950 – 2050[2]

Population growth

The United Nations medium growth projections[3] indicate that global population will expand from the present 6 billion to nearly 8 billion in 2025 (Figure 1). World population grew at an annual rate of 1.60 % over the last 25 years and is expected to grow at a 1.03 % rate over the next 25 years.

The reduction in growth rate is almost entirely due to the decline in population growth rates in the developing countries. The decline since 1975 is remarkable for these countries as a group – from 2.08 % a year from 1975 to 1990 to 1.70% from 1990 to 2000. The rate is projected to decline further between 2000 to 2010 to 1.40% and to 1,14% in the 2010 to 2015 period.

By 2025 more than 80 % of the people are expected to live in developing countries (Figure 2)[4]. This has powerful implications for food requirements, labour supply, and per capita land and fresh water resource availability. With nearly the same water and land resource base, we must grow enough food for 2 billion more people by 2025 and create jobs for those people not directly engaged in agriculture, while supplying expanding domestic and industrial water demands.

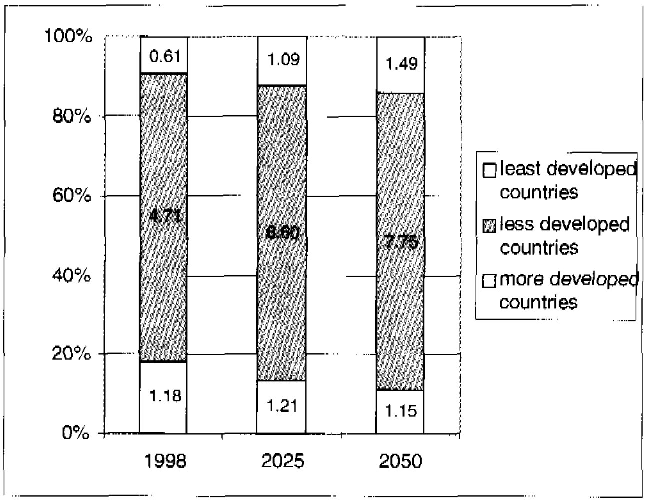

Figure 2 Global population distribution between least, less and more developed countries[4]

Urbanisation

In 2025 about 84% of the population in industrial countries and 56% of developing country residents is expected to live in urban areas (Figure 3)[5]. This represents a dramatic shift in population from rural to urban areas. In absolute terms, urban areas will acquire about 1.7 billion new residents, which is nearly equal to the total growth in world population over this period. Much of this growth will be the result of internal migration, as rural residents, especially younger residents and males, leave more traditional rural life for higher wages and the bright lights of the city. Where this occurs, agricultural will be left increasingly to older people and women.

Since average urban incomes are typically higher than rural ones, urbanisation will encourage dietary shifts to preferred cereals (rice and wheat) and higher meat consumption. An almost static rural population means that agricultural productivity (output per unit of labor) will necessarily rise, along with yield per unit land and per unit water. Increased productivity will be accompanied by rising agricultural wages, increased reliance on purchased inputs, better water management, greater mechanisation, and larger or more specialised farms.

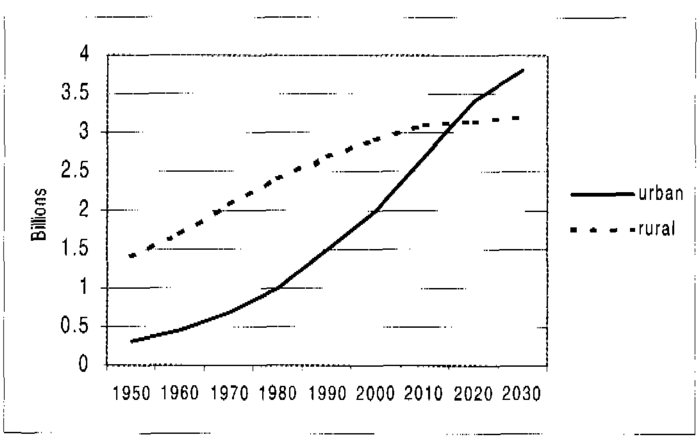

Figure 3. Urban and rural population levels in developing countries [5]

At the same time, major urban areas will harbour pockets of extremely poor people who will lack social and kinship ties with nearby cultivators (Box 1)[6]. Demands on the renewable water resources by municipal and industrial uses will expand and pollution by domestic and industrial waste will increase, putting additional stress on the water resource base.

Box 1. Population Growth and Urbanisation in West Africa

Urban population corresponds to 40% of the total population of West Africa today. It was only 13% in 1960 and is expected to be 65% in 2025. This will result in a number of important consequences for food production and food security:

- as the percentage of food producers will decrease in relation to the total population, farmers will have to be more productive to feed the urban population
- more than 50% of the population will be concentrated in a triangle Abidjan-Abuja-Port Harcourt and more than 80% will live in a 500 km wide area along the coast
- the connection between rural areas and urban markets will become stronger because of multiplication of urban centres

Energy prices

Opposite to present price trends and policies in many energy using countries, a panel of experts commissioned by the World Water Council predicts that real costs of energy are likely to drop over the medium-term future[7]. If so, this development will make a variety of practices, such as pressurised water application, pumping of ground and surface water, and reclamation of brackish and polluted water more attractive. In addition it will make a whole range of capital and infrastructure goods less expensive than they would otherwise have been, as the cost of their energy content declines. Effects on water and agriculture will be mixed. On the one hand, lower energy costs may facilitate the shift to water-saving pressurised irrigation. On the other, it may encourage continued mining of groundwater reserves. However, energy users will be expected to pay the full energy cost, which may lower the profitability of some water use.

Technology

The world will experience continued rapid development in the fields of information, communications, remote sensing, and biotechnology. Biotechnology will likely furnish seeds with higher yield potential, better resistance to drought, tolerance of saline water, and better pest and disease resistance. Information on markets, weather, etc. will become more widely available, enhancing producers' ability to make sound management decisions. Irrigation agency management capabilities are also expected to improve as a result of these technologies, allowing better service provision at lower cost.

Water and land management technology will improve and become more accessible and affordable, especially for smallholders due to cheaper production, open markets and lower energy prices enhancing the productivity of land and water and increasing food production.

Market economics and trade liberalisation

The drive toward market-based economies will lead to continuing reductions in subsidies in some countries and reduced implicit taxation of agriculture. There will be a growing trend of privatising state-run organisations delivering agricultural services such as electricity and water, and prices of these services are expected to increase. Farmers will adopt new technologies (especially for higher value crops) and more flexible cropping strategies to respond to changing markets as well as long-term weather forecasts. Farm sizes are likely to stabilise or expand as rural non-farm employment opportunities expand. Trading in water and water rights will expand significantly and global trade in agricultural commodities will continue to grow. Regional trading blocks will strengthen, facilitating intra-regional trade (Box 2)[8]. Common regional policies on water and environmental issues may act as catalysts for reforming national agricultural and water policies. However, in areas of smallholder agriculture with non-competitive farming systems, smallholders may fall back to subsistence agriculture or migrate to urban areas.

Box 2. Trade in Central Asia

The Central Asia Vision proposes to:

- develop an interstate agreement on agricultural production on the basis of the most suitable agro-climatological zones for the major food and fiber crops in Central Asia. This includes a trade agreement on agricultural products between the Central Asian governments
- establish a regional policy at government level on the joint management and efficient use of water resources

Democratisation

Recognition of the power and worth of democracy in forms of governance sustain movement in this direction at all levels, from the national to the community. In addition to its strong ethical basis, democracy can correct failures and excesses in systems, giving it a very practical importance too. Often this trend has accompanied trade liberalisation and a shift to market-based economic systems, but not always. When fully manifested, with mechanisms of accountability and transparency in place, this will result in more efficient resource allocation and management systems, and reduce costs of building and operating water-related infrastructure.

Environmental awareness

Growing awareness of the importance of natural ecosystems to planetary health will generate pressure to improve the quality of return flows to rivers from all uses – municipal, industrial, and agricultural. It will also lead to demands for larger in-stream flows in many rivers. The extent and health of wetlands will also be on the agenda. Many of these changes will be accomplished through regulation and enforcement, especially for agriculture related to use of agro-chemicals and use of genetically modified seeds. In some cases, however, especially in higher income countries, residents may buy environmental "goods" voluntarily, for example by purchasing water rights and allocating them for in-stream uses. Parallel markets are expected to emerge, with different price structures for genetically altered, traditional, and organically produced agricultural products.

Global warming

The gradual warming of the earth, 1.0 °C in the past 50 years, is leading to glacial recession, declining snow cover, and rising sea levels. Precipitation patterns are likely to alter, reducing water availability in some regions and increasing it in others. Increased variability in precipitation patterns will accompany this shift with a huge impact on both irrigated and non-irrigated agriculture. Precipitation patterns will include a greater proportion of extreme events, leading to higher and more frequent flooding and lower dry season flows in rivers. More intense rainfall will lead to increased erosion and higher sedimentation rates in reservoirs and canals. The production potential of past investments in water control facilities will be reduced where reservoirs can no longer be filled due to decreased precipitation.

2.4 Conceptual Framework

The conceptual framework shown in figure 4 summarises our approach and the points developed so far. A shared vision of the future captures our desires and provides a destination for our journey. Basic principles guide and bind our actions as we travel. At the same time, driving forces, which are worldwide in scope and impact and largely beyond our immediate control, will affect our course and influence the outcome of our choices and decisions along the way. It is important, indeed critical, that we make the right choices now, if we are to achieve food security in the year 2025. The challenges we face in the form of increased food demand, the nature of the choices confronting us, and a strategy for action, comprise the rest of this report.

Our aim is a world that is close to food-secure by the year 2025, and where environmental improvement and social progress are evident in both urban and rural areas. We need to act now in order to achieve our vision a quarter century from now. The suggested actions presented in Chapter 8 form a step in this direction, but these actions will need to be re-assessed and revised on a regular basis. It is our hope that his vision report can serve to stimulate policy debates and practical actions that result in real progress towards global food security and rural development.

Vision

A world of healthy people with access to adequate nutrition

Vibrant rural communities
Healthy environment
Opportunities to improve standard of living
Sustainable agriculture
Control over livelihoods and resources

Principles

Right of access
Sustainability
Democracy

Driving Forces

- Population growth
- Urbanization
- Technology
- Cost of energy
- Market economies and trade liberalization
- Democratisation
- Environmental awareness
- Global warming
-

Our Choices

Strategy for Action

Figure 4. Conceptual framework for the Vision of Water for Food and Rural Development

3 Food and Water Demands for 2025

Our vision imagines a world of healthy people with access to adequate nutrition. Achieving this depends both on producing sufficient food, and providing people with the means to obtain it. Water is an important contributor to both of these conditions.

3.1 Nutrition and Diets

The human food supply comprises three principal sources – agricultural crops, livestock, and fisheries. In terms of total tonnage, crop agriculture accounts for about three-quarters of food consumed (77.5%), with livestock (15.9%) and fishery products (6.6%) making up the balance. Livestock and fisheries products, of course, have nutritional importance beyond their caloric Value because they serve as sources of concentrated protein. All of these commodities, however, are based on energy fixed through photosynthesis, and growth in the livestock sector and, to a lesser degree, fisheries, have important implications for crop production, in addition to their direct nutritional impacts.

The single most important component of nutrition is calorie per capita consumption. The standard for developing countries is an average of around 2,200 kcal per person per day. With most diets (figure 5)[9], if people satisfy their calorie requirements, they will also satisfy their requirements for protein, minerals and vitamins. A major exception to this rule is when a very high percentage of total calories are from rice, which is low in protein. Other exceptions occur with low vegetable consumption, which may cause vitamin and mineral deficiencies. But, on the whole, the principle target is adequate calorie consumption.

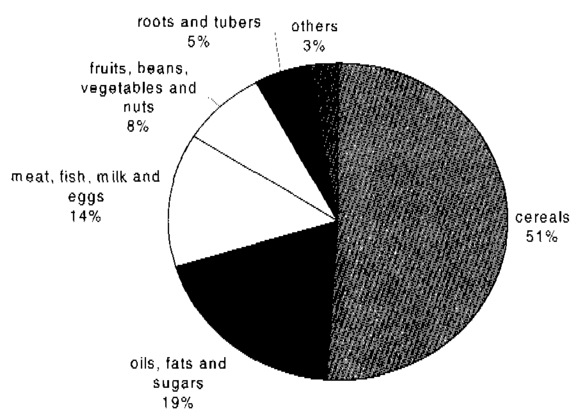

Figure 5 Average global diet 1988-1990

But even if the average calorie intake of a country is 2,200 kcal per capita per day, this is not enough to assure that everyone in the country is actually obtaining enough. People with relatively high incomes tend to over-consume calories, mainly from animal products. Therefore it is necessary to have substantially higher average calorie consumption in a country to achieve enough for poor people. How much higher this amount must be is largely a function of the distribution of income and diets in a country. As a rough estimate, something in the range of 2,700 to 3,200 kcal per day is considered to be adequate for most countries to satisfy basic food needs. In figure 6 it can be seen that Sub-Saharan Africa and South Asia in particular, are presently suffering from under-nutrition and though slightly less, will remain so in 2025 under continuation of present trends[10].

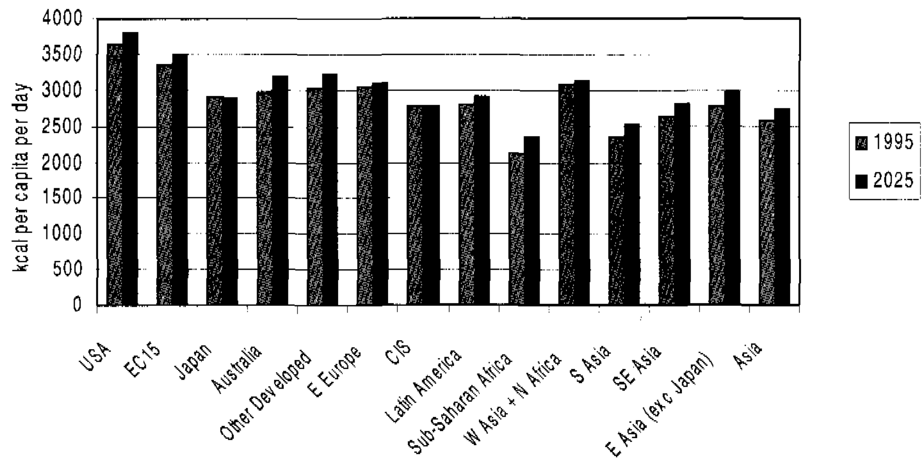

Figure 6 Nutrition levels in Kcal per capita per day in 1995 and 2025 - IFPRI base projections of October 1999.

3.2 Demand for food in 2025

At its most basic level, the need for food depends on the number of people on the planet. First, global population will continue to expand over the next 25 years, at an expected rate of 1.5% during 2005 - 2010, but steadily decreasing. Today's population of 6 billion will then have reached almost 8 billion by 2025, an increase of about 30%. As a result, the demand for food will increase over this period, but at a slowing rate. The composition of the demand will also change due to dietary shifts. On average, global demand for cereals will grow by 37% between 2000 and 2025, for a yearly rate of increase of 1.27%.

The nature of the demand for these food products will also change as incomes rise and urbanisation continues its rapid advance. The urban population, which comprised 43% of the world population in 1990, is expected to reach 61% of the population by 2025. As incomes rise, and time becomes more valuable, there is a shift first from maize and coarse grains to rice, and then from rice to wheat, as the preferred cereal. There is an accompanying shift in growth from cereals to meat and fish as income levels rise further. Increased demand for meat leads in turn to strong demand by producers for maize and other coarse grains as animal feed. In developed countries, where meat consumption is already high, there is presently a shift from beef to poultry, for price and health reasons, though growth in total meat consumption is relatively flat.

Over the period 1994 to 1997, actual growth in production was distributed 69% to wheat, 20% to rice, and just 11% to all coarse grains - including maize. Of the projected cereal demand growth, 35% will be in maize, 31% in wheat, 18% in rice, and 16% in other coarse grains. The projections thus represent a striking change in composition of demand and a stunning reversal in the roles of maize and other coarse grains on the one hand and wheat on the other.

Together, the still expanding population and changes in food preferences will result in continued strong demand for additional food production, though the types of cereals demanded for food and feed, and the mix of cereals and animal products in the diet, will shift significantly. These trends will also lead to an extraordinary increase in the importance of developing countries in global food markets.

Crop agriculture

Cereals

The early 1960s began a remarkable period of growth in cereal production in the developing world. This Green Revolution led many countries to food self-sufficiency and ended, at least in Asia and the Americas, recurrent famines and widespread starvation. Green Revolution Technology was a combination of new short-statured seed varieties, chemical fertilisers, and irrigation. The absence of any one element in the mix prevented achievement of breakthrough increases in yields and production.

Annual growth in cereal yields averaged a very impressive 2.9% in developing countries during the peak Green Revolution period, falling by 35% to 1.9% during the post revolution period (Table 1). Growth in area under cereals continued to expand at roughly the same rate during both periods in developing countries, while in the developed countries, it contracted significantly. Reasons underlying the slowdown in yield growth include the already high levels of inputs in many Asian countries, which approach economic optimum levels, increased input requirements caused by increased intensity of land use, and falling cereal prices which slowed growth in input use and reduced investments in crop research and irrigation infrastructure. Another reason is that in some regions, especially Sub-Saharan Africa, the green revolution still has to start. Lack of access to water, land and agricultural inputs has constrained the growth considerably.

Table 1. Annual growth in all cereal crop area, production and yield, by region, 1967 – 1994 (% per year)[11]

	Peak Green Revolution 1967 - 1982			Post Green Revolution 1982 - 1994		
	Area	Production	Yield	Area	Production	Yield
Developed countries	0.23	1.92	1.69	-1.27	0.01	1.30
Developing countries	0.48	3.36	2.87	0.46	2.34	1.87
World	0.37	2.61	2.24	-0.24	1.27	1.51

During the coming quarter-century, rates of yield increase are expected to decline further, averaging 1.0% for all cereals worldwide during the period (Table 2). As predicted by IFPRI through their IMPACT[12] model simulations, annual cereal yield growth rates will be somewhat higher in developing countries (1.2%) than in developed countries (0.9%), and in developing countries highest for maize (1.4%) and wheat (1.3%) while rice yields are expected to increase at a slower pace (1.1%). Yield growth will provide almost all of the production increases, with global cereal area expanding at a rate of just 0.25% annually while irrigated area grows by 0.6% annually between 1995 and 2020. More than half of the growth in area will be in Sub-Saharan Africa, where crop yields are very low.

Table 2. Projected annual growth in cereal yield, by region, 1993 - 2020 (% per year)[10]

	Wheat	Maize	Rice	Other grains	All cereals
Developed Countries	0.91	0.85	0.71	0.69	0.86
Developing Countries	1.33	1.40	1.11	1.14	1.21
World	1.10	1.05	1.08	0.73	1.03

Per capita consumption of cereals will be virtually constant on a global basis, with declining per capita consumption at higher income levels balancing increasing demands of lower-income countries. Wheat consumption will increase slightly, driven by a 6% increase in annual per capita consumption over the period in developing countries, while per capita consumption of rice and maize will fall.

Despite the absence of overall growth in per capita demand for cereals, population growth and strong demand for feed grain will drive an increased global demand for grain. Between 2000 and 2025, total cereal demand is expected to increase 37%, from 1,937 million tons to 2,655 million tons, an annual rate of increase of 1.27%.

Roots and tubers[13]

Many of the developing world's poorest farmers and food-insecure households are highly dependent on roots and tubers as a significant if not principle source of food and income. In many parts of Sub-Saharan Africa, roots and tubers account for about 20% of calorie consumption. In Asia and Latin America, they provide an important supplemental source of carbohydrates, vitamins, and amino acids in food systems that are dominated by other commodities. The production and processing of roots and tubers, which tend to be very labour intensive, are also important sources of employment and income.

While much of the focus in developing country food production in recent years has been on cereals, similarly large rates of increase in production occurred for potatoes and yams although growth was much lower for cassava and sweet potatoes. By 1995, about 630 million ton of roots and tubers were produced on 49 million hectares worldwide with 70% of the production taking place in developing countries.

IMPACT projections suggest that global demand for roots and tubers will increase by 37% between 1995 and 2020 to reach 864 million tons, with more than 97% of the increase occurring in the developing world. Sub-Saharan Africa alone will account for more than 40% of the increase in demand.

A rapid expansion in the demand for roots and tubers for livestock feed has been under way for some time, particularly in Asia, and is likely to continue as demand for meat products grows rapidly in coming years.

Average yields for roots and tubers in developing countries are well below those in developed countries, 11.6 tons per hectare versus 16.7 tons in 1995, and are far below technically feasible levels. The potential is great for increasing production through improved varieties and other farming innovations as well as improved policies. Better yields for these crops would bring significant benefits to the food systems in developing countries, particularly to poor producers and consumers.

3.3 Livestock

Livestock production has grown at a average annual rate of 2.92% over the period 1961 to 1994, which is considerably more rapid than growth in cereal production over the same period. Moreover, while in the developed countries the rate of annual growth in demand for meat[14] is low and slackening (0.71%), it is rapid and accelerating in developing countries (4.69%). Thus though per capita meat consumption is more than four times higher in developed countries, the gap is closing as demand in developing countries expands.

Typical conversion ratios, the amount of feed grain required to produce an equivalent weight of meat, are shown in box 3. The actual average ratio for meat production in developing countries for the period 1981 - 1994 was 2.3, while in developed countries it was 4.9. This difference is largely due to the more extensive use of grazing, hand-gathered natural fodder, and plant wastes as livestock feed in developing countries. In the future, however, it is likely that relatively more feed grain will be used in developing countries, raising average conversion ratios, since livestock production will grow more rapidly than both population (labour supply) and crop agriculture (residues). Offsetting this strong growth in demand somewhat is contracting feed grain use in developed countries, caused by an ongoing shift in consumer preference from beef to poultry and by improving conversion efficiencies due to breeding, use of animal growth hormones, and better animal health and nutrition.

Box 3. Livestock Conversion Ratios

(grain/meat)

Poultry	2:1
Pork	4:1
Beef (feedlot)	7:1

Over the coming 25 years, overall per capita demand for meat is expected to grow by 15%. However in developing countries, led by China and East and Southeast Asia, per capita demand may even increase by 39%, more than twice the global level. This increase in per capita consumption, together with continued population growth, will cause total demand for meat products to expand at an annual rate of 2.8% per year in developing countries, compared with just 0.6% per year in the developed world. This yields an overall rate of growth of 1.8% and an increase in overall demand of 56% above 2000 levels.

Most of the growth in livestock production will take place in developing counties, though at slower rates than during the immediate post Green Revolution period. The production growth rate for all meat in the developing world is expected to decline from 5.9% to 2.7% during the coming 25 years, while in developed countries it will stay roughly constant, declining slightly from 0.9% to 0.7%. In absolute terms China and the rest of Asia will show the greatest growth in production, particularly for pork and poultry.

It has been suggested that a reduction in meat consumption in developed countries, either through voluntary changes in dietary patterns or through policies such as taxes on livestock, would release cereals from livestock feed to food for poor people in developing countries. IFPRI examined this hypothesis using the IMPACT model and found that a decline in consumption of livestock products in the developed countries has virtually no impact on food security for developing countries. More livestock products would enter world markets, reducing their price in developing countries where consumers would increase their consumption. However, reduced demand for maize and other coarse feed grains would have little impact on prices of wheat and rice, the main staple foods in most developing countries and therefore little gain in the consumption of these staples. There may be health benefits for people in developed countries from reducing consumption of meat products, but such forbearance will not translate into better nutrition for the poor in developed countries, other than by making meat products more affordable[15]. and possibly saving water on water guzzeling meat foods, for use on competing demands.

Fisheries

An estimated 15 to 20% of animal protein consumed is derived from aquatic animals[16] Worldwide, people eat more fish than any other type of animal protein. Fish are particularly important in the diets of people living in developing countries. Of the 30 countries most dependent on fish as a protein source, all but four are in the developing world. About three-quarters of fish production is used for human consumption, with the remainder going for reduction into feed and industrial products. Per capita consumption of fish totalled about 15 kg (live weight equivalent) in 1995.

Nearly three-quarters (73%) of fisheries production, came from marine capture fisheries, in 1995, with another 6% coming from freshwater capture fisheries (Table 3). At present, therefore, 4 kg of every 5 comes from wild fish populations.

Table 3. World fisheries production in 1995[17]

	Production Million tons	**Share of total production** %
Inland		
- capture	7.4	6.3
- aquaculture	13.9	11.8
Sub-total	21.3	18.1
Marine		
- capture	85.6	73.0
.- aquaculture	10.4	8.9
Sub-total	96.0	81.9
Sub-total capture	93.0	79.3
Sub-total aquaculture	24.3	20.7
TOTAL	117.3	100.0

It is widely believed, however, that the present level of ocean fishery harvest is at or beyond the long-term sustainable limit, and that future growth in fishery products must come almost entirely from marine aquaculture (mariculture) or freshwater aquaculture.

Future growth in aquaculture is expected to be dramatic. Estimated production in 2025 is expected to nearly triple to 71 million tons (Table 4). China dominates aquaculture production at present with 63% of the global total and more than ten times the output of the next largest producer, India. High growth rates projected for China suggest that it will continue in this role in the future.

At present 57% of the output from captive fisheries comes from freshwater. As a protein source freshwater aquaculture is important in food security, especially for the poor[18]. The most common aquaculture species, catfish, tilapia, and carp, tolerate a wider range of growing conditions than do high-value mariculture species such as shrimp and salmon. Freshwater aquaculture is also more dispersed and therefore accessible to larger numbers of both producers and consumers. Although higher growth rates for marine aquaculture will close the gap slightly, freshwater production will still predominate, while marine aquaculture will be more important as a producer of export commodities.

Table 4. Projected world aquaculture production, 2025[19]

	1995 production	**2025 production**	**2025 share**
	Million tons	Million tons	%
Freshwater aquaculture	13.9	37.2	52.5
Marine aquaculture	10.4	33.7	47.5
TOTAL	24.3	70.9	100.0

By 2025, if capture fisheries maintain their current level of production, the share of aquaculture in total fish production will double, from 21% to 43% of the total. And since the portion of fishery output that is used for feed and industrial products comes primarily from marine capture fisheries, aquaculture's share of fish production will be closer to half of the total.

Water requirements for aquaculture, while not large in volumetric terms, are strict in terms of reliability, as an entire harvest can be lost if ponds dry out prematurely. Moreover, freshwater as well as brackish aquacultures are very sensitive to the quality of incoming water as this may be contaminated with organic and inorganic chemical residues. This problem has plagued rice/fish culture programs in many locations.

Valuable mariculture species salmon and shrimp are both high in the tropic chain and require 3 or 4 kilograms of rough fish to produce a kilogram of product. This is expensive and places a heavy demand on maritime fish stocks. Although grain feeding has not proved successful because of an incomplete protein composition, biotechnology experiments are underway which may lead to grain-based ration for these species. This could result in a modest increase in feed grain demand in coming years.

Prices

Prices predicted by the IMPACT model for different meats and cereals are shown in Table 5. IMPACT model projections suggest that cropped area will expand only slightly (0.25% per annum) during the coming quarter-century while irrigated area grows by

0.6% annually between 1995 and 2020, less than half the annual growth rate of 1.5% during 1982 - 1993. The model results indicate that cereal prices will remain stable until about 2010, after which they will fall modestly. This itself is a sharp departure from recent trends, which have seen cereal prices declining fairly rapidly over the past two decades. Stable prices will tend to encourage input use, tickling yield growth rates upward.

Table 5. Projected world prices of meat and cereals, 1995 - 2025, for the IFPRI base scenario in US$/ton

	Wheat	Maize	Rice	Other grains	Beef	Pig meat	Sheep meat	Poultry meat
1995	162	116	336	111	2,028	1,063	2,387	1,255
2005	163	120	351	109	2,000	1,064	2,389	1,213
2015	159	120	323	104	1,952	1,032	2,299	1,191
2025	144	112	260	90	1,851	956	2,097	1,178

3.4 Water Availability

Water is an essential element of the natural environment. All living things depend on it in one way or another, and the natural ecosystems that it supports perform important functions for planetary health – including sequestering carbon and recycling carbon dioxide into oxygen.

Human beings are also a part of the natural ecosystem, and, like other living things, we depend on water for our survival. For this purpose, we abstract water from its natural locations to other places where we can more conveniently consume or use it. In so doing we alter the natural environment in which other organisms exist. As our numbers have grown and our capabilities have expanded, we have learned to abstract from streams and aquifers volumes of water which no longer constitute marginal ecosystem changes.

We now have the power to make major alterations in those ecosystems - power literally to determine whether certain species continue to exist or not. That power, and our awareness of it, oblige us to act responsibly, always bearing in mind the second of the basic principles outlined in Section 2 - the obligation to preserve the global heritage and bequeath to succeeding generations the ability to feed themselves.

We now face the challenge of feeding 8 billion people by the end of the first quarter of the twenty-first century. At the same time, we desire to improve the standard of living of at least the poorest two-thirds of this population[20]. This will require the use of resources - energy, minerals, water, as well as people - and this use will have unavoidable impacts, some of them destructive, on natural ecosystems. We do have choices, however, and the degree of damage we cause, and how we mitigate it, is up to us. The obligation that comes with power and awareness is to weigh the involved trade-offs carefully and to make well-judged choices among alternatives.

It should be borne in mind that freshwater ecosystems also perform services that humans value directly, providing food, flood protection, water purification, water storage, recreation, and cultural, aesthetic and spiritual significance. Moreover, the precautionary principle warns us against making changes that we don't understand reasonably well, especially those that may be irreversible. Nevertheless, to survive as the civilisation we are, we must and will continue to alter the planet's natural hydrology to support ourselves. The challenge is to do this wisely and responsibly for both ourselves and our progeny.

Renewable supply

Globally, some 40,000 km^3 of water is annually available on a renewable basis. This represents about 7,800 m^3 per person per year. However, because of tremendous spatial variations in precipitation, flows are unevenly distributed over the earth's surface. Because of temporal variations in precipitation, much of the flow occurs in seasonal floods. Of this amount, only an estimated 9,000 km^3 to 14,000 km^3 per year (8 to 13% of terrestrial precipitation) may potentially be controlled with technically, socially, environmentally, and economically feasible water development programs. At present, about 3,400 km^3 (3%) is withdrawn for various uses of which irrigation is the most predominant accounting for about 70% of total withdrawals that largely constitutes a consumptive need. Most other withdrawals are for domestic and industrial water supplies and are largely non-consumptive in nature. Hydropower, ecosystems, navigation, recreation comprise important in-stream users of water.

Only a portion of withdrawn water will generally be depleted. Depletion is caused by evaporation from water and soil surfaces; transpiration by plants, flow into sinks such as the oceans or saline seas, pollution to the extent that this water is unfit for further use; or incorporation into a product, such as a soft drink or a pineapple. Because transpiration is a necessary aspect of photosynthesis, irrigation is a large water consumer, though it returns a significant portion of its withdrawals to streams and aquifers. In-stream uses, such as navigation and power generation, are largely non-consumptive in character, where the consumptive effects of municipal and industrial withdrawals are related principally to the pollutants included in their return flows.

Role of storage

Rainfall and flow in rivers are hugely variable. In many parts of the world, more than three-quarters of the annual precipitation falls during less than half or even one third of the year, often during just a few weeks or months of intense rainfall. During periods of heavy rainfall or high river discharge, much of the incoming water is lost by flowing to a sink, usually the ocean, quickly and without being available to meet human or environmental needs. Storage is a way of increasing the net useable supply of water within the confines of the total renewable resource. In economic terms, the purpose of storage is to capture water when and where its marginal value is low, or even negative, in the case of floods, and reallocate it to times and places where its marginal value is high. Marginal value here includes all of the economic, social and environmental values of water.

Water is stored naturally in soil and in groundwater aquifers as precipitation soaks into the ground and moves downward. Natural storage is also found in the form of snow and ice in mountain ranges such as the Himalayas in Asia, the European Alps, or the Sierra Nevada in California. Precipitation falling as snow during winter is released during the warmer months as the snow melts. Lakes and swamps also store water, releasing it more slowly than it flows in. Although losses to evaporation and seepage are incurred in changing flow patterns in this way, especially in swamps and wetlands where water is spread thinly over a relatively large area, these natural storages often increase the net availability of water in times when it is most needed.

Humans have also created storage by constructing large and small dams across rivers and sometimes seasonally dry valleys creating reservoirs to capture and control heavy runoff. To date, more than 45,000 large dams have been constructed and many more small ones. These large dams have the ability to regulate some 3,500 km^3 of water, which is roughly equivalent to the total of average annual withdrawals worldwide. New surface reservoirs are a subject of much debate and controversy as their collateral impacts on local society and the environment may be considerable. Some of these impacts are inundation of land, resettlement of people, and disturbance of the river ecosystems and fish migration routes. In addition, surface reservoirs are subject to sedimentation and water losses through evaporation. However, reservoirs may perform functions that are difficult to replace by other means.

In addition a huge amount of storage is available in the world's groundwater aquifers. Advantages of sub-surface storage are that it does not inundate land, is not subject to sedimentation, does less interfere with river ecosystems and has no evaporation losses. Such reservoirs can be separated into rechargeable and fossil aquifers, the latter of which no longer have a pathway to a source of recharge on the earth's surface. Humans have also taken measures, sometimes by accident, to increase the recharge to groundwater aquifers. These include the practice of surface irrigation, especially in growing rice where percolation losses accrue to groundwater, water spreading basins, injection wells, terraces, and water harvesting facilities.

As water becomes increasingly scarce in many regions of the world, a higher proportion of the normal flow of water will be consumed, and the risk of shortages in periods of low flow, harming human uses and damaging ecosystems, will increase. For this reason, the need for additional storage as a proportion of the total water consumed will increase in the future. Each of the storage technologies has comparative advantages and drawbacks under specific conditions. Where possible, substantial gains can be achieved by combining technologies – large reservoirs, small reservoirs, links between them and groundwater storage – in an integrated system.

Reuse

Water is often used and reused many times on its way from an upper watershed to the sea. Sometimes, as much as two-thirds of the water diverted for irrigation returns to the river downstream. Likewise, of water withdrawn by industries and municipalities, more than 90% typically returns to the river as either treated or untreated wastewater. Each time it is used, however, water's quality is degraded to some extent. Municipal wastewater that has undergone tertiary treatment before being discharged may have very little impact on the quality of downstream river water. Industrial wastewater is more problematic but it too can be regulated and treated to minimise the pollutant load it contributes to downstream river flow. All too often, however, urban wastewater streams are treated minimally or not at all before being discharged into the river, and riverside industries, particularly in low-income countries, are still dumping polluted wastewater back into rivers without any form of treatment. Many large cities are located in coastal zones and other human users do not directly feel the impact of their effluent discharges (though there may be considerable negative impacts on coastal ecosystems and recreational areas). Other large cities, such as Cairo and New Delhi, are inland and upstream of major irrigated areas. Here inadequate regulation and treatment of municipal and industrial wastewater discharges can render the water unusable downstream or reduce the available supply by requiring larger in-river flows for waste dilution. Wastewater pollution can harm the health of agricultural workers and compromise the safety of the food supply. This is a particular problem since agriculture on the periphery of major urban areas is often devoted to growing fresh produce for the urban markets, crops that are far more susceptible to contamination by polluted water than for example cereals.

Often agricultural areas lie upstream of major urban concentrations and agricultural return flows make up a portion of a river's discharge as it passes the urban area. Although usually not as heavily polluted as urban wastewater, irrigation return flows often carry agricultural chemical and fertiliser residues, and concentrated salts from soil or the incoming irrigation water, affecting the quality of water withdrawn for municipal use and that available for in-stream uses, including natural ecosystems. Awareness of the risks involved and of the chemistry and technology of water reuse is growing and local councils and groups are particularly active in Northern Africa and the Middle East.

Addressing these problems requires recognition of the fact that water is reused extensively within most river basins and adjustment of basin planning and water allocation processes to consider the types and sequence of uses and reuses which occur and their water quality impacts. It also means that major investments in wastewater treatment facilities will be required to reclaim degraded downstream water supplies, and that the use of fertilisers and agricultural chemicals must be moderated and controlled through regulation and education.

In some basins it may be possible to plan the sequence of water use more completely. In such system water moves from an application requiring higher water quality, such as drinking water, to less demanding applications, such as cereal production, and finally to a low quality application such as turf or pasture irrigation. Israel has developed this approach to a high degree.

Non-conventional sources of water

Several non-conventional sources of water are sometimes developed for special purposes. These sources comprise water that is generally considered to have reached a sink, or become unfit for use as fresh water, such as seawater, incompletely treated urban wastewater, or brackish water. Increasingly in water scarce areas, urban wastewater is reused in agriculture after treatment. However, the amount of water available is relatively small compared to agricultural demands, and quality concerns persist. In the peri-urban areas in many developing countries vegetables, fruits etc are cultivated for domestic urban consumption using such treated or mostly untreated waters. Removal of hazardous elements or pollution preventive measures are necessary before its use for agriculture.

Brackish and moderately saline water can be used for aquaculture, or to produce salt tolerant crops. Or such water can be desalinated and made fit for any use, though the cost is still high. Desalination is now sometimes employed to produce drinking water where other sources are unavailable and where society can afford it. However, new reverse osmosis technology is bringing the cost down, and if electricity costs fall as predicted, desalinated water may become a feasible source of supply for producing high value agricultural crops using precision technology. It is, however, unlikely to become a common source of agricultural water.

3.5 Water Management Regimes in Agriculture

Agriculture depends on water. Generally, plants grow best, and produce the most, when they have an adequate supply of water available and do not experience damaging water stress, especially during the critical stages of growth of crops. The roots take up the water that plants use for transpiration. This means that water must be stored temporarily in the soil root zone to allow crops to overcome periods without rainfall or other water supply. Such storage may be good for a day or two, or sometimes for many weeks, depending on the soil, crop, and climate.

We distinguish various kinds of agriculture on the basis of how water is supplied to the root zone. Means of supply extend from total dependence on direct rainfall to complete irrigation. In a very real sense though, all agriculture, and all other water uses, depend completely on rainfall.

Excess soil water can also constrain production (rice is a notable exception). Productive agriculture therefore also sometimes depends on "artificial" drainage based on shallow ditches, buried pipes, or wells to remove excess water.

Based on these different possible interventions, the following water management regimes exist: rainfed, irrigation only, drainage only, and irrigation and drainage.

Of the 1,500 million hectares of global cropland some 250 million hectares (17%) are irrigated and approximately 150 million hectares are provided with drainage infrastructure. Currently about 60% of global food crop production originates from rainfed agriculture and the remaining 40% from irrigated agriculture.

Rainfed agriculture

Rainfed agriculture is still the most important agricultural production system. In rainfed agriculture rainfall and, in certain cases capillary rise are the only mechanisms for replenishing soil moisture and no artificial supplies are provided. Rainfed agriculture is practised under a wide variety of conditions. On the one hand there are the vast plains of the American mid-west, eastern Canada, and northern and central Europe which are blessed with generally adequate and reliable rainfall. Especially in areas with adequate drainage the yields are little constrained by water excess. Other rainfed agricultural areas, including most of those in developing countries, receive a less generous and less reliable natural water supply, and yields may be just 25% to 35% of the potential.

Rainfed agriculture under conditions of reliable rainfall has advantages of not requiring costly irrigation infrastructure and leaving flowing or stored water in rivers, lakes and aquifers where it is available to support ecosystems and for other human use. Given adequate holding sizes, such rainfed agriculture can still provide reasonable livelihoods for farmers.

Where rainfall is not reliable, drawbacks express themselves. Under these less favourable conditions, improved farming practices, like land levelling, tie ridging, and others that increase water intake after rainfall can improve the retention capacity of water and nutrients in the soil and increase yields. Practices that reduce non-beneficial evaporation, such as mulching, can have similar effects. However, if rainfall is erratic, farmers will rationally minimise their investments in labour, improved seeds, fertilisers, water management, and land preparation to minimise their losses to crop failure during drought. Not knowing which years will be good ones, they will do so every year. Thus, in the absence of reliable seasonal weather forecasts, yields will be sub-optimal even in good rainfall years. Better agricultural practices combined with the result of bio-technical advances (drought resistant varieties) and modern technology can contribute considerably to the improvement of rainfed production systems.

Producing household food requirements in such areas requires a larger cultivated area than is required for irrigated agriculture due to lower production potential. Producing a surplus for the market and a surplus for retention to cover years of failure expands the area requirement further. As the scale of the operation increases, the need first for animal power, and then mechanical power sets in. In densely populated regions such as South and East Asia, expansion of rainfed agriculture generally means moving onto lowlands or into forest reserves, marginal lands and fragile ecosystems on hill slopes, which are generally not desirable options. In other areas, expansion is still possible, though labour or power may be limiting.

Water harvesting

Water harvesting is another technique that lies on the boundary between rainfed and irrigated agriculture. Water harvesting concentrates rainfall as runoff from a larger area for use on a smaller area. It is distinguished from irrigation by the fact that the catchment is contiguous with the benefiting area, and that it is uncontrolled. The objective is simply to catch as much water as possible and store it in the root zone. If the amount of water captured exceeds the amount that can be stored, this practice also results in recharging the groundwater beneath the target area. In some areas such practices have been used for hundreds of years. In other areas, more recent attempts have been made to introduce the practice more widely. However, the area affected by rainfall harvesting is relatively small, and its overall impact on agricultural food production is quite limited. It can have a significant impact on regional food supplies and incomes however.

Recession agriculture

Recession agriculture is another technique that lies on the boundary between irrigated and rainfed agriculture. In recession agriculture, crops are planted after the high water peak on a river or lake has passed and the soil is fully saturated with water. The planting schedule follows the recession of the water line and relies of this residual water stored in the soil to supply the crops. Shorter duration crops are obviously favoured and rivers and lakes with broad shallow beds are required. Recession agriculture also benefits from the natural fertility in the sediments deposited by the receding water and does not create problems of salinisation. A big advantage is that the technique does not require infrastructure and therefore no management is required other than that needed to allocate the limited foreshore land to cultivators. However, if the floods do not occur due to late rains or drought or because of excessive floods, large areas will not be harvested and food shortage and even famines may occur. This system of recession agriculture can still be found on the margins of many lakes and rivers in Africa, Asia and South America. Its potential for improved food supplies and incomes too is largely local in nature.

Irrigated agriculture

Full irrigation is needed when no crop can be reasonably grown and yields will be very low unless water is supplied. Full irrigation is needed for virtually any productive agriculture in arid and semi-arid regions as well as in monsoon regions in the humid tropics to allow production of dry season crops. Full irrigation often requires major infrastructural works to capture, store, transport and deliver the required water supplies. Such major works are generally managed by public agencies. Today, increasingly, countries are restructuring management processes to provide a controlling role for water users, in exchange for their bearing a major share of the cost for providing irrigation service.

Full irrigation can also be carried out on a smaller scale using smaller water sources or individual wells, pumpsets or alternative resources, like domestic wastewater. Farmers have often managed these smaller schemes in the past and these management practices will endure. They can be in full control of development and management of their system according their own set of values and rules, enabling them to fit the technology and operations to their financial and managerial capability. However, some governments still manage even small-scale schemes, usually at a high cost in efficiency and cost of operation.

Supplementary irrigation is supply of water to crops to increase yields and to reduce risks of crop failure where, under normal circumstances reasonable yields can be expected. Farming in rainfed areas can be made more productive through supplementary irrigation where cropping seasons can be extended and production risks by short periods of rainfall deficit can be reduced. Supplemental irrigation increases productivity by providing water during critical crop growth stages when rainfall is temporarily inadequate and by reducing risk and inducing farmers to increase the level of inputs supplied year in and year out. Its productivity can thus be very high. Challenges involved in supplying supplemental irrigation include the need for low-cost irrigation infrastructure capable of distributing small amounts of water across relatively large areas, and for institutions, which can effectively manage this very challenging allocation problem[21].

Environmental Impacts

Irrigated agriculture has significant impacts on the environment and on downstream water users. Perhaps the most important and often overlooked impact of irrigation is the land-saving it permits by concentrating agricultural production on a smaller land area than would otherwise be possible. With increasing land pressure due to population increase, there is particular pressure on marginally productive rainfed lands. Thus, the area of rainfed land savings from new irrigated areas is often quite high, since a very large area of marginal land would be required to replace the production of a small area of highly productive irrigated land. A similar case can be made for irrigated terraces in hilly areas. Although terraces, which provide important erosion control benefits, can also be found in rainfed areas, their high costs can normally be justified only under the greater productivity of irrigated conditions. In areas of chronic and severe soil erosion due to cultivation on slopes (e.g. Madagascar), irrigated terraces can offer an environmentally sustainable alternative. However, especially on steeper slopes where most work is done manually or with animal traction, the feasibility of these practices will reduce when mechanisation becomes a necessity. Then the necessary precautions have to be taken to avoid the more severe erosion once the terraces are left and not maintained anymore.

Irrigation has often provided additional benefits to the farming communities through the use of irrigation water for other purposes, especially in poor rural areas. This contribution is often under valued. In areas with brackish groundwater, such as much of Pakistan, irrigation canals are a primary source of domestic water and its quality has important health impacts. However, irrigation, often combined with poor drainage, has also influenced the spread of water related diseases such as bilharzia and even under poor drainage conditions malaria.

Many other impacts of irrigated agriculture are environmentally negative. Residues of agricultural chemicals wind up in surface runoff and groundwater, contaminating them for other users and for agriculture itself. Likewise, excess phosphates and nitrates from fertiliser applications on both rainfed and irrigated land are carried into groundwater. When these nutrients contaminate surface water, they can lead to algae blooms and fishkills, and, eventually, to eutrophication.

The use of water by plants has the effect of concentrating naturally-occurring salts in the irrigation water, which then accompany return flows to groundwater or to surface streams and rivers. Irrigation in arid regions can also leach naturally-occurring toxic elements such as selenium from soils and into surface and ground waters. Over-irrigation can lead to waterlogging problems, which is not necessarily an environmental problem[22], but does negatively affect agriculture.

Drainage and flood control

It is estimated that some 500 million hectares or roughly one-third of global cropland is not naturally adequately drained for optimal production. Artificial drainage, by bringing large areas of naturally waterlogged land under production, has contributed importantly to raising food production on about 150 million hectares, mostly located in Asia, Europe and North America. Drainage has also contributed to agricultural intensification and diversification and as such to making the sector more competitive and financially sustainable. However, due to recent recognition of the value and importance of natural wetlands, new reclamation based on this type of development has come to a virtual standstill.

Much existing agricultural land still suffers from inadequate drainage or salinisation both in rainfed and in irrigated areas. In Southeast Asia, large areas annually suffer from severe water logging and flooding due to monsoon rains and tropical storms. In irrigated areas the practice of irrigation without adequate drainage has exacerbated natural drainage problems in humid and sub-humid areas. In arid and semi-arid areas some 20 to 30 million hectares of land is suffering from water logging and salinity due to irrigation or high canal percolation rates. Improved drainage can lead to important production improvements in these areas by restoring healthy root zone moisture conditions. The improved production potential also stimulates the effective application of agronomic measures such as high yielding varieties, fertilisers, and mechanisation.

Improved drainage may also have some important drawbacks. Increased drainage capacity in upstream areas results in larger flows in the downstream parts of the catchment, increasing the risk of inundation and consequent damage there[23]. Increased drainage capacity also reduces the residence time of water in the catchment and consequently reduces recharge of groundwater. The resulting lowering of groundwater tables may have serious effects on the ecosystems and bio-diversity. In such areas high groundwater tables would have to be maintained.

Agriculture, but also other developments in the catchments, such as logging or road building often reduce the water retention capacity in the catchment. Quicker storm water runoff results in higher flood peaks with consequently higher inundation risks in the downstream located agricultural lands and population centres. At the same time, the quicker runoff provides less opportunity to recharge the groundwater and therefore stream-flows in dry periods will decrease. This in turn leads to the need for additional water storage. Moreover, it may cause an increase in soil erosion, resulting in increased sedimentation in reservoirs and water systems, reducing their lifetime and increasing maintenance cost.

In Western Europe these drawbacks are taken seriously and efforts are being made to restore the natural absorption and regulation capacity of the catchments through integrated approaches of land use planning and water management.

Groundwater and conjunctive use

Groundwater, as a distributed source of stored, often high quality water, plays an increasingly important role in water supply for food production. In many arid and semi-arid zones, groundwater is the primary source used to meet both domestic and agricultural needs. In other regions, groundwater serves as a buffer to overcome dry spells or periods of drought. In many agricultural areas, groundwater is used as a supplement to surface irrigation, increasing efficiency, reliability and flexibility of water supplies and providing greater security. The surface and ground waters are interdependent and are to be considered together as a renewable water resource, which must be used conjunctively. Influent and effluent streams, infiltration and interflow, recharge due to riverflow and re-emergence of streams in river low stages, are manifestations of such interdependence.

However, over-development of groundwater as a resource for food production is becoming a serious concern. In many countries, aquifers have been over-exploited and water tables are falling. In some cases fossil groundwater is being extensively pumped and utilised. Rough estimates of annual depletion in countries like India, China, the United States, North Africa and the Arabian Peninsula adds up to about 160 km^3. The bulk of this over-pumped groundwater is used to irrigate grain, which suggests that in the order of 180 million tons of grain, or 10% of the global harvest is being produced by depleting water supplies [24]. Ironically, an equal or greater amount of food production is under threat from rising groundwater tables in surface-irrigated areas of the world.

In irrigation areas where domestic water is provided through shallow wells, increased irrigation efficiency can reduce recharge and lower the groundwater table below the level of domestic wells. Water table lowering due to overdrafting of groundwater for irrigation also affects water availability in the shallow wells used without tubewells.

Water quality in some aquifers is also declining. Causes are salinisation or fertiliser and pesticide residues leaching into groundwater from both irrigated and rainfed land. Similarly leaching into groundwater occurs from urban lawn care products in developed countries, and industrial wastes. It may take years for such pollution to become problematic and when it shows up it may be too late to resolve it.

3.6 The IWMI Base Scenario - Demand for Water in 2025[25]

Based on the required calorie intake and trends in diets, predictions can be made of the demand for different kind of food. These in turn can be translated in requirements for water to enable the production of the food necessary for adequate nutrition in 2025. When these requirements are balanced against the availability of water, water-short areas can be identified, along with the need for investments in water-related infrastructure. IWMI has produced a base scenario[26] for water demand in 2025. Within an overall framework of social, technical and economic feasibility, it relies on substantial investments and changes in policies, institutions and management systems to reach four major objectives:

- achieve an adequate level of per capita food consumption, partly through increased irrigation, to substantially reduce malnutrition and the most extreme forms of poverty
- provide sufficient water to the domestic and industrial sectors to meet basic needs and economic demands for water 2025
- increase food security and rural income in countries where a large percentage of poor people depend on agriculture for their livelihoods through agricultural development and protection from excessive (and often highly subsidised) agricultural imports
- introduce and enforce strong policies and programs to increase water quality and support environmental uses of water

It should be noted that the model does not extrapolate from current conditions to predict what is likely to happen in 2025, but rather indicates what needs to happen, in terms of water development and management for the above objectives to be achieved. The potential water resource available in various regions and countries to meet the requirements of 2025[27] is extremely varied (figure 7). Realising the objectives listed above requires three major actions in the field of water resource and irrigation management in water scarce countries:

- greatly increase the productivity of water resource use
- substantially increase the amount of developed water supplies
- substantially reduce the social and environmental costs of water development

As shown in the accompanying map, the forty-five countries modelled are grouped into three basic categories of projected water scarcity.

Group I consists of countries that face physical water scarcity in 2025. This means that, even with highest feasible efficiency and productivity of water use, these countries do not have sufficient water resources to meet their agricultural, domestic, industrial and environmental needs in 2025. Indeed, many of these countries cannot even meet their present needs. This category includes countries in the Middle East, South Africa, and the drier regions of western and southern India and northern China and contains 33% of the total population. The only options available for these countries is to invest in expensive desalinisation plants and/or reduce the amount of water used in agriculture, transfer it to the other sectors, and import more food. The degree to which they can increase the productivity of water depends very much on the possibilities they have to change their irrigated staple food production to high value crops or to other more productive uses. This requires access to markets for farmers and countries for these higher value products to enable payment for the food crop to be imported or bought locally. An alternative is the import of water into the region through inter-basin transfers as being considered in India and Northern China.

Group II represents countries that do have sufficient water resources to meet 2025 needs but which will have to increase water supplies through additional storage, conveyance and regulation systems by 25% or more over 1995 levels to meet their 2025 needs.

Many of these countries face severe *financial and development capacity* problems in meeting their water needs. Forty-five percent of the population will live in these countries with substantially underdeveloped water resources.

Group III consists of countries that will need to develop less than 25% more water supplies to meet their 2025 needs. In most cases this will not pose a substantial problem for them. In fact, several countries in this group could actually decrease their 2025 water supplies from 1995 levels because of increased water productivity. Twenty-two percent of the population will live in these mainly developed countries, with little or no water scarcity.

Together, Groups I and II contain of 78% of the population in 2025. Of course this does not mean that everyone in these countries will directly be experiencing water scarcity. As usual, the economically better-off members of most countries will have enough water and food, while poor and weak people will suffer the major part of the burden.

Consequences for water development

For the forty-five countries in their model, IWMI estimates that in 2025 under their base scenario total diversions for agriculture, domestic and industrial use will be some 4,120 km^3, an increase of 29% over 1995. This includes unused and reused water. The total diversions of unused water or the primary water supply[28] (PWS) though considerably lower, is estimated to become some 2,720 km^3, increasing by 22%. The difference between these two figures is due to the recycling and reuse of PWS in meeting needs for diversions. China, India and the USA will be by far the greatest water users. Together, they account for some 1,440 km^3 of PWS, or 53% of the 2025 total.

Irrigation is, and will remain as, the largest single user of water, accounting for about 67% of both diversions and PWS in 2025. However, irrigation is also the most slowly growing water sector, with both diversions and PWS increasing only 17% over the period. Domestic water use will comprise only 11% of diversions, but will increase by a huge 84% over 1995 levels. Industrial diversions will account for 22% of total diversions and will grow by 60% over the period. However, about 90% of industrial diversions are available for reuse downstream, assuming that return flows are of reasonable quality. Good quality return flows are not a given, however, and making industrial return flows of acceptable quality will be a major challenge.

Primary water supply

To meet the increased 2025 needs, the world's primary water supply will need to increase by 22%, from around 2,120 km^3 per year in 1995 to 2,720 km^3 per year in 2025. This amounts to an increase of diversion capacity and associated regulation works as surface and sub-surface water storage sufficient to release roughly 600 km^3 of water per year (for comparison, the average annual release of the High Aswan Dam in Egypt is 52 km^2/year). In addition to these net demands, is estimated that 1% of the existing live storage capacity of the world (6,000 km^3) or 60 km^3 is lost every year because of sedimentation[29]. Moreover, replacement of the roughly estimated 200 km^3 per year that is provided through unsustainable overdraft of groundwater resources would be needed to achieve sustainable water use. By 2025 thus a total additional primary water supply of around 2,600 km^3 is required.

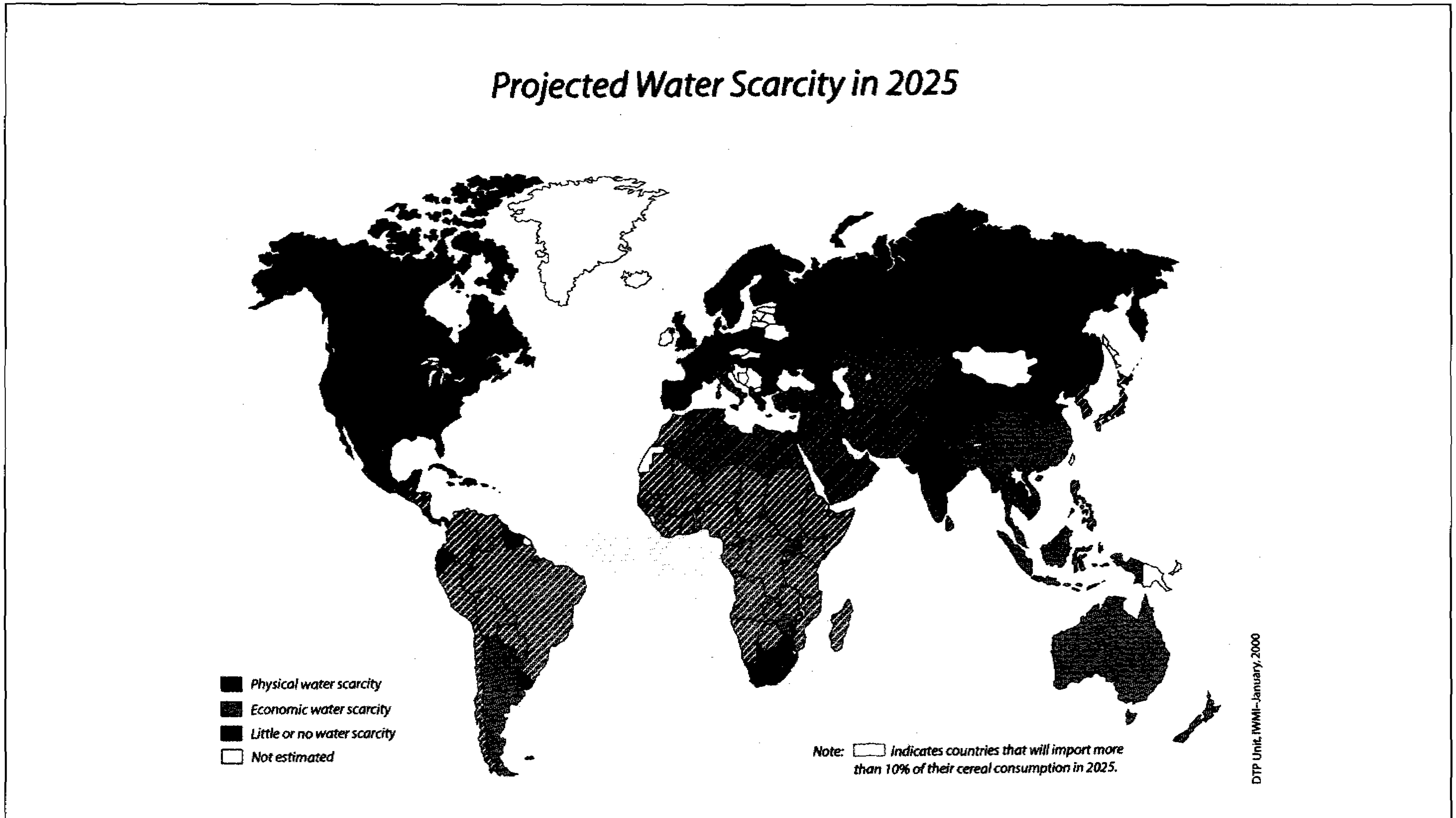

Figure 7 Water scarcity in 2025[30]

This amount comprises an annual increment of new storage to augment PWS of 20 km^3, additional storage of 60 km^3 each year to compensate for storage lost due to siltation, and an increment of 6.7 km^3 each year for 30 years to eliminate the current level of groundwater overdraft. Note however, that in spite of this substantial increase in storage, the net increase in storage by 2025 will be only about 860 km^3, since over the 30-year period, 1,800 km^3 of storage will be lost due to siltation.

Taking into account the (often underestimated) additional evaporation losses from future reservoirs (at present around 300 km^3/year[31]), the total primary water supply requirement in 2025 for all sectors is expected to be nearly 3,000 km^3, or effectively a 41% increase over 1995 levels. It must be remembered that this requirement is after utilising the water savings resulting from fairly optimistic assumptions about increased water use efficiency in agriculture. The additional water will have to come from creating additional storage in new large, medium, or small surface reservoirs, or expanding conjunctive use of groundwater, coupled with artificial groundwater recharge.

Irrigated area

To meet the required nutrition levels, the net irrigated area has to increase by 52 million hectares or 22%. Gross irrigated area increases 29%, by nearly 100 million hectares. The difference between the 29% growth in gross irrigated area and the 17% growth of PWS for irrigation shows the substantial increase in irrigation system efficiency at the country level. These savings are used to provide water to additional irrigated area.

The irrigated cereal area is projected to grow by 30%, compared to a 10% reduction in rainfed cereal area. The reason for this is that total cereal area increases by only 3%, and therefore most of the growth in net irrigated land is at the expense of rainfed land.

Yields

Irrigated cereal yield is projected to grow by 40% between 1995 and 2025, compared to a 12% increase for rainfed yield. Lastly, because of these differences in growth of areas and yields, there is the remarkable role reversal in contribution of irrigated and rainfed agriculture to total cereal production. In 1995 irrigation produced 43% of the world's cereals, while rainfed area produced 57%. In 2025 these percentages are expected to be reversed.

3.7 Challenges Facing Irrigation and Drainage

Irrigation and drainage are vital and necessary legs of the Green Revolution tripod of seeds, fertiliser, and water control. They have played a critical role in the prevention of famines and widespread starvation. They helped in the rising standard of living of billions of people in the developed and developing world.

Nevertheless, the performance of many irrigation and drainage systems is significantly below potential due to a variety of shortcomings. These include inadequate design, use of inappropriate technology, system layouts that do not adequately reflect existing conditions, inappropriate governance arrangements, and poor management practices.

The most obvious manifestations of these shortcomings in irrigation are unreliable main system water supply, water wastage and poor maintenance practices. Improvements in tertiary level water management by farmers are often thwarted by unreliable water supplies. Users are discouraged from organising themselves and participating in the operation and management of the water delivery system, and unwilling to pay water charges when service is poor and unreliable. Irrigation can also cause certain environmental problems, in the areas of drainage and salinisation, habitat change, and human health.

The most obvious manifestations of shortcomings in drainage are inappropriate design and technology, poor maintenance practises, and adverse environmental impacts (water quality degradation, undesirable changes in downstream flow regimes). Over-irrigation and injudicious planning of roads, canals and other rural infrastructure blocking the natural drainage ways also cause many of the drainage problems, especially in irrigated areas. There is considerable scope for preventing and alleviating drainage problems by more integrated planning and water management. This can include integrated use of canal and groundwater for water table control, consideration of upstream and downstream relationships, adapting land use to the natural drainage conditions, exploration of opportunities of biological drainage and serial re-use of low quality drainage effluents.

Irrigation and drainage are necessary ingredients in global food production, and their importance can only grow as we work to meet the food demands of 2025. At the same time, we are obliged to make these systems work more effectively and more efficiently, and to mitigate their negative consequences.

4 Meeting the Demand for Food

4.1 The Shape of the Challenge

Continuing growth in world population generates the need for continued increases in food production. Stable or falling energy costs and continuing technological development are promising trends which will lead to increased production potential and lower production costs. Likewise, the continued advances in forms of governance and accountability, at all levels, will improve the performance of many services, including irrigation and drainage. Urbanisation and rises in income will change the composition of food demand, requiring shifts in patterns of production and trade, while providing new opportunities for producers.

Another major trend, global integration is a two-edged sword. On the one hand, it promises lower costs for agricultural inputs, equipment, and a wide range of other goods. It offers wider markets for competitive agriculturists and provides pathways for accelerating regional and national development through access to export markets. At the same time, it threatens the livelihoods of farmers in resource poor situations with competition from cheaper imported food. It also raises the risk that unbalanced power relationships will lead to poor terms of trade for weak developing economies, when in fact limited-term preferential trade provisions could assist struggling agricultural economies.

Rising environmental awareness, continuing degradation of a whole range of environmental resources, including land, air and water, and the prospect of rising global temperatures provides significant restraints on our options for harnessing water resources and for producing more food. Our analyses of options must be far more complex then they were just 20 years ago, in recognition of interrelationships of which we previously were insufficiently aware.

To meet the changing demand for food described in the previous chapter, several kinds of actions are required. Globally, our core response must be to improve the productivity of water. Where land is limiting, yields per unit area must also be raised. Modest expansion of cultivation onto new lands and extension of irrigation onto currently rainfed land will be required. New storage will be needed to supply expanded irrigated area, if all the world's people are to have access to an adequate diet. These physical measures for increasing food production must be accompanied by a rethinking of livelihood options for the rural poor, especially those with limited access to resources and poor infrastructural environments. This leads to a differentiation between two fundamental development directions:

- *increasing the yield frontier* in those areas where present levels of production are close to the potential and governance, economic and technology infrastructure are available

- *closing the yield gap* in low yield areas where, with improved governance, economic and technology infrastructure, and management, considerable production gains can be achieved with current technology

These two thrusts will be discussed in a subsequent section.

4.2 More Crop per Drop

The world has to feed more people while relying on only marginal increases in water and land. This requires a mix of site-specific solutions in the fields of technology, policies, management, institutions, and investments. We do not have the option of simply increasing the area of irrigated land only to meet the growing demand for food. The land and water required is simply not always available. Although, developing new sources of water will also be a necessary part of the solution, we also will need to markedly improve water efficiency, water productivity, and land productivity, in addition to expanding the area of both rainfed and irrigated land.

Baseline projections using the PODIUM model indicate that even with somewhat optimistic assumptions of productivity growth, efficiency improvements, and expansion of irrigated area, we will still require 15 - 20% more water for irrigated agriculture to provide all people with an adequate diet by 2025. This means that substantial additional storage is required in the form of reservoirs and groundwater development and recharge. In addition, we will need to replace storage lost due to siltation.

Increasing water storage is costly in many ways: financially, environmentally, and socially, when people are displaced by reservoirs. There is no escaping the need for increased storage, but we need to look to gains in productivity as a complement and to some extent as a substitute, to increasing storage. We need to extract more crop and But the real key to alleviating scarcity, reducing the need for new water development, and producing enough food is to increase the productivity of water used in agriculture. There is a need for more crop and more value per drop of water consumed by agriculture.

Improving the productivity of water in agriculture[32]

If the average worldwide yield could double with water consumption by crop evapotranspiration at essentially the current levels, there would be no need to expand irrigated area, and develop new supplies. Is this feasible? In many cases, water productivity is already at very high levels, and further gains are unlikely unless there is a dramatic improvement in crop varieties. In other areas, there is tremendous scope for increasing the productivity of water through new investments and incentives. More widespread use of existing technologies for in-field soil and water management can make substantial differences in yield levels, provided it is combined with conservation tillage, and appropriate levels of all other inputs, such as fertilisers, pest control measures, and good quality seed. An IWMI study of fifty irrigation systems around the world showed a 6-fold difference in the productivity of water between the most productive and least productive cases. In India, closing this gap would translate into a yield increase of from 2 to 4 tons per hectare. While it may be very difficult to close these productivity gaps, increases in water productivity will certainly be an essential component of a viable food production strategy.

To increase crop per drop, either production must be increased, keeping water constant, or the same amount of production must be maintained while using less water. There are several ways to achieve this:

- increase the productivity per unit of crop consumption (transpiration)
- reduce non-beneficial evaporation or flows to sinks
- reduce pollution
- reduce uncommitted outflows, either through improved management of existing facilities or through development of additional facilities
- reallocate water to crops with higher water productivity

Within each of these broad strategies, more detailed measures can be identified. The choice of strategy for increasing water productivity will be guided by economic and social factors. Existing water rights will often constrain choices, especially when there are options of reallocation. In such cases the basis of water rights may need to be reconsidered. Local availability of water will be an important consideration dictating an improvement strategy. In choosing among various strategies, cost-effectiveness is a central consideration. It may be more cost-effective, for example, to reuse water through pumping than to modernise existing infrastructure to increase beneficial depletion of available water.

Most measures to improve water productivity assume that there will be improvements in management through new or restructured organisations. These management improvements are discussed in Chapter 6. The following provides details of the key strategic options for increasing 'crop per drop'.

More production per unit transpiration

There are several possibilities to enhance the production per unit transpiration:

- *changed crop varieties.* Plant breeding plays an important role in developing varieties that yield more mass per unit transpiration. For example, by reducing the growth period while keeping the same yield, the production per unit transpiration increases
- *crop substitution.* Different crops vary dramatically in their water use, and in their economic returns. Farmers can switch from a more to a less water-consuming crop or switch to a crop with higher economic or physical productivity per unit of water consumed by transpiration
- *deficit, supplemental, or precision irrigation.* With sufficient water control, it is possible to achieve more productivity per unit of water by irrigation strategies that may not meet full evaporative requirements, but instead increase returns per unit of transpiration
- *improved water management.* Better timing of water supply, or better timing of the crop cycle, can reduce stess at critical crop growth periods, leading to increased yields. By increasing reliability of supply, farmers are motivated to invest more in other agricultural inputs leading to higher output per unit of water

Reducing non-beneficial evaporation and flows to sinks

The first task to reduce non-beneficial evaporation and flows to sinks is to carefully identify these flows, remembering that water diverted primarily for agriculture may serve other beneficial purposes. Reduction of non-beneficial evaporation can be achieved by:

- reducing evaporation from water applied to irrigated fields through irrigation technologies (e.g. drip irrigation), agronomic practices (e.g. mulching), changing crops or planting dates to match periods of less evaporative demands
- controlling evaporation from fallow land, decreasing the area of free water surfaces, decreasing phreatophytes and controlling weeds

Reduction of flows to sinks can be realised by interventions that reduce surface runoff or deep percolation that flows to sinks like the sea, and is not required for environmental or other commitments.

Pollution control

Controlling pollution can increase the amount of water available for reuse by:

- reducing flows through saline soils or through saline groundwater to reduce mobilisation of salts into irrigation return flows
- shunting saline or otherwise polluted water directly to a sink and avoiding the need to dilute it with freshwater
- utilising a basin-wide irrigation strategy that controls reuse of return flows
- reducing pollution entering irrigation water supplies through return flows of municipal and industrial users
- reducing pollutants originating from rainfed and irrigated agriculture

Using not yet committed flows

Even with present levels of infrastructure development, there is much outflow beyond downstream commitments that could be tapped. This can be done by:

- *improved management* of existing facilities to obtain more beneficial use from existing water supplies. For example, removing a head-tail problem would allow irrigation of more area. There are a number of policy, design, management, and institutional interventions that will allow an expansion of irrigated area, increasing cropping intensity, or increasing yields within service areas
- *adding storage facilities* and releasing water during drier periods. The storage could take many forms besides impoundment behind reservoirs, including storage in groundwater, and storage in small reservoirs and in ponds on farmers' fields
- *reusing return flows* to increase irrigated area

Reallocating water between uses

Reallocation of water from lower to higher value uses (from agriculture to municipal and industrial uses or from low value to higher value crops) affects downstream availability. Such reallocation can have serious legal, equity and other social considerations that must be addressed.

4.3 Appropriate Use of Irrigation and Drainage Technology

Irrigation technology

The technology is already available that can supply crops with the optimal amount of water and nutrients at any time. In these high-tech systems, networks of sensors, processors and controllers connected to computers control water flows and nutrient supplies in drip and sprinkler systems responding to real time crop requirements. However, this technology is still expensive and is mainly used in highly commercialised farming often combined with green houses. Making these technologies available at a lower cost and workable in the gravity systems, which predominate, could contribute considerably in increasing the productivity of water.

There is scope to increase the cropping intensity and cropped area if water use and irrigation efficiencies can be improved and storage can be further developed. Water is still used with low efficiency at field level in many countries and could be increased by using more sophisticated sprinkler and drip systems. However, surface irrigation is currently by far the most common technique used especially by small farmers. There is little chance that all these areas will be converted into more efficient pressure techniques, and one can expect that surface irrigation will still be dominant in 2025. However, the scope for improvement is considerable. Local irrigation performance can increase rapidly with the implementation of new irrigation techniques but this will require a reliable, flexible and affordable water delivery system.

Measures to improve irrigation and drainage efficiency also need to consider the environmental as well as social consequences. Farmers outside the official perimeters of the irrigated area often utilise drainage water, which could be eliminated by more careful water management within the system. In irrigation areas where local residents depend on shallow wells for their domestic water, increased irrigation efficiency may reduce recharge and lower the groundwater table below the level of domestic wells. In irrigated areas where residents depend on canals for domestic water supply and bathing, new infrastructure such as pipes or steeply sloped canal profiles may restrict access. As a general rule, however, improvements in irrigation and drainage technology yield environmental benefits. Improved conveyance efficiencies, for example, reduce the incidence of stagnant water and hence related diseases (e.g., malaria and bilharzia).

Drainage technology

Drainage can contribute to food production both by preventing the frequent occurrence of yield depressing water logging of the root zone and by providing conducive soil moisture regimes for improved varieties, fertilisers and other inputs and agronomic measures. Drainage for part of the irrigated land in arid zones is an absolute must for preventing water logging and salinisation to guarantee long term sustainability of irrigated agriculture. While most drainage technology is economically quite feasible and will be adapted by the farmers when time is ripe, this might not be the case for small, subsistence level farming. Here a more pro-active role of the public sector is required to promote drainage development. Governments also hold a special responsibility for water logging and salinisation control of irrigated land as much of these problems are beyond the control of the affected farmers.

Greenhouses

Using greenhouses can dramatically increase yields and water use efficiencies through the combination of reduced non-beneficial evaporation, transpiration and controlled water supply through drip or sprinkler systems. Greenhouses also allow for a better niche marketing, to provide profits that cover the investments. However, the cost involved does not make these techniques suitable for cereal production but it provides an opportunity for smallholders to increase their income provided that credit systems and markets are available and accessible.

4.4 Increase Crop Yields

In areas where land rather than water is the limiting factor, the emphasis must be on improving output per unit area. Average crop yields increased rapidly from the beginning of the green revolution in the late 1960s to the mid 1980s, but the rate of growth has decreased since. This tends to confirm the long-held suspicion that yields are approaching their economic frontiers, especially in high-income countries. Here new technology is required to push out the yield frontier. Because such countries are typically strongly market-oriented, the private sector can be expected to provide much of the research needed to accomplish this.

Within the present level of technology however, there is still tremendous scope for improving land and water productivity in many countries, including several of those with large irrigated areas (India, Pakistan, and parts of China). In these countries, yields are rising but still show a considerable gap relative to potential. The key to increasing productivity in these areas is not the pushing out of the high-end yield frontier but rather increasing low-end yields through better application of current technology. Public investments are needed in basic infrastructure such as electricity and roads, reforms in governance regimes for irrigation, expanded rural credit, and encouragement of private sector entry into the field of irrigation technology supply. Reliable water supplies in these countries play a critical role in reducing risks to farmers, leading them to invest in higher levels of production inputs and capital improvements.

In Sub-Saharan Africa and certain other areas the green revolution has failed to take off, and yields are low and highly variable. Currently, access to technology and its affordability and appropriateness constrains yields. Bio-technical advances in salt tolerant, pest resistant, and drought avoiding and drought resistant varieties could make major contributions here. This last category might make the difference between a harvest and total crop failure in marginal rainfed areas. However, because of the limited market, such varieties are not likely to be developed by private firms, and, if they are, they may be unaffordable to poor small producers. Publicly funded research and development will be needed.

Improved and affordable water harvesting and supplementary irrigation technology can increase water availability and stabilise and enhance crop yields. Because the record of medium and large scale irrigation development in this region has not been good, emphasis would have to be placed on individual irrigation technologies such as shallow wells and small pumpsets or treadle pumps. In some locations, small locally-managed irrigation schemes can be developed.

It is important to consider the variety of livelihood activities engaged in by rural households in much of Sub-Saharan Africa, which can include rainfed agriculture, micro-scale irrigated gardens, animal husbandry, fishing, and off-farm employment. In addition to productivity gains, many local groups and governments in these regions aim for activities that add more jobs per drop. Development strategies must remain sensitive to the complexity of these arrangements and intervene carefully and sensitively.

Although the timetable for development may be extended, it is important not to establish development goals in this region that condemn residents to eternal subsistence. Ultimately, it will be necessary to make the necessary improvements in the larger economic picture – infrastructure development, human resource development, suitable economic policies, and so on – that will allow rural residents in these resource-poor environments to participate in the rise in standards of living occurring across the world at large.

4.5 Improve Productivity of Rainfed Agriculture

In rainfed agriculture, use is made of the water fraction that otherwise would have returned back to the atmosphere through direct evaporation and transpiration by non-food plants or percolated to the deep groundwater. Increasing the output of rainfed agriculture would make a significant impact in global food production. Development of low cost water and soil conservation technologies, which include water harvesting, soil tillage, mulching, bunding, and terracing could reduce the water risk and lead to increased input use and substantial increases in yields. This will only occur if the risks associated with variable rainfall are minimised and a certain level of insurance against droughts and floods can be provided.

Under certain agro-climatic and hydrologic conditions, farming can also be productive in marginal rainfed areas through supplemental irrigation to overcome short-term drought periods that are critical to the crop and reduce yield. Where there are cost effective ways to store water before critical crop stages and apply it when the rain is insufficient in these critical stages, crop production could increase considerably.

4.6 Expanding Cropped Areas

More production can be realised by selectively developing new cultivable areas. We envisions a very modest 0.25% annual increase in cropped area. On top of this, the loss of production capacity due to urbanisation, industrialisation and desertification needs to be compensated. Expansion of rainfed agriculture will often entail conversion of natural forests, lowlands, mountain slopes or marginal soils, resulting in ecosystem disturbance and increased erosion.

Irrigation offers the potential of achieving the ame production increment on less land,. However, in many regions the best sites are already occupied and development of new areas will be costly. In Sub-Saharan Africa there is still a significant potential for irrigation development, but experience suggests that development initiatives should focus on individual or small-scale farmer-managed schemes, rather than large government-managed infrastructure. The biggest absolute expansion of irrigated area will most likely occur in some of the biggest potential food importing countries and also in the exporting USA. If not accompanied by adequate environmental regulation, some of these developments will entail considerable environmental cost, since the water supply in the major river basins of these countries is already over-subscribed.

Sustainable irrigation development needs to be based on secure land and water rights, access to credit and other inputs and efficient markets. These conditions do not prevail in many parts of Africa. In the Mediterranean and North Africa region, expansion activities will be based on new water sources including the mining of fossil groundwater, projected water savings from improvements to existing schemes, reuse of municipal waste water, and expanded water harvesting practices.

In waterlogged lowland areas such as in South East Asia and Africa, expansion can be realised by providing drainage systems. Improved drainage in these areas will ultimately lead to some lowering of groundwater tables but may result in reduced streamflow during low flow periods. The scope for expansion is however limited as many of these areas are already reserved or claimed for wetland protection. Reclamation of salinised or otherwise degraded land already equipped with irrigation facilities should also be emphasised. Installation of drainage systems and improved water management practices could return large areas to productive use.

4.7 Food Security and Trade

Food security and self sufficiency

The FAO[33] defines food security as a situation in which all households have both physical and economic access to adequate food for all members and where households are not at risk of losing such access. Food security at national as well as household level can be achieved by a combination of local production, secured imports to make up deficits and effective food distribution systems. Ultimately, the principle determinant of food security is the purchasing power of the individual or household unit (Box 7)[34].

Food self-sufficiency, on the other hand, refers to the situation where all food needs are met through domestic production. National commitments to full self-sufficiency without relying on trade are made for political rather than economic reasons. It is a difficult and expensive task, and countries attempting it will become increasingly rare.

Box 4. Food security and self sufficiency in West Africa

...emphasis and goal should be focused on food security, but food self sufficiency should be pursued on an economically viable basis up to the limit of renewable water and other resources available to the Nations, without sacrificing on the rights and privileges of their neighbours and incurring non reversible ecological change.

A number of factors are eliminating the self-sufficiency option for more and more countries. First and most important is the shifting nature of global trade, and the growing prevalence of international trade in all kinds of goods, not only food. Other factors include reduced availability of water and land resources, labour scarcity, and insufficient returns to food crop production. Many East Asian countries, for example, enjoy adequate water and land resources, and achieved rice self-sufficiency during the Green Revolution. However growing populations and the strong expansion of higher-wage industrial and service sectors have led countries such as Malaysia to adopt a policy of only partial self-sufficiency, relying on imports for the balance.

Our vision, however, does not rely on international trade to fill the gaps in all food deficit countries. Food trade provides food security only if the importing country can afford to buy the food. For some Middle Eastern countries facing extreme water scarcity and sharp population increases, the strategy of substituting food imports for irrigated agricultural production (imports of "virtual water"), can be paid for through economic growth in other sectors [35]. But international trade does not solve the food security challenge in cases where the food imports are a result of agricultural and economic development that fails to keep pace with growth in basic food demand. In such cases, it may be impossible to finance the required imports on a continuous basis, leading to malnutrition and dependency on food aid from abroad.

FAO has designated 86 countries – 43 in Africa, 24 in Asia, 9 in Latin America and the Caribbean, 7 in Oceania and 3 in Europe – as low-income/food deficit countries. Ten of these are among the most populous countries in the world, including India, China, Indonesia, Pakistan and Nigeria. In all, 45 of these countries are on a course to double their populations in 30 years or less[36].

Africa has a long history of rainfall fluctuations with droughts of varying lengths and intensities. This has important implications for food security, as one good harvest may need to be stored over a period of several poor years. Africa's ability to earn from exports to buy food on the world market has not improved in recent years and this places many Sub-Saharan countries in extremely difficult positions in this regard.

Where imported food is available, distribution is often problematic because infrastructure for transportation and administration is inadequate. Moreover, people's access to food depends on their income. Currently, more than 1.3 billion people are absolutely poor, with incomes of a dollar a day or less per person, while another 2 billion people are only marginally better off. Income growth rates have varied considerably between regions in recent years, with Sub-Saharan Africa, West Asia and North Africa struggling with negative growth rates. In such regions people's own capability to feed themselves is of utmost importance. Rural development is essential and security, basic infrastructure, improved technology, and better land and water management practices are important conditions to achieve it.

International trade regimes in agricultural commodities

The IMPACT model predicts a rapidly increasing world trade in food, resulting primarily from the developing world's growing cereal imports from the developed world. The projected cereal imports by developing countries will increase, from 107 million ton in 1995 to 211 million ton in 2025[37]. Wheat imports will show the biggest absolute increase, almost doubling from 63 million ton in 1995 to 129 million ton in 2025 (Figure 8). The biggest increases in wheat imports are projected to be in the MENA region, South Asia and China as in these regions either water or land resources are constrained. In percentage terms the increase in exports of maize from developed to developing countries is the highest, from 30 million ton in 1995 to 68 million ton in 2025. Export of other coarse grains and rice also slightly increases until 2025.

To save water and to enhance the productivity of scarce water resources, high-consumption low-value crops can be imported and the water saved utilised for other more productive purposes such as high value crops that can be exported. Poor countries such as many in Sub-Saharan Africa, will have sufficient exports to pay for the imports. Import quotas, product quality regulations, and health and environmental criteria restrict export possibilities and make production of export crops unattractive or uncompetetive. Farmers must also make considerable investments in restructuring their farming systems to sell to export markets. Moreover, public goods such as production knowledge, quality assurance systems, and infrastructure and marketing systems needed to compete in global markets is often lacking. And for some commodities, a modest increase in international market supply may depress prices, raising production risks to unacceptable levels. A gradual shift to higher-value crops will likely occur if secure access to markets is negotiated and technology, inputs, and needed public goods are available at reasonable prices.

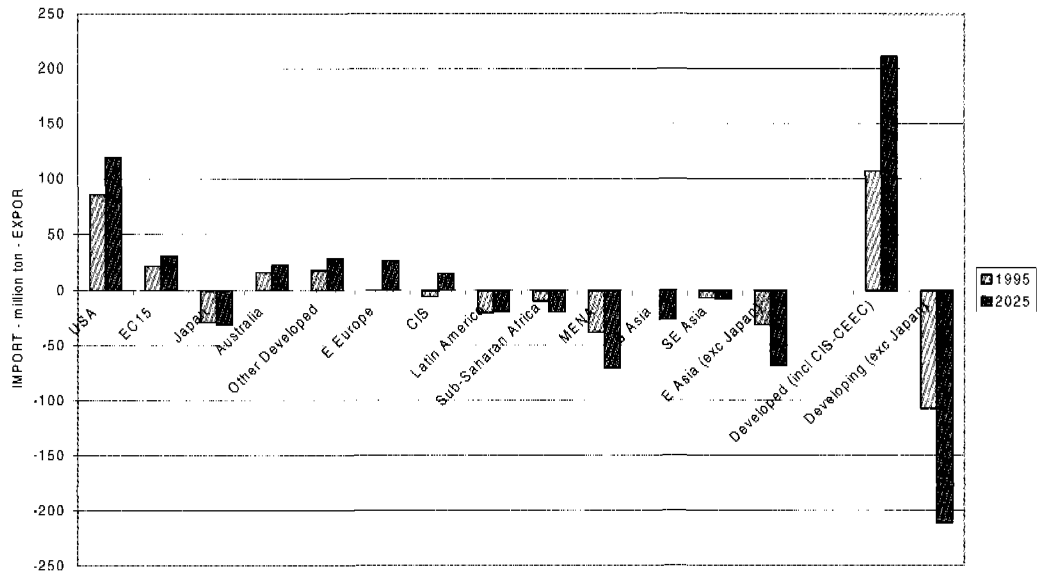

Figure 8 Cereal Import and export 1995 and 2025 – IFPRI base scenario

Countries in transition to market economies, particularly those in Eastern Europe and Central Asia that were a part of the former Soviet Union, are confronted with special problems. Saddled with irrigation and other infrastructure not designed with market oriented farming in mind, these countries are presently faced with a production cost structure that prices them to a large extend out of the market. Adjustment here must be phased.

In global markets irrigated staple food production will most likely be out-competed by the large-scale rainfed production systems in Canada, the USA, and Brazil. This is the scenario envisioned in the IMPACT model projections. To create an alternative outcome will require concerted efforts to improve competitiveness in other producing countries. For food deficit countries without alternative foreign exchange generation potential, international trade agreements should make provisions for a transition period, in coordination with national development strategies.

5 Water, Rural Livelihoods, and Rural Development

5.1 Introduction

Part of our vision is vibrant rural communities, in which all people have secure livelihoods and a reasonable standard of living, where women and men have effective control over their resource base, supported by responsive and service-oriented agencies. These two vital aspects of our Vision, sustainable livelihoods and a sustainably managed resource base, are now explored in this chapter and the next[38].

These rural communities are the guardians of the food supply, the water supply and the bio-diversity on which the increasingly urbanised human race depends. People living in mountain and hill regions are the first guardians of the water of river basins that rise in mountain areas. Those living and working in and around wetlands affect the ecological role of these locations. Those living in delta areas serve as managers of these vital food source regions and may be called upon for disaster preparedness measures to cope with the impacts of floods and droughts. Valuing the role of water in the livelihoods of rural people, who produce food, and maintain the systems for food production, is a central principle in water management for food and rural development.

Rural societies are dynamic entities, with change driven by a range of both local and external forces. Social relations, the potential and reliability of environmental resources, access to external goods, credit, markets and institutions, and forces such as population growth, industrialisation and economic change at local, national and global levels all determine the nature and consequences of change. Such change can bring many benefits, and indeed is the driver of development. It can also create negative impacts and uncertainties that dictate where development is not happening and create vulnerabilities that limit and undermine the livelihoods of rural people, and the poor in particular who have the least capacity to cope with such vulnerabilities.

5.2 Water Management, Rural Development and Rural Poverty Alleviation

In 2025 about 84% of the population in industrial countries and 56% of developing country residents will live in urban areas. This represents a dramatic change from the present situation and will result in a relatively static level of rural population in many developing countries. But rural water management will have to support this population distribution, and ensure that acceptable livelihoods and environments are available. In developing countries the importance of women farmers is increasing as fewer men farm, and women achieve greater rights and recognition. Some observers estimate that worldwide, women farmers are responsible for as much as 50% of food production[39]. Their responsibilities increase in Sub Saharan Africa and the Caribbean, where they produce up to 80% of staple foods. The introduction of new approaches and technologies to meet the demand for food requires womens' direct involvement because productivity improvements have to come directly out of their hands.

Profitable agricultural production and rural employment are engines without which poverty cannot be reduced, resources cannot be managed sustainably, and food security cannot be assured. This is particularly true in parts of developing countries where the poor are concentrated, food security is most at jeopardy and livelihoods are least able to adjust to local, national and international trends. There are many dimensions of rural poverty and food insecurity, including the effects of globalisation and the impact of many government policies. Our central concern here is on the relationship between the management of water resources and prospects for sustainable rural livelihoods, but these cannot be understood in isolation from this wide range of other factors that influence both.

The form this relationship takes varies greatly around the globe. In prosperous regions such as most rural areas in Europe, the wise management of water sources is part of a renewed concern for restoring the rural landscape and enhancing rural quality of life. In the transition economies of Central and Eastern Europe and much of the former Soviet Union, the focus is on re-invigorating rural areas for both agricultural production and for providing livelihoods, in the context of economic transformation. It is in the developing world, however, that maximising the rural livelihood value of water development is of greatest concern. How can the management of water resources support the livelihoods and improve the development prospects of rural communities in ways that do not jeopardise the integrity of these resources and the natural ecosystems on which those communities depend?

There are 1,100 million farmers in the world, of which 1,050 million are in developing countries. The majority of these farmers, an increasing number of whom are women, have limited access to external inputs and other productive resources. Resource poor farmers practice 60% of global agriculture and produce 15 - 20% of the world's food, but this farming sector is responsible for 80% of agricultural production in developing countries and is key to local food security.

For these resource-poor farmers, the improvement of agricultural production requires an improvement in access to resources. The heart of rural development lies in the management of natural resources, and in particular providing equitable access to resources, including water. Similarly, ensuring that all rural people have a voice in major decisions affecting their lives is a basic dimension of social development and is essential for the sustainable management of the resource base on which they depend. The basis of this should be a radical reform of the basis of water resources management in rural areas, with the goals of the reforms being to:

- create improved and secure rights at the local level to water resources
- ensure that mechanisms to avoid conflicts between competing uses exist
- develop sustainable management regimes in which the potential benefits of water resources are maximised in ways that do not jeopardise their long-term integrity
- develop institutions, based on existing social relations, that empower the poor to take the key decisions on the management of water resources

- provide the means (financial, technological and institutional) for the choices made by local people to be realised, including appropriate external support where needed
- reduce the vulnerabilities that come from floods, droughts and other natural hazards

5.3 More Local Value Per Drop: Production, Livelihoods, and Water Use

Our vision is to ensure not only food security, although this is certainly fundamental, but also to ensure that the development and use of water contributes to the improved security of livelihoods, access to gainful employment and new opportunities, and a quality of life that respects human values and the environment.

Box 5. Access to water is important for livelihoods because:

- it extends cropping options, and thus food, cash crops and livestock feed across the year
- it extends employment for families with and without land
- it improves yields and thus output, for home consumption and sale
- it may support crop diversification
- it can support more home gardens and small livestock close to the home
- it allows people more opportunities to exchange gifts of food and seed, to build social networks
- participation in water management committees widens people's social networks
- small farmers spend additional income locally, improving local markets for goods and services
- water rights may be exchanged and traded between groups to help people pursue livelihood diversification, and different income strategies at different times in their lives
- it can help stem migration, keeping families together, and keeping communities more active in a wider range of community and watershed management activities

For the year 2025, global food shortages are unlikely though malnutrition will persist due to limited accessibility to food. Smallholder production, especially in rainfed areas, will continue to be significant for local food security and in some areas also for export. A vital issue in these areas is to support smallholders remaining in agriculture who otherwise would be left landless and unemployed. These people should be provided more opportunities to feed themselves and to share in new food markets, by producing more, or produce better quality, through among others better water management. For small farmers, water management brings greater security, but will not necessarily bring a decent income from a small plot. Thus these people first need to gain more security through water benefits and then use their water as part of a broader strategy to support and develop their livelihoods.

Rural development programmes look in general at increasing income from land, through intensification of production, and sometimes also redistribution of land. Achievement of our Vision requires a new emphasis on increased value from every drop of water, with greater benefits for local people. The value of water is not simply the income it generates. It is also the security it gives, the number of people it supports and its role in maintaining the wider resource base. The conventional methods of agricultural economics for farm budgeting and modelling farmer behaviour are inadequate to show water value, and farmer responses to it.

Strategies to achieve the aims of more local value per drop include actions at farm-level, community level and national government and international level.

Action at farm-level

In recent years, there have been a number of key technology developments in different agro-ecological zones, for better management of water. However, new farmer-oriented research and development initiatives are needed for new water management technologies that give better local value.

More people can be employed per drop of water used in production. To provide opportunities for subsistence farmers or landless and unemployed, a redistribution of water and land rights may be needed. Ensuring options for participation by women and marginalised groups also provides opportunities for poor people to gain new access to water benefits. Indeed, irrigation and drainage development by itself can offer improved employment security to landless labourers by evening out demand for agricultural labour over the entire agricultural year, as compared with the few intensive periods of labour demand at planting and harvesting in rainfed areas. These changes can also contribute to the development of more diversified, secure livelihoods in which farming is part of a wider range of income opportunities in which the vagaries of climate and agricultural conditions are 'buffered' by opportunities off the farm.

Action at the community-level

Water development that allows increased agro-processing before marketing, for example locating facilities near irrigated areas, also increases the local value gained from water. Water systems as well as agricultural support services can be oriented towards opportunities for agro-processing. New community-based resource management processes are also needed. In particular, actions to secure the integrity and develop community control of common property resources, including many water resources, and to develop equitable water allocation mechanisms are essential.

There are examples from around the world where communal resource management is practised. Indeed it has been the foundation of rural societies for thousands of years. Communal management is particularly important in areas where wetlands, mangroves, rangelands, forests, or irrigation systems play a major part in the livelihoods of the poor. Traditions of communal resource management, and the knowledge on which they are based, are eroding in many areas as rural economies are commercialised, resources are privatised and government control replaces community control. There is a need to reverse these trends and to find strategies that maximise the benefits of traditional community controls whilst mitigating the inequalities that they can bring.

Better services for production remain critical for future food production and increased value from water. Private sector investment in agricultural services is already substantial, in the form of contract farming, marketing, provision of inputs like seeds, fertilisers, pesticides and equipment, agricultural repairs and specialised cultivation services. There are many new opportunities for entrepreneurs to take up roles left by the withdrawal of governments from service provision, including input supply. However, it is difficult for individual businesses to thrive in smallholder areas where purchasing power and equipment investment is limited and credit schemes are inadequate. Civil organisations (e.g., producer organisations) thus need to be promoted to help provide or coordinate the necessary supply services.

Actions at government and international level

Governments play and will continue to play a critical role in rural development and resource management. Governments define the legal, policy and institutional frameworks within which water resources are managed and rural economies and societies function. These frameworks can include both the laws that mandate or limit water rights and institutions and indirect influences such as macro-economic policies and subsidy regimes. Government agencies are directly responsible for many aspects of water and rural development services, including establishing and running irrigation and water supply schemes, agricultural and other extension services, education, health and social development programmes and others. All have a huge impact on rural resource management, community development and livelihoods sustainability. The effects of all of these arenas of government actions need to be taken into account in defining the future trajectories of rural livelihoods development and water resources management.

Governments also implement most large infrastructure schemes, often with substantial overseas development assistance. Whilst recognising the great benefits many major water projects have created, there is a growing awareness of negative side effects of water development, both social (e.g., displacement of rural residents from reservoir areas) and economic (the opportunity costs of expensive water infrastructure in terms of alternative benefits that could have accrued from the same level of investment in other kinds of activities). The issue of water-related debt is emerging as a reminder of the high stakes involved in high cost infrastructure development. To achieve the Vision, there is a need to ensure that such projects and their impacts really do contribute to the development of these regions and to the reduction of their 'water debt', rather than adding further to debt problems.

5.4 Water Management and Poverty Reduction

Water projects can bring many positive changes to the lives of poor people, and can work particularly to improve the lives of rural women. Small farmers greatly value additional water supplies for the increased security they bring. However, many pro-poor programmes have not pulled farmers out of poverty as originally hoped. Where holdings are very small, increased water supply may still be insufficient to give a family income above the poverty line, as market conditions leave them with a stagnant or declining income. Adverse tenancy and power relations in a location, or poor water reliability can also limit impacts of water development for poor people. Inappropriate design, poor construction, and insensitivity to gender imbalances and social differentiation also limited impacts of smallholder irrigation intervention. Because of the adverse power relations, small farmers may need assistance from outside organisations (both governmental and NGO) to help them gain access to technologies they can manage, join in new partnerships with the private sector, or become entrepreneurs themselves.

Pro-poor policies in rural water development can be made a key dimension of water development related to resource mobilisation, rural institutions, irrigation systems and rainfed areas. When mobilising new resources, policies can include pro-poor allocation systems. Governments and civil and private organisations can choose to encourage new small landowners on all new irrigation developments. Another major tool is to recognise the claims of unregistered, and hence, 'illegal' water users. Some of the new approaches within the water sector which show promise in helping alleviate the underlying causes of rural poverty include:

- *Restructuring irrigation systems.* The renovation and modernisation of irrigation systems can provide more benefits to the poor and entails a mix of technical as well as institutional reforms. Bringing the poor into the dialogue about system priorities and performance can yield new ideas that can benefit all stakeholders
- *Improved design and operations:* Working with more participatory consultation processes can show inequities in water distribution, and possible steps to improve performance. Such consultation can increase understanding of options during water-scarce periods when poor irrigators and female irrigators may find it especially difficult to obtain water. For example, flexible cultivation rights can re-allocate irrigable land to tail enders during seasonal water scarcity
- *Extending new water availability to the poor.* When rehabilitation improves the water supply of systems, new water rights can be given to the poorer people or those without irrigation. Examples of such 'pro-poor' extension of irrigation systems can be found in Nepal and Peru
- *Linking irrigation management transfer (IMT) to service improvements:* IMT programmes offer new opportunities for representation. Both small-farmers and women can be given better opportunities for participation. This can take the form of negotiating new water rotations that give greater equity between the head and tail ends of an irrigation system, or recognition of domestic water needs as a legitimate objective of an irrigation system

Livelihood improvement through drainage and flood control

Drainage and flood control have been used extensively as an instrument for rural development all over the world. Drainage can create better opportunities for agricultural development and it also provides better sanitary and health conditions in rural areas. There are also many measures available to mitigate the devastation that floods and storms can bring like early warning systems, and safe refuges for people, livestock and vital possessions.

Livelihood security in rainfed areas

Many of the poorest rural communities are found in rainfed agricultural areas, where cultivation conditions are often more marginal, rainfall is variable, infrastructure, services and market access less developed and all conditions are far less suitable for the 'Green Revolution' style packages that have transformed agricultural production in more favoured areas. In these marginal areas, farming is based on the ability to maximise the benefits that come from rainfall and soil moisture, which in turn means that water development needs to aim to retain and use as much of this scarce resource as possible. This can happen on-farm or be augmented by community-level structures such as small check dams in water courses that retain rain waters. Farmers around the world have developed systems to 'harvest' the rainfall they receive. There is great scope for improving both rain harvesting and on-farm water management, through both these 'low-tech' traditional approaches and through 'high-tech' innovations such as drip irrigation. At times, the introduction of new cropping options (including tree crops that are less susceptible to seasonal rainfall variations) will be the best option. In these and other ways, there is tremendous scope for addressing the uncertainties that undermine development prospects in rainfed areas.

In semi-arid drought-prone areas, additional institutional measures can also help poor farmers survive drought, and recover after drought. Crop insurance schemes are one option, together with assistance schemes that help recover productive assets that they may have lost during a drought. Employment schemes during drought, especially those incorporating soil and water conservation measures, can also keep poor people resident and better able to revive production after a drought. In wetter areas, a focus on integrated environmental management, bringing together flood control, drainage, soil and water conservation and afforestation can help all farmers produce more and withstand natural disasters.

5.5 Water Rights, Human Rights, and Future Uncertainties

The stakeholder consultation process has shown the demand that access to water for food security be treated as a basic human right. To address this issue, and achieve the Vision, action is necessary on the fronts of inequity and injustice. There is also a need for this basic but controversial concept to be formally adopted at a policy level.

Social equity for marginalised groups

In the past, some countries undertook large-scale redistribution of land and water rights, breaking up large holdings to give land to small farmers and labourers. However, the economic and political ideologies that drove such reform are no longer current and radical reform is unlikely. What is more critical at this time is a 'pro-poor' policy that helps the poor, and particularly indigenous groups and ethnic minorities, to defend their rights within the context of water rights consolidation and sectoral transfers that will emerge from contemporary economic policies.

Historically many indigenous societies lost not only their land rights but also their water rights under colonisation and colonial resettlement plans. Following Independence, inequities often persist along ethnic lines, where governments are dominated by ethnic elites. There have been some major advances in the reclamation and protection of water rights of indigenous or disenfranchised peoples. Actions by native groups in North and South America have proven the effectiveness of concerted action to appeal against 'inequitable' water reform legislation. Demands for 'equity' and 'justice' have also increased recognition of indigenous practices in design, operation and administration of water systems, and opened an important debate about dominant paradigms in engineering design and legal reform. In the Andean region, local groups have challenged new 'modern' irrigation scheduling arrangement that threaten their irrigation rights and flexibility of operations, and the security of priority food crops. In

Box 6. Registering Customary Water Use

The Government of South Africa recently adopted a national water law, that vests water rights in the persons who use the water productively on a certain portion of land, irrespective of the land rights of that person. This law will benefit women specifically. Claims on urban irrigation possibilities have attracted special interest as a means to help the urban poor. By forming a co-operative, 'illegal' urban irrigators in Addis Ababa, Ethiopia were able to get rid of their 'squatter' identity. The co-operative acquired assets for irrigation and marketing, made a significant contribution to vegetable supply in the city, and their supply was highly rated for both freshness and variety.

countries like Zimbabwe, Tanzania and Kenya, new conditions of legal pluralism, and new recognition of customary and tribal law, are providing a basis for new interpretations of water rights.

The emergence of larger-scale systems, whether using surface or groundwater, can lead to the concentration of control over water resources in the hands of a relatively few larger, more powerful sections of rural societies. They have also, in places such as much of India and Bangladesh, led to local 'water markets' in which the owners of irrigation technologies sell water to other sections of the community. These developments have led to emerging inequalities in access to water for food production and even, in extreme cases, to local monopolies in which the poor are excluded altogether. Addressing these issues of access to and rights over water is vital for the poor in such areas.

Globalisation of trade brings in a new set of uncertainties as well as opportunities. As markets open, the production of some agricultural areas may become uncompetitive, while new, previously unforseen export markets may emerge. The rural poor are at a particular disadvantage on both fronts: competing in export markets in the context of international quality standards and bulk-marketing, and in identifying and responding to new market opportunities, which requires access to investment and information.

Women food producers, who play a vital and increasing role in food production in many countries, face an additional set of challenges. In many countries women still have no formal rights to own land and hold water rights in their own names. In irrigation systems in particular, women often cannot register as holder of irrigation plots, and it is difficult for them to retain any rights as female-headed households if they become divorced or widowed. Women also merit better access to decision-making roles in governance and general administration of water resources, at both local and basin level, as well as to jobs in operational system management.

5.6 Complex Emergencies in Water Management

Just as water scarcity is a problem which can reach emergency proportions, water availability is often a key part of the solution to alleviating crisis. In 2025, the world will continue to be marked by many types of emergencies where targeted water development can play a short-term life-saving role. Currently the world is still affected by war, and disasters and shocks, that often come together to create 'complex emergencies'. The need for international action to prevent war over water is self-evident.

Humanitarian aid

Emergency relief can address immediate food and housing problems, but longer-term problems of employment and food security are problematic after emergencies. An influx of refugees can disrupt existing arrangements for agricultural employment and land tenure. They also change local market for foodstuffs. Some relief agencies have sought to develop small and currently unused water sources for small-scale irrigation projects for refugee settlements. These provide options without high infrastructure costs, should the refugees be able to return. Others have sought to generate new forms of employment for refugees, sometimes in construction of public works, and sometimes in assisting agricultural employment.

Coping with droughts and floods

Droughts and floods are found throughout the world, but disproportionately affect the poorest and most vulnerable whose livelihoods are least secure. Drought is particularly a problem for food production for many poor people. It occurs in most regions of the world, but reaches its most dramatic and disrupting forms in the semi-arid and drought-prone regions in Africa, South America and Asia. Floods and major storms such as cyclones can also destroy crops and sweep away years of investments in agriculture. During the last three decades, many people have lost livelihoods once based in agriculture, and there has been widespread famine, malnutrition and migration. The UN Convention to combat desertification has programmes for action, on which there can be added action around water. Options include:

- strengthening the knowledge base and developing monitoring systems on drought and desertification
- integrated action on conservation of water, within agriculture, forestry and land and water management
- studies for water deployment to livelihoods of the greatest local value. In some areas this may be small industry and agro-processing, or tourism

There are also many measures available to mitigate the devastation that floods and storms can bring. Perhaps the most important of these are disaster preparedness systems, including early warning systems, safe refuges for people, livestock and vital possessions, effective disaster relief measures and structured assistance to aid with post-disaster recovery when livelihoods have to be rebuilt and assets re-established.

5.7 Conclusion

The issues associated with water, livelihoods and rural development have many dimensions and vary tremendously from place to place. In many parts of the world, great progress has been made in the last two generations to relieve the rural poverty and deprivation that many saw as the inevitable lot of the human race. In other areas, formidable challenges still remain. Experience over these two generations has told us that successful rural development reflects a complex range of factors, but also that one key element is the effective and sustainable management of the local resource base. This resource base, and especially the water resources within it, are vital to both the current livelihoods and the future prospects of the poorest sections of the global community. Concerned and effective actions to preserve and enhance it, to ensure that local communities (and especially the poor) have secure access to and control over it and to develop improved systems for its sustainable management are the foundation of rural development. This in turn will both enhance the lives and livelihoods or rural communities and ensure that the food and other rural products on which the rest of us depend continue to be available.

6 Institutional Dimensions of the Water for Food and Rural Development Sector

Progress in using water more effectively to serve the interests of food and rural development, will not come from technological innovations alone, nor from policy pronouncements. Ultimately it is people who produce the food and make use of the water – the farmers, labourers, and rural service providers – who implement rural development. Our vision calls for an enabling institutional environment in which rural livelihoods are enhanced and agricultural and water productivity is improved, as a result of farm families actively pursing their individual interests. What kind of institutional arrangements can support the enlightened self-interest that can drive the rural socio-economy?

In many countries an urgent need is expressed to develop a healthy institutional framework for water resources development and management and provision of other water related services. The complicated process of establishing such frameworks is tied to the larger processes of economic liberalisation and democratisation at work in society as a whole. Assumptions about the role of government and private sector organisations have changed dramatically in the past decade. As we look ahead to the first quarter of the next century, it is almost certain that the debate over public versus private sector roles will continue to be lively. However, the development of the potential requires more accountable and service oriented support institutions that, whether they are public or private, operate as close to their client group as possible.

6.1 Institutions, Technologies, and Policies

By "institutions" we refer to the many types and levels of organisations, associations, agencies, in both the public and the private sector, and the rules, policies, and legal frameworks which govern their behaviour. In more concise terminology, "institutions" refers to both organisations and rules. Policies are often included within discussions of institutions, but policies alone cannot create organisations, nor can we assume that policies will take the form of effective rules. Policies may be ignored, or may simply be irrelevant to actual conditions. For example, pronouncement of a policy to transfer management of irrigation systems from a government agency to user associations must be grounded in real organisations (e.g. water user associations) and effective rules (e.g., rewards/sanctions if transfer is, or is not, carried out). If these or similar conditions are not met, the policy has no effect; it cannot be "institutionalised".

Technologies also depend upon institutions in order to be utilised effectively. For example, precision levelling of fields has the potential for significant water savings through carefully controlling the amount of water delivered to the crop. But applying this technology to actual fields requires a complex set of institutional responses: an agricultural extension service to create a demand for these services, training capacity to train the operators, market infrastructure to ensure availability of the equipment and spare parts, and financing arrangements that allow farmers to make the investments over a period of time.

Institutional arrangements set the incentives governing water use and infrastructure investments, and provide forums for water users to participate in the decisions that affect their lives. Thus, institutions have a role to play in both improving the physical productivity of water, and improving the social and livelihood benefits to farm families. In our Vision these institutions have a user or client focus and especially in the least developed countries a livelihood orientation. This means devolution of decision making to users who have the possibility to fully participate and to control these institutions which govern the water resources on which their livelihoods depend. In addition to the direct water users, the public at large ("civil society") has the right of access to information related to these decision-making processes. This requires management processes at all water management levels that are user-oriented and transparent with effective accountability mechanisms in place.

6.2 Key Principles

There are four key principles that define the institutional trends we foresee in our Vision for 2025. Taken as a group, these four principles describe a qualitatively new relationship between farm households and the state. In our Vision, farmers and other end-users of water have a voice in decisions about the water resources on which their livelihoods depend. The four principles are:

- *subsidiarity*. Following the principles outlined in the Dublin statement, decisions on irrigation and drainage investments and practices should be taken on the lowest feasible level. Often this is at the level of local governments or even at the level of water user associations or federations. The trend towards decentralisation is likely to continue through the coming decades, although paradoxically, the role of centralised policies and regulations will also become more important, even as decentralisation is taking place in routine management functions
- *participation*. In nearly every aspect of development, the participation of stakeholders including women is gaining recognition as a vital ingredient for social betterment along with economic efficiency. In the irrigation and drainage sector, participation in decision-making regarding new investments, as well as planning and routine operations and maintenance, is becoming standard practice. Although there may be great resistance from entrenched interests, our vision anticipates that direct and indirect management participation of farmers will increase steadily, and will be accompanied by a restructuring of conventional irrigation and drainage agencies, and by new roles for NGOs and private companies
- *accountability*. New expectations are emerging that the agencies or organisations charged with irrigation and drainage regulation, management, investment, or other services should be held accountable to the end users of those services and to society at large. While this vision does not anticipate an end to financial mismanagement and malpractice by 2025, we do anticipate a re-working of institutional structures that will encourage open dialogue and decision-making. The participation of users

will provide a check on government agencies, while new regulatory functions of government will provide a cross-check on user groups

- *transparency.* Information about investments, contracts, water allocation, staffing levels, etc. will help support the principles of accountability and participation, and counter the incentives for malpractice. Transparency about water use by competing sectors (e.g., power, industry) as well as water quality and pollution sources will become increasingly important as water competition increases. The profound advances in access to both global and local information via the Internet offers the potential for transparency, but this must be combined with education and public awareness to create a demand for transparency

6.3 Relevant Agencies and Organisations

While most countries have a single nodal agency charged with irrigation and drainage-related functions, such as a Department of Irrigation and Drainage, there are many other agencies and organisations at national and local levels which play important roles in irrigation and drainage development. These often include departments of agriculture, water resources, rural water, rural development, planning, finance, etc. On the local level, village or district governments may be directly involved in irrigation with only indirect support from central line agencies. Outside the government, other organisations are concerned with irrigation and drainage like professional associations, NGOs, research institutes, training institutes, consulting firms, and private companies.

Direct management of irrigation and drainage systems is in many developing countries normally the responsibility of a government department, which controls the network down to the local level. Between the level of the government department and the individual farmer, most countries recognise the role of water user associations as legal entities charged with local water distribution and maintenance.

The role of Water User Associations in developing countries

Local associations of water users serve the same functions as irrigation agencies, but on a very localised level. In some countries such as Nepal and the Philippines, the major portion of the irrigated area is managed locally, through village-based water user associations. Typically such associations manage very small irrigation canals that were constructed by the users, perhaps centuries ago, and the associations have grown up around the need for operating and maintaining these canals. In many developing countries such traditional canal systems have been the target of modernisation efforts by government agencies, often funded through international development assistance. The relatively crude physical infrastructure of many of these canal systems was rebuilt and absorbed into the domain of the government agency, which replaced the management functions of the indigenous water user associations.

Today, local water user associations are recognised as resources of "social capital" which will have an increasingly important role to play in the coming decades. Instead of absorbing such associations into the state organisation, the capacity of associations is developed so that they can improve the performance of their own irrigation and drainage systems. This participatory approach was re-invented in the Philippines in the 1970s and has since evolved into a global trend that combines participation with various degrees of privatisation. In many developing countries a major focus of this process is the institutional challenge of establishing new water user associations which can serve the management functions previously handled by government. In Mexico, for example, the government has transferred the management of most of the 82 irrigation districts to newly created water user associations formed under the terms of the 1992 water law (see Box 6)[40]. The expectation is that these associations will be more responsive to the water needs of their farmer members, resulting in higher productivity at lower cost to society and to their client-farmers.

Box 7. Irrigation Management Transfer in Mexico

In the mid 1980s when Mexico was in the throes of a debt crisis, the government was broke. The large irrigation districts under Federal control suffered as maintenance was deferred and the productivity of unpaid, demoralised engineering staff declined. Out of necessity, the government reorganised the state irrigation agency to create the National Water Commission, or CNA in its Spanish acronym, with a mandate to turn over the management of the irrigation districts to associations of users created specially for this purpose.

In 1990, Mexico transferred the first irrigation district to the users. By 1995, more than two-third of the country's 3.2 million ha network - divided into 80 irrigation districts, had been transferred to 316 irrigation associations. The transfer program was initially in the most productive irrigation districts, which were best organized and with the most commercially oriented farmers. The most important criterion for selecting districts was the potential of the user organisation to become financially self-sufficient, with users paying the fees to cover the costs of operation, maintenance, and administration.

What could the government offer the farmers as an incentive to accept higher costs for their irrigation? In fact, there was a carrot as well as a stick. The carrot was management autonomy. The farmers would be free to set their own rules for when to clean the canals, and how to distribute the water. The farmers would hire their own technical staff - engineers and accountants - to run their system. The canal would be theirs on a 20-year concession, which is in practice a transfer of ownership.

But there was also a "stick". If farmers refused to take over management, the government could offer no assurance that the canal network could be kept in repair. The government in effect threatened to default on its conventional understanding with farmers regarding levels of subsidy in the irrigation sector because it no longer had the financial means to do so. The government, however, also promised and provided technical, organisational, and legal assistance in realising the transfer.

Drainage associations have existed since long in many developed countries but are still rare in many developing countries because drainage systems in these countries are not as widely existing as irrigation systems. Drainage associations generally are not only involved in with the management of the system but also with the development. The merits of combined irrigation and drainage associations is still a topic of debate.

New rural institutions for water management and poverty alleviation

The withdrawal of many state agencies from local water management will bring new roles for civil society. New associations are emerging to run community irrigation systems, farmers' organisations and catchment committees. They provide a collective need or service that also brings benefits back to that community. These new civil water associations have great potential to protect the interests of poor producers, and engage them within other collective actions to improve livelihoods, e.g., in organising the purchase and marketing of goods.

Groundwater marketing groups. Irrigation systems can be developed and managed by the land poor if they are supported to take opportunities to become water sellers. Competitive water markets that give choice to water buyers can help the poor, but this requires flexible legal arrangements that allow companies to form and reform and change their activities to help the growth of new water supply services. The long-term prognosis for competitive and affordable groundwater markets that help the poor faces uncertainty, unless public action can regulate groundwater use and energy supply in ways complementary for sustainable water use and equitable access.

New catchment organisations. In many countries, catchment-level councils are being established as a means to negotiate water rights and responsibilities across competing sectors within the hydrographic unit of the catchment. Under the South African Water Act of 1998, Catchment Management Agencies are formed with considerable stakeholder participation and efforts to include poor men and women. These newly forming catchment councils face some financial and technical challenges, but their increased importance seems assured.

6.4 Reform of irrigation and drainage agencies

Towards a service orientation

The irrigation and drainage organisations in many developing countries, which typically have a monopoly control over major irrigation and drainage systems have become targets of reform because of widespread concern about the financial sustainability and management effectiveness of many of these organisations. Investment costs for developing public irrigation and drainage schemes are almost always partly or fully subsidised and recurrent costs of operation and maintenance are insufficiently recovered directly from users, resulting in a regular drain on government recurrent budgets and deteriorating infrastructure. Weak systems of accountability encourage endemic financial malpractice, defective construction, and frequent rehabilitation. The incentives are typically perverse; the problem can be characterised as the lack of an appropriate management framework based on principles of user- or service orientation, financial self-reliance, accountability and transparency (see Box 7)[41].

Under pressure from government leaders, farmers, and international finance agencies, irrigation and drainage agencies are undergoing a transformation in functions and roles which will result in a very different institutional picture by the year 2025. Some agencies will remain structurally similar but will adopt a 'service-orientation' providing a range of services on request, from water deliveries to agricultural extension and information[42].

After proven successful, other agencies might follow by withdrawing from the local levels of management and transfer these functions to water user associations and federations of associations.

A third option will be to out-source services to private sector providers, with the government role focusing on the regulation and monitoring of the services.

Box 8. Introducing Service Oriented Management

Introduction of service oriented management involves a process of identifying, designing and implementing the technical and institutional modifications needed for sustained operation of the system on the basis of an appropriate set of service arrangements and organisational charters. The ability to enforce the agreed service standards is crucial to ensure service delivery and compliance with its specifications and conditions by the parties involved. This requires the development of a mutual dependency – e.g. service for payment – that can take various forms including service agreements. These provide a detailed description of services to be provided, payment in return for services, monitoring and verification of service provision, consequences of failure to comply with agreements by both parties and rules for arbitration of conflict.

The service needs and expectations of the farmers will be influenced by the price they have to pay for those services, especially where they have to pay the full cost. Recognising that services can be provided in different ways using different levels of technology at different levels of cost, service-oriented irrigation management would thus require a mechanism to ensure that the services needed by farmers are provided at the lowest possible cost. Consultation processes, clear service relationships, transparent administration and accountability mechanisms are among others conditions that have to be put into place for the introduction of effective service-oriented management.

Water rights

Clear, objective and transparent systems of water rights are a first condition for reliable services and accountability. One of the elements to be considered is the social function of water, especially the protection of rural poor. Such systems, especially if water rights are tradable, require appropriate administration for planning purposes but also to protect society and the poor against undesired market effects. Undesirable inequities in access need to be corrected so all users, including women, gain similar rights.

Reliable systems of property rights for water are important precursors to orderly transfers of water among users and uses. Such property rights regimes, and mechanisms for transferring rights, are in place in Chile, and are evolving in California and elsewhere in the western USA. In other locations, such as Luzon in the Philippines and Tamil Nadu in south India, transfers are taking place on an ad hoc basis as major urban concentrations simply appropriate water resources from peri-urban areas. Such appropriations have major equity implications and can destroy livelihoods based on previous uses of the resource. Secure property rights and transparent market-oriented transfer mechanisms can protect current users and encourage and facilitate transfers to higher value uses.

Cost recovery, service fees and water pricing

Service fees provide a means of financing water services and is an essential element in service – client accountability mechanisms. Cost recovery schemes need to be designed in relation to social and political conditions.

Towards Integrated Water Resources Management Institutions

Managing water for food production competes with other water using activities and is therefore part of a process of basin level water management. The higher the degree of water use and water scarcity, the more urgent the need for an integrated approach of water management. Though in some developed countries already established, in many countries this integration is still constrained because of the fragmentation of water management responsibilities among different institutions (Box 8)[43].

To optimise the productivity of water and to reduce the possible problems and conflicts between the different interests and stakeholders a platform is required for coordination of water use, water allocation, pollution control and in some cases flood protection. Solving these problems requires establishment or changes of water use rules and quantity and quality standards. It also involves the development of a required capacity for co-ordination, planning, decision-making and policing of water use and users and pollution both in surface and sub-surface water systems. This platform should represent all interests so all stakeholders should in principle, have a voice in decision making. To protect the interest of society at large this platform would have to be under governance of government and should have planning, decision, control and sanctioning powers. This basic function is to be executed at (sub-) basin level and to be effective it requires[44]:

- a decision making capacity on (sub-) river basin level that reflects the interests of different uses and users
- a clear regulatory framework with norms and standards for decision making
- a system that provides reliable information on the availability, use and quality of surface and ground water in the (sub-) basin
- a system that allows analysis of several scenarios for development and use of water at basin level
- an effective and transparent accountability mechanism
- power to control and sanction violations
- sufficient capable people to meet the integrated water resources management (IWRM) demands on coordination, planning, development, management, and control

To make this possible an enabling environment has to be created based on adequate water and institutional development policies, including human resource development and backed by the necessary normative and executive legislation. These higher level actions are important because this is the only way access to decision making processes

Box 9. Europe's Vision on Organisational Structures

Sustainable management of water resources requires an organisational structure, which is responsive to the needs of society and the users, and is financially autonomous. This can be achieved by service oriented management where agreed levels of service are delivered at the lowest associated cost. Consultation processes should lead to clear service agreements, which form the basis of the accountability mechanisms between service providers, users and society. Clear performance monitoring systems must be brought in place. Decision making and financial management must therefore become completely transparent. It is evident that the management responsibility and the control functions must be completely separated.

With service oriented management the principles of subsidiarity and delegation of tasks should be materialised. This means:

- that tasks which can be executed on a subordinated level should not be claimed by a superior administrative level
- that tasks which can be more efficiently executed by private facilities, should not be assumed by the public administration

by the stakeholders can be regulated. Moreover, ineffective rules, accountability and policing mechanisms assure that water use and control problems cannot be solved.

6.5 Roles of the Private Sector in Managing Water

Private sector participation in the water sector is most developed in the hydropower and water supply and sanitation sub-sectors. In the irrigation and drainage sectors the private sector is at present often limited to involvement of contractors, consultants and manufacturers for temporary projects. The degree of involvement or participation of the private sector is distinguished in terms of ownership of the infrastructure, the identity and legal status of the system operator, and where applicable the ownership of the shares of the operating company. Three main types can be distinguished: delegated private management, direct private management and public limited companies.

Delegated private management or concessions is outsourcing of construction, operation and maintenance activities to private firms or farmers and farmer groups. The direct private mode refers to water utilities that are both privately owned – companies with profit orientation with shares that can be traded on the stock exchange - and privately managed.

The public-owned Public Limited Company (PLC)[45] refers to a mode of organisation where local and provincial government representatives and stakeholder groups like banks and producer associations own the utility's infrastructure and the (often non-tradable) shares of the company. The operator (PLC) is an autonomous for-profit organisation falling under commercial law. The public water PLC is different from delegated private management (concessions) in that the operator is owned by public rather than private shareholders. Furthermore, the public water PLC is mostly a permanent concessionaire where under delegated private management it is a temporary concession-holder. The public water PLC also differs from direct public management in two important respects: consumer influence and autonomy. PLC's are quite common in Western Europe and in the United States. Though they are rare in the rest of the world, examples in water supply can be found in the Philippines, Chile, and South Africa, among others.

In this vision, the role of the private sector in managing irrigation and drainage systems will besides outsourcing, progressively increase, especially in those areas where users are charged for the full costs of the operations. The mode of operations will differ from place to place but, as irrigation is for many countries of crucial strategic importance, society needs to maintain control over the managers. PLCs provide a good opportunity and their applicability in irrigation and drainage could be more.

Non-government involvement in irrigation and drainage services

The trend to transfer service functions from government agencies to civil groups and private companies will likely accelerate over the coming two or three decades, posing potential benefits and dangers to the poor. On the benefit side, greater transparency and better access to water may materialise as private company management replaces public sector service providers. On the danger side, the poor will require regulatory protection from the state to guard against potential exploitation from profit-seeking service providers who would normally enjoy a monopoly on irrigation services (as is usually the case when farmers have only one source of irrigation water). The challenge will be to harness the management incentives of the private sector within the regulatory security of the public sector. A critical factor will be the strength of local management and service agreement required from commercial private sector involvement.

6.6 Regional Collaboration

Economic development in countries sharing a single river basin is usually highly interlinked, especially if droughts and floods disrupt economic activities. Regional collaboration is necessary to realise different inter-related aspects for water, food and rural development and to optimise the productivity of the available water, land and human resources.

The sharing of surface and groundwater resources, the development and use of storage, and the management of floods and droughts are a first concern to many riparian countries. This involves establishment or strengthening of governmental and non-governmental organisations (research and development, professional associations, think-tanks) and the development of regional river basin authorities involved with or responsible for planning and management for international rivers. Common political approaches and measures for preventing transboundary water pollution also need to be developed and adopted and finally the consequent rules and financial conditions for common water use and its monitoring should be adapted. Sharing of data and relevant information is a first and very important step towards such collaboration.

Optimising cross boundary water productivity also concerns the development of interstate water or agricultural agreements on the basis of most suitable agro-climatological zones for major (food and fibre) crops. This may be attractive in regions in one major river basin where the economy is still insufficiently developed to afford major food imports. Moreover, it provides an opportunity to protect the rural development initiatives based on agricultural development against international or global competition local smallholders never can compete with. Such approaches can only be realised if there are regional trade agreements on the most important crops. Such arrangements are proposed in Central Asia, South Asia, West Africa, and Southern and Eastern Africa. Local production is to be stimulated by for example removing duties on crops imported from the region. This comes very close to the development of a common agricultural market, which is being seriously considered in among others Central Asia and West Africa.

6.7 Regulatory Responsibilities

To ensure that the interests of society at large are respected and well taken care of, the delegated management authorities have to be well embedded in a framework of regulation and legislation. Devolution of management puts a heavy burden on government capabilities to legislate, regulate, control and sanction. It is, however, easily overlooked that government needs to have the capacity to prepare these regulations, to monitor and police the implementation and to update the regulations as necessary. This requires highly qualified and skilled staff that to attract these people, requires labour conditions and career opportunities compatible with the private sector.

For a regulatory function to be performed well it requires a system that enables effective development and implementation of laws and regulations, enables all stakeholders to participate in decision making and provides effective and transparent accountability mechanisms. This always should include the consideration of strengthening of the judicial system as an ultimate resort for conflict resolution. Without an accessible and reliable judicial system, no reform based on principles of participation and democratisation, can be successful and development efforts may be ineffective.

The developed world has largely completed development of its water resources, unlike the developing world, which has still a long way to go. Unfortunately, many conflicts and controversies are plaguing these development efforts. Removal of these obstructions require well designed conflict management mechanisms without which the vision will not materialise.

7 Regional Variations

To meet the effective demand for food products in the next century, food production and consequently water withdrawals for agricultural uses need to increase substantially. To meet this demand pattern in an efficient, equitable, and environmentally sustainable fashion will be a major challenge, especially for many developing countries in the coming decades and may require fundamental changes in the way water is allocated and food is produced. These challenges will be different for each region and will be importantly influenced by their levels of water scarcity and economic development.

The strategies for the different regions should relate to the direction, strength, and relative effects of growing water insecurity across countries and regions. They should focus on the potential and feasibility of increasing the productivity of water, introducing (new) water-saving technologies, and generating the necssary levels of investment in infrastructure and management. In addition, reforms in trade and (water) pricing policies can have substantial impacts on the future of water security in many regions. Reforms in the institutional and legal environment can empower water users to make their own decisions regarding water use, giving them improved livelihood prospects, while at the same time providing a structure that reveals the real scarcity value of water.

This chapter focuses on the regional water-food linkages based on the outcome of regional consultations held during the first half of 1999. The trend and scenarios outlined reflect the views of the regional representatives who participated in the consultation meetings.

7.1 Southern and Eastern Africa

300 million people live in this region on 4% of the world's arable land. The population of this region is increasing at an average rate of 3%, rural growth rate is slightly lower at 2% and urban at 5%. In Southern Africa, the urbanised population will exceed the rural population after 2015.

In the recent past, in this region only in Botswana, Mauritius and Swaziland have experienced an increase in dietary levels. All other countries still have vulnerable and malnourished groups.

Agriculture is relatively more important to the economy of this region than in the rest of the world, but irrigation is less developed than anywhere else. Compounding the effect of erratic rainfall, farming lands are generally very small. In more than half the countries, the cultivated area per person economically active in agriculture is less than 0.5 ha and only in four countries is it more than 1 ha.

Rainfall is highly unreliable due to its spatial and temporal variability, resulting in regular crop failures. There is major physical (land and water) potential for irrigation development. Two-thirds of the countries have developed less than 20% of their potential.

In all but four countries in the region, less than 5% of the cultivated area is irrigated (Figure 9). While two countries have developed more than 85% of its irrigation potential, half the countries in the region has developed less than 10% of their potential. The three countries with the most irrigation potential have each developed less than 10% of their potential irrigated area, while Rwanda and Burundi, which have cultivated area of less than 0.25 ha per person economically active in agriculture, still have significant potential to develop irrigation. Madagascar and South Africa together have 85% of the developed irrigation in the region.

Food security in the region is to be obtained through an appropriate mix of improved internal production systems and imports. Improvement of the production systems includes diversification of production and an increase of productivity per unit of land and water. This requires major investments in developing water resources, storage and associated community based infrastructure for irrigation and watering points for livestock. Supplementary irrigation will become increasingly important, even in areas of traditionally higher rainfall, as global climate change will increase the variability of rainfall even more.

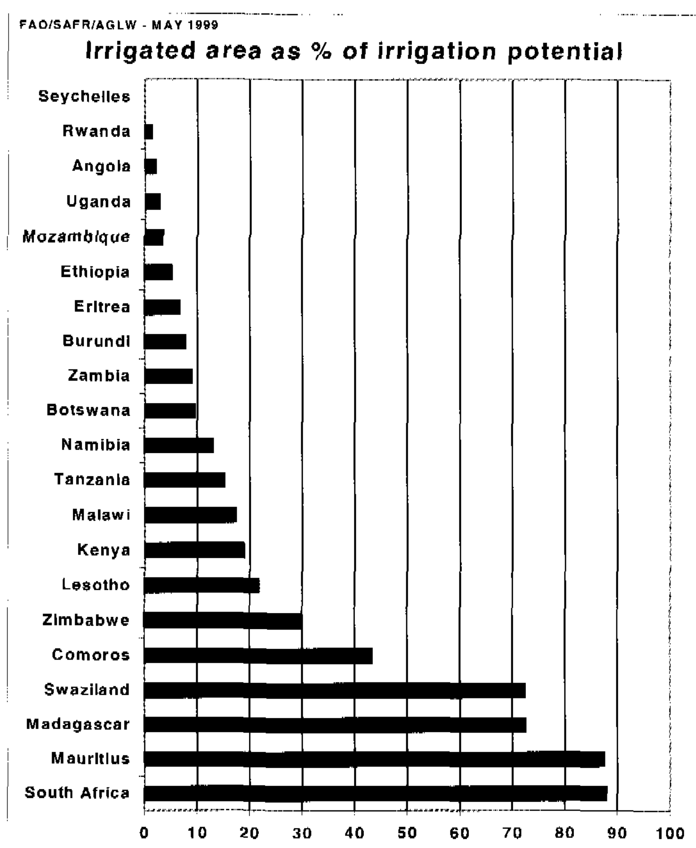

Figure 9 Irrigated area as percentage of potential irrigation area

Experience with smallholder irrigation schemes shows a positive effect on rural livelihoods and up to 300% improvement over rainfed production. The success of smallholder irrigation is particularly significant in areas where farmers can develop individually, using low cost technology and control or manage their own affairs in the schemes.

Irrigation development has to be underpinned by secure land and water rights and access to credit. Investment in irrigation is crucially important for this region , yet this region is also the poorest of the world's regions, with the least financing potential. High priority needs to be given to establishing an enabling environment to encourage investment from the private sector, both directly and through public-private partnerships.

At local levels, the establishment of credit and savings groups has proved important in rehabilitation and irrigation management transfer processes. The industrial base is to be broadened to support agricultural production and processing for employment generation and local manufacturing.

The entire region can be classified as economically water scarce with the exception of South Africa, which is physically water scarce. This region withdraws at present only 4% of its total renewable water resources as compared to the world average of 8%. Besides the island states, only six other countries in the region dependen exclusively on internally renewable water resources. The East and Southern African region has important shared river basins, such as the Zambezi and Limpopo , while it also shares for example the Nile with the Northeast Africa region.

Optimal use of land and water resources requires coordinated regional and national policies through the establishment of river basin organisations with capable staff developing and sharing information on land and water. Concerted capacity building efforts have to be made to make this possible

7.2 West Africa

West Africa's population is expected to grow from 260 million today to approximately 490 million in 2025. Urban population corresponds to 40% of the total population today. It was only 13% in 1960 and it is expected be 65% in 2025. More than 50% of the West Africa population will be concentrated in a triangle - Abidjan-Abuja-Port Harcourt - and more than 80% in a 500 km wide area along the coast.

The whole region is classified as economically water scarce. The present population of West Africa could scarecely be supported by domestic production, without the assistance of irrigation which reduces the risk associated with the extreme rainfall variability in the region. An intermediate level of inputs and integrated pest management would be largely sufficient to support the present population and even twice as much as the 2025 expected population, with a very limited additional contribution from irrigation.

Agricultural development will focus on a mix of improved local production and imports based on intra-regional trade where countries grow the crops for which they have a comparative advantage, but with limited food imports at a global level. This should be supported by the promotion of consumption of local rather than imported crops.

Rainfed agriculture will remain the primary source of traditional cereals. Self-sufficiency of traditional cereals is the basis for household food security of the rural population. Rainfed agriculture will increase at roughly the rate of population growth. Irrigation will grow as fast as the urban demand in fruit, vegetables and rice.

To maintain the present proportion of 63% of local rice production versus total demand, would for 2025 require a production of some 14 million tons of rice on at least 2,800,000 ha irrigated land. Development will focus on small schemes particularly in inland valley bottoms. However, these valley bottoms are also of special ecological importance . The estimated vegetable demand of 30 million ton for 2025 would require some 1.5 - 2 million ha though as second crop rice areas can cover part of this.

There are adequate natural resources for sustainable expansion of both rainfed and irrigated agriculture in West Africa. This should be done using appropriate and affordable technologies to improve water use efficiency and water productivity, which are flexible and take into consideration traditional farming practices, values and capabilities. Flexibility of irrigation scheme design is required to enable farmers to manage their own systems and to allow them to diversify the cropping pattern.

Realising West Africa's irrigation potential will require improved governance and associated institutional reforms, and peace and stability in addition to increased investment in agriculture and associated rural infrastructure. A special priority is capacity building at many levels, including small-scale irrigation associations, consulting firms, NGOs, input and equipment providers, and river basin institutions

7.3 The Americas

The Americas can be subdivided into four very distinct socio-economic, geographic and cultural sub-regions: North America (Canada, USA and Mexico), Central America[46], the Caribbean and South America[47].

The total population is approximately 826 million. In North America, growth rates are relatively low. Mexico's population is expected to grow 43% and the USA and Canada 25% between 1995 and 2025. In the other parts of the Americas growth rates are very high. The present population in Central America is 34 million people and with the present growth rate of 2.3% will be doubled by 2025. Here, projections indicate that 72% of these people will live in urban areas. Colombia and Brazil also have very high population growth rates. In South America the population is nearly 344 million of which 80% lives in urban areas! This trend of urganization is linked not only to health services, employment and education opportunities but also to capital intensive farming technologies which improved production, but brought about a decline in labour demand.

The region contains some of the world largest rivers and the countries sharing these rivers are generally "water rich". However, there are many areas even within the water-rich countries,which suffer from droughts. In North America roughly 12% of all renewable freshwater is used. In South America, on an annual basis only 1% of the total volume of water is withdrawn. Throughout North America, groundwater accounts for a significant portion of freshwater withdrawals. Mexico and USA are particularly reliant on groundwater, which accounts respectively for one third and one fifth of reported freshwater extractions. Agriculture uses 43%, 71% and 64% of the groundwater abstraction in Canada, USA and Mexico respectively. By 2025 a fundamental shift from 'supply' to 'demand' management will be in place. Rather than seeking new freshwater resources to 'tap', the North American countries will focus their attention on increasing the efficiency of water distribution and use and reduction of agricultural pollution.

The water situation in the island states of the Caribbean region is becoming more and more critical. Most of these countries are experiencing or approaching a situation where estimated water demand exceeds the maximum annual renewal of fresh water resources. Barbados, the Bahamas, Antigua, Barbuda and parts of the Netherlands Antilles already rely heavily on desalinised water. Safe water in this region is fast becoming one of the most important factors threatening socio-economic development and a cause of conflict between competing uses: agriculture, tourism, industry and domestic use. In many of these island states the focus of agriculture is not only on food but also on industrial (e.g. sugarcane) and export crops. Expansion of the plantations is still foreseen in some of the countries. However, the insufficient diversification in the economy from agriculture is a major problem. Wastewater reuse practices for irrigation is successfully practised in Cuba and the Netherlands Antilles. Its further development would be an important contribution to increased productivity of water in the region.

Almost all countries in the region suffer from extreme natural events: droughts and floods. Hurricanes are common occurrences in the Caribbean and Central America posing enormous challenges in water management and flood protection. In many parts of the region large sums of money must be spent on civil works to prevent or reduce damage due to floods and inundation.

Agriculture is in Central America the main economic activity and each of the countries project expansion and intensification of the agricultural sector. The regional free trade treaty will expand their markets. Though this is regarded as an improvement this market will still be strongly regulated through regional economic blocks and treaties.

The level of technological development in Central America is low due to the limited access to technology. This is caused by the high cost, lack of human resources adequately trained to adapt it, and little capacity to execute research.

The total irrigated area of the Americas is approximately 40 million hectares, half of which is in the US. The potential for irrigation development is enormous, especially in South America but because of the topography, development costs are very high. Many of the large farms utilise sophisticated irrigation technology, which is beyond the financial reach of smaller farmers, especially those without land title.. Rainfed agriculture is still and probably will remain predominant in the region. In South America irrigation area is expanding slightly overall just over 2% per year) but with significant difference across countries, ranging from 7.5% per year increase in Colombia to 6.2% annual decrease in Bolivia.

Institutional reform has been an important feature in the water sectors of many countries of the region, including Mexico, Argentina, and Chile. Mexico has adopted a strong policy of irrigation management transfer to water user associations, while Argentina and Chile have implemented water pricing and water markets. Institutional changes in the region will continue to shift towards user-management and water markets, with a greater regulatory role for the state.

7.4 East Asia

The total population of the region is at present more than 1,700 million and is expected to increase by around 50% by year 2025. The average population density of the region will rise from 1.3 person/ha to 2.0 persons/ha. By 2025, per capita natural water availability will drop from 10,000 to 6,700 m^3/year. In daily per capita values, natural water availability will decrease from 27 to 18 m^3 /person /day.

All the countries in the region have a monsoon climate except for West and North-West China. Although, the annually available water resources are considerable, a significantly large proportion of precipitation results in unused runoff during the relatively short wet season. At the same time, per capita water resources are relatively small because of the high population density.. In 1995, the total amount of water resources used was 4.9 % of the total water resource availability. However, the percentage of water-use varies greatly among the different countries, from 1% to 30%. More than 70% of water use in the region is devoted to agricultural purpose or irrigation of staple crops, mainly rice. Domestic and municipal water use is in the range of 10-20% of total water use, while industrial water use is about 10% or less of total use. Some of the countries of the region are under-going extensive industrialisation, urbanisation and fast economic growth. The burden of feeding the huge urban population is compounded by the transfer of agricultural land to urban and industrial use. UN forecasts indicate that the urban population in these countries will increase to about 50% of the total population by 2025.

Land holdings are small with a large proportion of farm families living at or below subsistence level Land pressure is driving an expansion of agriculture into marginal and ecologically fragile lands including forest areas.

While wet season rainfall is generally adequate for rice cultivation, cropping is often not possible in the dry season without irrigation. These conditions indicate the need for the region as a whole to increase investment in water storage to secure dry season supplies and reduce damage due to floods and inundation in the wet season combined with an improved management of supply and demand. Conjunctive use and ground water management are relatively recent measures that have significant growth potential.

7.5 South Asia

Present population in South Asia is some 1,220 million people, expected to grow to some 1,780 million by 2025. Malnutrition levels in the region are high. Rapid economic growth is required to address the issues of security of food and livelihood at all levels: household, national and regional;if not, the region will be heading for a food crisis.

Given the socio-economic conditions –large population and small holder agriculture – the current policy consensus within the resion is that food security cannot be left to the uncertainties of the global market. In the even of global food shortages , it might be not possible to obtain the region's vast requirements on the world market at affordable prices. –The goal of some countries of the region is therefore to attain food self-sufficiency in production of food grains and generate exportable surpluses through optimal utilisation, development, and effective management of water resources. The planning for self-sufficiency in food includes the optimisation of agro-ecological variations at the regional level; no country in the region should lose as a result of regional specialisation.

Taking the region as a whole, water is the main limitation to increasing food production. Technological developments in bio-technology and irrigation water use efficiencies will help to increase the productivity of land and water to a large extent. However, the critical factor would be increasing the utilisable quantity of water through additional storage.

In its scenario the region envisages a basin oriented management including a supra national regional body for cooperation in water resources planning and management based on a regional water policy. At the national level, basin and irrigation management organisations should become multi-disciplinary institutions focussed on integrated water and land resources management with participation of all stakeholders at all levels from local to regional. Women play a key role in establishing the practices of water utilisation and water institutions would be reformed to allow a democratic structure with accountability and transparency at all levels.

7.6 Central Asia

Central Asia largely coincides with the Aral Sea Basin and consists of deserts, mountain ranges, inter-mountain valleys and dry and semi-dry steppes. The total population of the Aral Sea Basin is about 40 million of which some 62% live in rural areas. The annual population growth is declining and at present is about 1.5%.

The main water sources are the Syr Darya and the Amu Darya Rivers with a combined annual runoff of some 120 km^3, of which only 10% reaches the Aral Sea. There are various natural and man-made lakes in the region with a total storage of some 100 km^3.

Less than 10% of agriculture is rainfed and this proportion is not expected to increase. Agriculture contributes importantly to the GNP (50% before 1990). However, the current transition towards a market economy has resulted in a decline of production as farmers are unable to cover the cost to operate and maintain the irrigation infrastructure.

In order to raise the standard of living in the region, irrigated agriculture must be revitalised and related institutions and infrastructure must be optimised. Controlled restructuring of state-farms, the creation of a regional market and a financial and economic support system are needed to break the vicious circle of declining production.

To effect this, regional co-operation and agreements are required on the agricultural production on the basis of the most suitable agro-climatological zones for the major (food and fiber) crops, on trade of agricultural products, and on development of a regional policy for joint management and efficient use of water.

To increase the productivity of water rehabilitation and modernisation of existing irrigation systems and rural infrastructure is required. This is to be accompanied by a set of incentives for farmers to make optimum use of water and land with due consideration to the environment and a market economy.

Authorities in the region recognise that the most important component for improved water and ecosystem management in the region is qualified staff. Failure to implement sound decisions on water allocations, water rights and reform of the water sector could contribute to further political conflicts, environmental degradation, poverty and low life expectancies in the region.

7.7 Middle East and North Africa

The countries of the MENA region are facing significant population growth, from 350 million in 1995 to an estimated 613 million in 2025. Population is concentrated in very small parts of the region that are fertile and well supplied with water and transportation facilities. Most countries are experiencing a negative or low growth of the rural population, with the exception of Syria and Egypt (about 2% growth per year), while in all countries, urban population growth plays an important role. It is expected that by 2025 the urban population will be greater than the rural population in all countries of the region.

Most of the MENA countries have an arid and/or semi-arid climate and are classified as physically water scarce. There is little scope for further development of water resources and the emphasis must be on improving the productivity of available water.

The availability of fresh water per capita is steadily decreasing as population grows and water resources development has reached a ceiling in many countries. Fresh water resources vary from a low of 220 m^3 per capita in Jordan and 330 m^3 per capita in Palestine, to about 2,000 m^3 per capita for Turkey and Iran. Countries facing immediate water stress Tunisia, Israel, Palestine, Jordan, Egypt. The latter two countries, though better endowed, contain regions of severe shortage. Countries not currently experiencing water stress except in local areas are: Iran, Morocco and Turkey.

There are four major international rivers in the region – The Nile, Euphrates, Tigris and Jordan – on which major irrigation developments are based, and for which sustainable and equitable development must be achieved through international cooperation. Deep Saharan aquifers containing fossil waters are also shared among different countries: Algeria, Tunisia, Libya and Egypt, and these too require international cooperation, all the more since they are finite resources and their exploitation will be limited.

Irrigation plays an essential role in agricultural production in the region. Irrigated cereal yields reached 5.5 ton/ha in Egypt, while non–irrigated cereals elsewhere yielded a low 1.5 ton/ha. Expansion of the irrigated areas is highly dependent on maintaining existing water resources, developing new resources (including non-conventional water) increasing in use of wastewater, treatment of urban wastewater and generating water savings in existing processes. This requires investments in modernisation of agricultural production techniques, irrigation systems and reform of water management organisations. However, given the non-sustainability of some irrigated systems based on fossil water, an overall long term decline in irrigated area cannot be ruled out and a reorientation of local staple food production is necessary to ensure food security.

Ensuring food security in the region will depend more and more on imports. The increasing reliance on the world market for food supplies is felt to be a weakness of the region. The dependency on cereal imports was 33% in 1995, but it is likely that this dependency may rise to 50% or more by the year 2025. On the other hand, the current situation of producing and exporting cash-crops, while purchasing food supplies at low prices, is considered as a good opportunity, at least in the short term. This requires a more international market orientation of the producers and the supporting agencies that have to be reformed towards a service orientation. This also means that much attention needs to be paid to agricultural service oriented support services that enable the limitation of the use of agro-chemicals to meet international quality standards that regulate the access to export markets.

7.8 Europe

The population growth in Europe is stagnant or shows a slight decrease. Immigration is a main factor for potential growth.

The mainland of Europe is blessed with precipitation throughout the year, although with decreasing quantities from west to east. However, the far North and the South show a negative water budget (mean precipitation 300 mm/year),

Expansive river systems and meadows are prevailing in wide areas of Europe. Large rivers like for example the Rhône, Rhine, Elb, Danube, Oder, Dnjepr, Dnjestr and Volga, carry water all-year accompanied by subterranean flows. However, the rivers of the Balkan and Mediterranean countries are flowing through karst areas and fall dry in the summer season so that only limited groundwater and supplements from storage facilities can be utilised. Severe droughts have been observed here since many decades.

Because of its favourable climatic condition, most of the agriculture in Europe is rainfed and highly productive. Supplementary irrigation is regionally important, especially in South, Central and East. Drainage is imperative in most of the north-western part of Europe where part of the land is located near or under sea-level. In South, Central and East Europe it is used as a measure to complement to irrigation. In lowlands below sea level, drainage is part of the defence of the land against sea and river floods and storm rainfall.

Where Europe is at present still a net exporter of cereals, in future the level of exports is expected to decrease. The Western European countries are more and more concerned with environmental protection and landscape improvement and management putting emphasis on ecological friendly agriculture and reduction of surpluses. This ecological development also means a rehabilitation of the landscape by conversion of or even taking out of production of less productive agricultural areas.

The principles of the water policy in the European Union are embedded in the environment policy, which is based on pre-cautionary principles and preventive action. Environmental damage should be rectified at the source and polluters should pay. This new policy postulates an integrated water management approach, which is river basin oriented and considers as legitimate the claims of society and nature.. Farmers will become more and more responsible for their nutrient balance and are limited in their disposal of agricultural pollutants through nutrient accounting systems.

High populated and industrialised areas in wide parts of Europe are suffering from groundwater depletion. Groundwater should be maintained in its natural condition. Existing contamination is to be removed or isolated to prevent spreading. A deterioration of groundwater quality is to be avoided.

Flood control is a Europe-wide priority , especially since the alluvial plains and lowlands are intensively occupied. The development of the water environment ihas the priority to reduce flood peaks and risks. This includes trans-sectoral measures on water retention in the catchment to be achieved through close cooperation between regional planning, water management, environment and nature conservation, agriculture and forestry as well as development of settlements.

In Central and Eastern Europe, the productivity of the agricultural sector has dropped tremendously due to the physical processes as erosion, water logging and salinisation, but also due to inefficient irrigation and drainage infrastructure and management systems. Recovery of the food production potential for domestic and export markets in the Russian Federation only, requires rehabilitation and modernisation of over 3 million hectares of existing irrigation systems and almost 2 million hectares of drainage infrastructure. This is to be accompanied by a reorientation of the irrigation and drainage agencies towards a service orientation.

Most Central and Eastern European countries are in a transition towards a market economy. They are now faced with a decrease in agricultural production due to reduced export possibilities and non-viable farming systems. The consequent agricultural sector reform has often resulted in a deterioration of socio-economic conditions for the rural population, which combined with an economic recession, has contributed to the decline of infrastructure and services. Revitalisation of rural economies has a high priority and this can be established by an integrated land and water management policy in which the creation of off-farm employment will be a priority.

8 A Strategy to Realise the Vision

To realise the Vision, many choices will have to be made by many primary organisations and groups. These decisions must be coherent to produce the desired result, yet the actors are generally independent of each other. A shared understanding of the problems we face and their consequences, possible solutions, and the interconnections and tradeoffs among them are crucial if actions are to focus on common objectives, and thus reinforce each other.

In realising the Vision, our starting point must be the creation of a common awareness and understanding among current and future decision-makers around the world. This must be done in schools, in the media, and in workshops, meetings, and conferences. Then those that are affected must make the choices and appropriate actions must be taken in the areas of economic policy and trade, investment, infrastructure, institutional reform, research, and capacity building.

A strategy for 25 years obviously cannot be completely spelled out. There are simply too many intervening and evolving variables that we cannot foresee at present. However, important initial steps can be specified and then more detailed programs can be developed regionally and locally. Our attempt in this chapter is to outline key issues that warrant our priority attention as we seek to move from a common understanding of the vision to concerted action to implement that vision.

8.1 Capacity Building

Existing organisations need to be strengthened, some new institutions need to be established (including both organisations and regulatory and legal frameworks), and the complex capacity required to build these capacities also needs to be improved. Sufficient qualified and skilled people are needed that bring about the changes and improvements within existing organisations but also to develop and manage the new organisations and institutions mentioned above. Moreover, the envisaged people and service orientation may require changes in attitudes and skills of staff and management processes. Motivated staff with sufficient knowledge and skills has to be developed through education, training and human resources management. The following actions are proposed:

Development of Institutions and Private Sector Involvement

In all the regional consultations a reform and strengthening of the water managing institutions was called for. These should be embedded in a system of integrated water resources management. To achieve this, the following actions are proposed:

- establish and empower multi-stakeholder basin management organisations in major national river basins to improve water management and to develop accurate and reliable water availability and water use data for future planning and management

- develop and introduce participatory multi-stakeholder institutions to manage groundwater basins, controlling overexploitation and facilitating recharge operations
- establish and support community-based watershed action programmes where local communities manage, conserve, and utilise catchment watersheds
- regularise and reform systems of water rights in a manner that recognises existing registered users, safeguards existing unregistered uses, and enhances the water access of poor and disadvantaged groups, e.g. women. Experiment with water trading and transfer systems, which increase economic efficiency while protecting the interests of small producers
- reform where required, irrigation and drainage management institutions and other institutions involved in water management by making them more people and service oriented, user-controlled and self-financing. Develop new missions for public irrigation agencies. Insure that user representation reflect the gender composition of those doing the farming
- establish charging and collection systems for water and rural electricity that recover at least the costs of operating and maintaining supply and delivery systems if the social equity mechanisms are not threatened by the establishment of such mechanisms
- facilitate exchange of experience and legal and political advice to help countries develop equitable and efficient systems of water rights, including principles and procedures for initial allocation of rights and rules and procedures for changes, reallocations, trades, and transfers.

Human Resources Development and Knowledge Management

- develop a local capacity for education and training of water and food production – related professionals and researchers, facilitate the exchange of existing knowledge between local users and technicians and professional water managers and establish or strengthen linkages between education institutions and water research organisations
- establish attractive career development programs for water-related professionals to ensure sufficient capacity and capability for planning, regulation and policing related to water resources use and management. Give preference to women professionals to improve their participation in water management, particularly at higher levels of governance and management
- synthesise existing knowledge on agricultural water management and make it available in readily accessible formats to policymakers, their advisors, and researchers in developing countries. Recognise the near-zero marginal cost of distributing such knowledge in electronic form and make full text versions and databases available at low or no charge.

8.2 Private Sector Involvement

The role of the private sector needs to be expanded and transformed if our vision is to be achieved. Steps to facilitate private sector involvement include:

- establish public-private investment partnerships to finance rural infrastructure (roads, power, communications, social services) and encourage private-sector investment in labour-intensive industry in rural areas
- stimulate the private sector in providing agricultural support services
- stimulate agro-industry to encourage their suppliers of raw materials to use sustainable production systems
- promote private-sector investment in development and marketing of micro-irrigation equipment
- in rainfed areas, support development of crop insurance programs and other coping strategies for drought

8.3 Investments in Infrastructure and Investments Policies

Investments are needed to meet the demand for food, to improve the productivity and development of water and to improve the livelihood of rural people. They should be directed to:

- development of water resources to enable community based irrigated agriculture, particularly in Sub-Saharan Africa
- modernisation of irrigation and drainage systems, particularly in water scarce areas in North Africa and the Middle East but also in Central and Eastern Europe, South and Central Asia, and the dry season irrigation schemes in South East Asia
- demand driven development of general rural infrastructure to revitalise or stimulate rural development and improve the livelihoods of rural people
- replace and augment water storage capacity in reservoirs and groundwater basins in the most water scarce regions and the regions suffering from seasonal water scarcity
- drain and reclaim degraded irrigated land and restore eroded lands
- flood protection and drainage of frequently inundated areas to improve rural livelihoods and secure or improve food production

Investment policies should be directed towards improvement of the productivity of water and sustainability of water resources based on participation of all stakeholders, including the women and the poor. Institutions must also place the utmost importance on accountability of leadership to members and stakeholders and transparency in all dealings. Specific actions are:

- to formulate coherent investment programs and priorities that:
  - respond to the key principles of subsidiarity, participation, accountability and transparency
  - foster the development of accountable, transparent and representative institutions
  - foster integrated water resource development and management
  - support improved agricultural water productivity
  - improve rural livelihoods

and based on these, identify projects and programs for international lending agencies

- tie development funding to establishment of institutional mechanisms giving a representative cross-section of local rural residents, including women and the poor, a significant decision making role in planning agricultural water development, modernisation, and operations improvement projects
- sustain international efforts to address the issue of financial malpractice with a strong emphasis on transparency

8.4 International Water Management

Many of the countries in different regions share international rivers and river basins. In all the regional consultations the desire of better international cooperation to improve the management of such basins was expressed, in particular:

- negotiation of water-sharing agreements on international rivers and establish river basin organisations to share information and to coordinate sustainable development and management of the rivers and their watersheds
- development of new environmentally and socially acceptable protocols for reservoir planning, design, and operation

8.5 Trade

Global trade is a key element of the Vision. To achieve adequate nutritional levels, food must be accessible and affordable. Therefore, trade arrangements should be developed that encourage water scarce regions to produce and export high-value crops and import water intensive staple crops. Trade regimes are also critical to building a food secure world, and must make special provisions for those countries not yet able to compete in world markets for their food supply.

The following actions are proposed:

- evaluate the economic implications of long-term imports of "virtual water", i.e. trade in food grains, in food deficit countries and regions. Examine, in particular, the comparative advantages of the importing countries in producing exportable commodities and goods, which can be used to pay for food imports
- develop international trade regimes, which promote socially and environmentally equitable production and distribution of food, while protecting agriculture-based rural development initiatives in very-low-income resource-poor countries This includes the support of the evolution of regional trade and marketing groups with developing country membership
- level the playing field by neutralising subsidies to developed country producers, and dropping import barriers to enable producers in developing countries to compete in the local and international markets on an equitable basis and as such to enable trade in virtual water

- guarantee the integrity of international food trade by negotiating international agreements prohibiting the interruption of market-based food trade for political reasons

8.6 Research

An important element in the achievement of the vision is the development of new or situation adapted technologies to improve the productivity of water, to increase the yields and to improve the livelihoods of rural people. This requires substantial investment and support in research and research capacity at both international and national level. Specific proposals are to:

- increase overall support for research on developing country agriculture and water use with focus on high input and low input producers to assure that a diverse set of user knowledge is integrated into the research activities and that the results are useful to a wide range of water users. Particular topics of priority are:
  - improvement of water productivity in irrigated and rainfed areas including water harvesting, groundwater recharge systems and supplemental irrigation
  - system designs and production systems that maximise both water productivity and poverty alleviation impacts of irrigation and other water control development
  - water quality of agricultural return flows and its improvement
  - institutional arrangements to enable optimal use of resources, technology to improve food security, water productivity and livelihoods
- support biotechnology research on crops and topics not likely to attract private sector interest but which are important to developing country agriculture, such as regionally important coarse grains and tubers and drought resistance and salinity tolerance traits in major cereals. This would have to include the research on impact of development and use of genetically modified crops.
- develop affordable and effective lower-impact pesticides and herbicides (including biological agents) and negotiate worldwide phase-outs of more persistent agricultural chemicals.

Endnotes

[1] Per Pinstrup-Andersen, Rajul Pandya Lorch, Mark Rosegrant; World Food Perospects: Critical Issues for the Early Twenty First Century. Food Policy Report, International Food Policy Research Institute, Wasgington D.C., October 1999.

[2] David Seckler, Upali Amarasinghe, David Molden, Radhika de Silva, Randolph Barker: World Water Demand and Supply, 1990 to 2025: Scenarios and Issues; IWMI Research report 19, 1998.

[3] UN Population Bureau, 1998

[4]More developed regions comprise all regions of Europe and Northern America, Australia/New Zealand and Japan. Less developed regions comprise all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean, and the regions of Melanesia, Micronesia and Polynesia. Least developed countries as defined by the United Nations General Assembly, as of 1998, include 48 countries, of which 33 are in Africa, 9 in Asia, 1 in Latin America and the Caribbean and 5 in Occania: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Cape Verde, Central African Republic, Chad, Comoros, Dem. Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, Lao People's Dem. Republic, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Samoa, Sao Tome and Principe, Sierra Leone, Solomon Islands, Somalia, Sudan, Togo, TuS2u, Uganda, United Rep. of Tanzania, Vanuatu, Yemen, Zambia. They are included in the less developed regions.

[5] United Nations, World Urbanisation Prospects 1998

[6] FAO-IPTRID 1999; Report on Regional Vision Water for Food and Rural development Consulation, Accra, West Africa

[7] There are some reservations and different opinions on the decrease of energy prices. The prices over 1999-2000 doubled because OPEC and the international companies have managed to fine tune their oil production and outputs. This is contrary to what the panel projects. Then there is a moral argument (Wulf Klohn) that fossile energy is also depleted and its development and use do not fully pay its environmental billmined and while

[8] ILRI 1999; Report on the Central Asia Regional Vision Water for Food and Rural development Consulation, Tashkent

[9] FAO, 1996; Food Summit, 1996

[10] Based on IMPACT runs using the assumptions in the Vision 2020 document but for the purpose of this vision process extended to 2025 by Mark Rosegrant.

[11] Rosegrant, Leach, and Gerpacio: Alternative Futures for World Cereal and Meat Consumption, IFPRI 1998.

[12] IMPACT (International Model for Policy Analysis of Commodities and Trade) is a global food model developed by IFPRI (M. Rosegrant and collegues) covering 37 countries and country groups and 18 major agricultural commodities. It balances supply and demand within agriculture with market-clearing proces for major agricultural commodities, including livestock products and feed. Starting with exogenously specified trends in national incomes, the model traces food demand, feed demand, and supply levels for 18 commodities, iterating theto market clearing prices for major commodities annually. The results are based on a large number of parameter assumptions taken from literature, including assumptions about the openness to trade.

[13] This contribution is drawn from IFPRI World Food prospects: Critical Issues for the Early Twenty First Century , october 1999

[14] Over the period 1981-94

[15] Rosegrant, Leach, and Gerpacio, 1998 Alternative Futures for World Cereal and Meat Consumption, IFPRI 1998.

[16] FAO. Fisheries and Food Security. 1999. www.fao/focus/e/fisheries/intro.htm.

[17] FAO. 1998: State of world fisheries and aquaculture.

[18] Actual freshwater fishery production may be 3 to 5 timesmore than reflected in statisticsbecause a large part of the catch is consumed or bartered locally. This is also important with regards to benefits forfeited in water development that damages or wipes out fish populations and points to the future importance of integrated fish crop systems for sustainable rural livelihoods. FAO-Fisheries, personal communication

[19] FAO. 1999: Fisheries and Food Security..

[20] Somewhat paradoxically, it is often only after reaching a certain level of security and comfort that a society feels able to devote substantial resources to mitigating accumulated environmental damage.

[21] The tendency will be for advantaged farmers to want to use limited water supplies for full irrigation on their farms rather than spreading it more thinly across a larger area.

[22] In the Western United States, some "artificial" arid region wetlands which have resulted from wasteful irrigation are now arguably proS1ted by environmental regulations, preventing irrigation efficiency improvements which would eliminate them.

[23] Sometimes this is even desired like in the Jonglei Canal in Sudan where it is proposed to increase water availability for the downstream Nile areas by draining the Sudd swamps and conveying it to the Nile where it can be stored and regulated in the Nasser Lake instead of evaporating in the vast swamps. This goes in this case at enormous cost for ecosystems, bio-diversity and environment

[24] Sandra Postel, 1999 – Pillar of Sand, Can the miracle last? Norton/Worldwatch Books.

[25] Most of the text is obtained from IWMI Water supply and demand in 2025.(2000).

[26] IWMI (2000) , Water Supply and Demand in 2025

[27] Seckler, D, U. Amarasinghe, D. Molden, R. da Silva, R. Barker. 1998. *World water demand and supply, 1990 to 2025: Scenarios and issues.* Research Report 19. Colombo Sri Lanka: International Water management Institute

[28] The amount of virgin water available to meet withdrawl demands.

[29] Andrew Keller and David Seckler 1999 : Water Scacity and the Role of Storage in Development Special subject paper for the Vision Unit.

[30] IWMI 2000: World Water Supply and Demand:1995 to 2025

[31] Worldwatch Institute 1990

[32] contribution of David Molden and Saktivadivel (IWMI)

[33] FAO-1996, World Food Summit, Food production: the critical role of water, Technical background document no 7

[34]:FAO-IPTRID; expert consultation on Water for Food and Rural Development in the West African Sub- Region; Accra, May 1999.

[35] Allan and Court 1996:

[36] Population Institute, World population overview and outlook 1999

[37] Based on IFPRI-IMPACT base scenario runs October 1999

[38] Ttwo papers were developed for the Vision for Water for Food and Rural Development': van Koppen, B. (1999) 'More drops per drop for the poor' and Vincent, L. 1999. 'Rural development, rural livelihoods and water management': Both are papers developed for the Vision for Water for Food and Rural Development'

[40] D. Groenfeldt, *Handbook on Participatory Irrigation Management (1998),* a training module of the World Bank Institute.

[41] H.M. Malano and Paul van Hofwegen (1999): Management of Irrigation and Drainage Systems - A Service Approoach, IHE Monograph 3; Balkema Publishers, Rotterdam-Brookfield..

[42] Promoting changes among farmers on agricultural and water management practices requires an intensive program on extension, training and education that is well addressed to the specific local problems. Change also requires the availability of the envisaged innovative inputs like bio-degradable pesticides, improved seeds, etc. In many countries these functions were executed by agricultural support or extension services. Many of these services are not up to this task as often the wrong messages are delivered to the wrong people. Especially the role of women farmers is often ignored or the needs are incorrectly understood. These services will play an essential role in implementing the vision and require appropriate strengthening and reorientation to be more user focussed.

[43] DVWK (1999): European sector vision on water for food and rural development; Bratislava.

[44] Van Hofwegen P and Jaspers F, (1999): Guidelines for Assessment of Institutional Frameworks for Integrated Water Resources Management, IHE Monograph 2, Balkema Publishers, Rotterdam-Brookfield.

[45] Blokland, Braadbaart and Schwartz (1999); Private Business, Public Owners – Government Shareholdings in Water Enterprises; The Ministry of Housing, Spatial Planning and the Environment the Netherlands and Water Supply and Sanitation Collaborative Council.

[46] CATHALAC; Vision on Water, Life and the Environment for the 21st Century, Regional Consultations Central America and the Carribean, December 1999.

[47] SAMTAC; Vision on Water, Life and the Environment for the 21st Century, Reional Consultations for South America, December 1999.

Annex A:

The Vision Unit Scenarios Applied for Water for Food and Rural Development

Critical issues

A number of critical issues have been identified that are important in making the right choices. They refer to trends or events which could make a major difference in the likelihood of the materialisation of one or other scenario, and which are currently very difficult to anticipate. For the Vision on Water for Food and Rural Development the most important are:

Water productivity trends. Will progress in water use efficiency, and more generally, water productivity, continue at its historical rates or faster? This is assumed in all scenarios, but if for some reason the rate of technological innovation (or the rate of adoption) falls behind historical levels, drastic changes in at least some of the scenarios are to be expected.

The expansion of irrigated agriculture. With agriculture accounting for 70% of total water use, the future expansion of irrigated lands will be one major factor. Two basic contrasting views exist. On the basis of historical trends and the need to produce food for the growing global population, the total harvested area is expected to increase by about 30 % by 2025. Even with optimistic yield and water efficiency assumptions, this would imply an increment of 15 - 20% in the required water resources above their level in 1995. However, an already detectable slow-down in dam building and irrigation investment, combined with dropping water tables will limit the expansion of irrigated land to 5-10 %. If the first alternative materialises, the associated large increases in water withdrawal and dam building will lead to severe water scarcity in many regions. If, on the contrary, there is a strong reduction in the expansion of irrigated land in the context of business as usual policies, then serious food shortages and sharp increases in food prices would result.

Massive increases in food production from rainfed agriculture. To date, most increases in food crop yields took place in irrigated land. Progress in rainfed agriculture associated to new crops, supplemental irrigation, deficit irrigation, rainwater harvesting, and some forms of precision irrigation could lead to fast yield increases in rainfed lands. That would generate an increase in food production without a concomitant increase in irrigation water. On the other hand, the opening of major rainfed areas for more intensive food production could lead to increased deforestation and could affect bio-diversity.

National food self-sufficiency vs. global food security. Continued emphasis on national food security (because of political, cultural or other reasons) could lead to overuse of water resources in some water scarce countries. On the other hand, a reliable and trusted global food security system would allow a more rational use of water, with the water-scarce countries reserving their water for domestic and industrial use, and fulfilling their nutritional needs trough food imports.

Public acceptation of genetically modified crops in the South and the North. Today an intense debate regarding the acceptability of genetically modified crop varieties in taking place, with Europe leading the opposition on the basis of environmental and health risks. While the debate is today largely confined within the North (essentially USA and Europe) it could develop in a world-wide issue, affecting trade and the adoption of new, drought tolerant, crops obtained by genetic modification. These positions could shift greatly on the basis of new scientific findings.

Public opposition against large dams. Opposition against the building of large dams, on the basis of their environmental and social impacts, has been growing in the last decades. Given that the major opportunities for water development are concentrated in the South, the attitudes in the South (as well as of the international financing agencies) will be critical in determining the future alternatives.

Significant changes in human values and lifestyles. This is one of the biggest critical uncertainties. In the absence of global changes in lifestyles and societal values away from consumerism, it is not at all obvious that purely technological and economic measures will be enough to resolve the water crisis. Conversely, if changes in preferences were to take place, (because of health-e.g. low animal protein diet, water-saving, because of solidarity towards the current and new generations- e.g. voluntary reductions in per capita consumption), the water problem could largely be solved.

With these simulation outcomes it will be possible to develop regional strategies to enhance food production with the water resources available in order to meet the nutritional needs. These strategies will be based on the and preferences for strategies expressed in the regional consultations that were organised for East and Southern Africa, West Africa, North Africa and the Middle East, Central Asia, South Asia, East Asia, the Americas and Europe. It is the stakeholders in these regions that have to make the choices and these choices very much depend on direction the global community will take.

The Vision Unit Scenarios

Three possible future world water scenarios were developed to explore some of the above-mentioned issues and to see their relative importance in the different regions. The *Business-As-Usual* (BAU) scenario describes a continuation of current trends in production and policy efforts, which leads to severe regional water shortages and possibly a global water crisis. The *Technology, Economics & the Private Sector* (S1) scenario focuses on *increasing the yield frontier* and projects rapidly increasing investments in agricultural research and development, irrigation and drainage and the water sector in general, with an increasing share of investments carried out by the private sector in the higher-income countries. As a result, water abstractions increase rapidly, food production increases, but many low-income countries risk being left out from increasing prosperity. The *Values and Lifestyles* (S2) scenario, on the other hand, focuses more on *narrowing the yield gap* through sustainable, integrated water resources management and the development of appropriate institutional mechanisms for water allocation and use, with large investments in agricultural research and development and water management in the lower-income countries.

Scenario Specification

Under the BAU scenario, projections for population growth and economic development remain in line with recent trends. Rates of investment in agricultural research and development drop even faster than in the recent past, and expansion of irrigated area all but ceases – reflecting the decline in investment in irrigation since the 1980s and the loss of existing irrigated area to land degradation, including salinisation and waterlogging. Rates of growth for cereal yields drop substantially compared to both historic and recent trends.[1]

Under the *Technology, Economics & the Private Sector* - S1 - scenario, economic growth accelerates, particularly in the higher-income countries. Market-based instruments are introduced in the water sector, fuelling rapid investments in water-related infrastructure and technologies, particularly in the higher-income countries. Global irrigated harvested cereal area increases by 25 % during 1995-2025. Agricultural R&D focus will be on strategic research towards raising the yield ceilings, and is supported by new developments in bio-technology and other yield-stabilising and -enhancing technologies. Yield growth accelerates particularly in irrigated agriculture.

Under the *Values and Lifestyles* – S2 – scenario, the UN 1998 low-variant population growth rates are applied reflecting a large drop in fertility rates from large investments in education, health, and income-generating opportunities in low-income developing countries. Incomes increase very rapidly in the lower-income countries, whereas the high-income countries experience medium growth through 2025. Agricultural R&D focuses on productivity maintenance research in order to keep yield increases up. This implies research to increase yields through improved resistance to biotic and abiotic plant stresses and particularly research towards closing the yield gaps between farm yields and practical farm and research station yields, especially in low-income countries, where the social benefits of stable and increasing yields are largest. The focus is on knowledge-based agriculture, that is equitable, profitable, and competitive, while conserving the natural resource base, promoting community-centered rural development, and diversified production structures[ii]. Investments in irrigation infrastructure (increasing by 4 percent[iii] during 1995-2025) are complemented with investments into supplementary irrigation, water harvesting, and other technologies appropriate for the situation in some low-income countries. Reforms in agricultural input and output markets, and price and trade reforms are carried out, and people from lower-income countries are more integrated into global food markets. In addition, changes in lifestyles at the consumer level slow down the transition towards increased consumption of meat products. For a more detailed description of the scenarios, see Gallopin and Rijsberman (1999) and World Commission on Water for the 21st Century (1999).

The scenarios are implemented using IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT). The basic methodology of IMPACT is described in detail in Rosegrant et al. (1995), and recent results are detailed in Pinstrup-Andersen et al. (1999).

World market prices for cereals

Under the BAU scenario, prices increase by 25 percent for wheat, by 43 percent for maize, by 32 percent for other grains, and by 34 percent for rice.[iv] These increases are due to the dramatic slowdown in cereal yield growth combined with low growth in irrigated area expansion. On the other extreme – the S2 scenario, - prices decline by 22 percent for wheat, by 29 percent for maize, by 38 percent for other coarse grains, and by 39 percent for rice.

The very high food prices projected under BAU are a sign that the investments in research and development, irrigation and water management, and other agricultural inputs stipulated are not sufficient to keep up with the increased effective food demands from a growing and increasingly affluent population. Cereals are unaffordable for many people in low-income countries, and governments in these countries have to increasingly rely on food aid for their basic needs. On the other hand, under the S2 scenario, rapid declines in world food prices increase food availability substantially in all low-income regions. With increased integration of these countries into global food markets, and the rapid increases in income under this scenario, food is accessible to the vast majority of the population.

Cereal demand

Under the BAU scenario, total cereal demand will increase by 37 percent, from 1,776 million ton in 1995 to 2,433 million ton in 2025 (Figure A1). Among the cereals, maize will show the largest increase in demand, at 278 million ton, followed by wheat at 169 million ton. The group of medium and lower income countries is expected to account for 86 percent of the increase in cereal demand; and China and India combined alone will account for 36 percent of the additional demand.

Cereal demand is expected to increase more rapidly under the S1 and S2 scenarios, mainly fuelled by rapid income growth and declining world prices for cereals. Demand is largest under S2 and particularly large for the lower income countries, where demand more than doubles from 1995 levels. Demand in developed countries, on the other hand, is lower under S2 (compared to S1) due to lower stipulated income growth.

Most current trends point to a stagnation of global per capita cereal food demand, with slightly declining consumption of cereals at higher income levels balancing slightly increasing demands of lower-income countries. Under the BAU scenario, per capita cereal food demand actually declines over the next 30 years for all three groups of countries, from an average of 157 kg in 1995 to 149 kg in 2025. However, the declines vary within the regional aggregates: per capita demand declines in the countries of the Former Soviet Union, but increases slightly in Sub-Saharan Africa. The declines in some less and least developed countries and regions will substantially increase food insecurity in these countries.

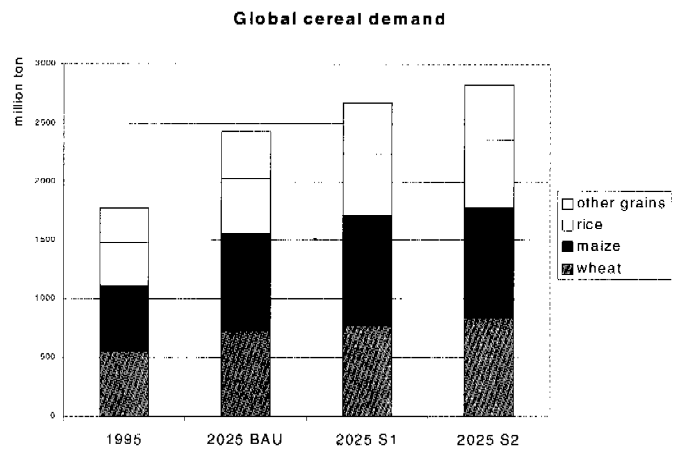

Figure A1 Global demand for cereals for Vision Scenarios – IMPACT simulation (IFPRI, 1999).

Under the S1 and S2 scenarios, on the other hand, average per capita demand of cereals as food increases to 168 kg and to a high 195 kg, respectively, by 2025. The increase in food demand under S2 is particularly dramatic in Sub-Saharan Africa, where food demand more than doubles, from 111 kg/capita in 1995 to 240 kg/capita in 2025, due to the combination of rapid income growth and low food prices.

Implications for food security

Figure A2 shows the outcomes of the scenarios on daily per capita calorie availability. Global calorie availability per capita is projected to increase under all three scenarios. Under BAU, availability increases by 6 percent, under S1, by 11 percent, and under S2, by a very high 25 percent. Calorie availability improves under BAU despite the decline in per capita food consumption. This is due, in part, to the increased consumption of meat and dairy products as well as vegetables and fruits by 2025. In addition, some low-income countries increase consumption of roots and tubers, which are a relatively cheaper staple crop, compared to cereals under this scenario.

Sources of growth in production

The increase in global cereal demand projected for the 1995-2025 period will have to be met through increases in yield and harvested area. Both current trends and future projections show that the brunt of future production increases will be placed on yield growth. However, some expansion in (irrigated) areas will be required to nourish future populations. Increases in yield and area will depend on sufficient availability of water for irrigation, supplementary irrigation, and precipitation. Increased agricultural production can also be a major contributor to poverty alleviation in rural-based low-income developing countries, both directly through increased income generation that enables access to food and other basic needs for the rural poor, and indirectly, through increased availability of food at affordable prices.

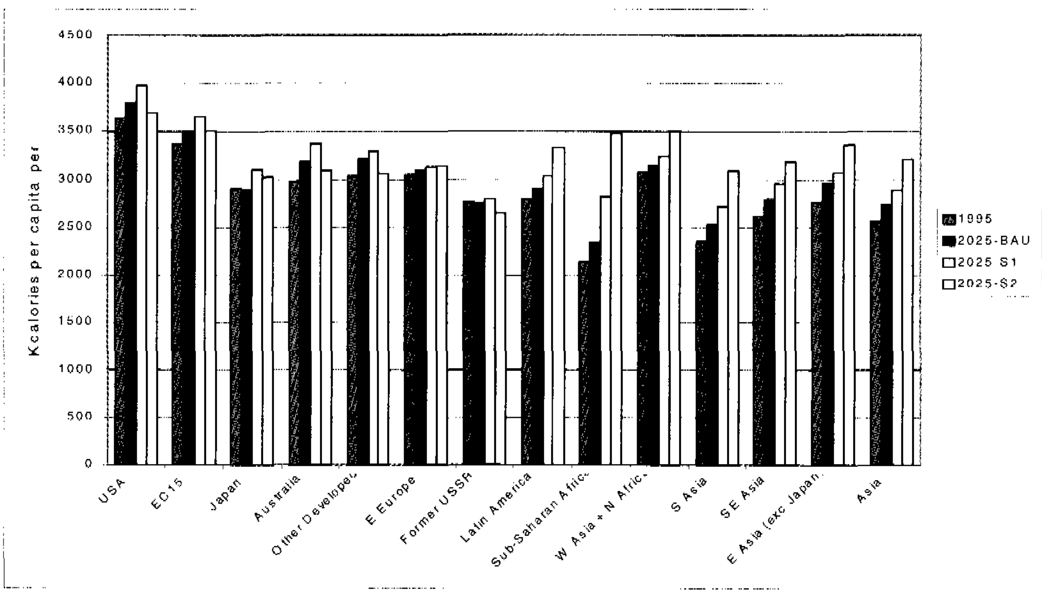

Figure A2 Average calorie intake per region for the Vision Scenarios – IMPACT simulations, (IFPRI, 1999)

Yields

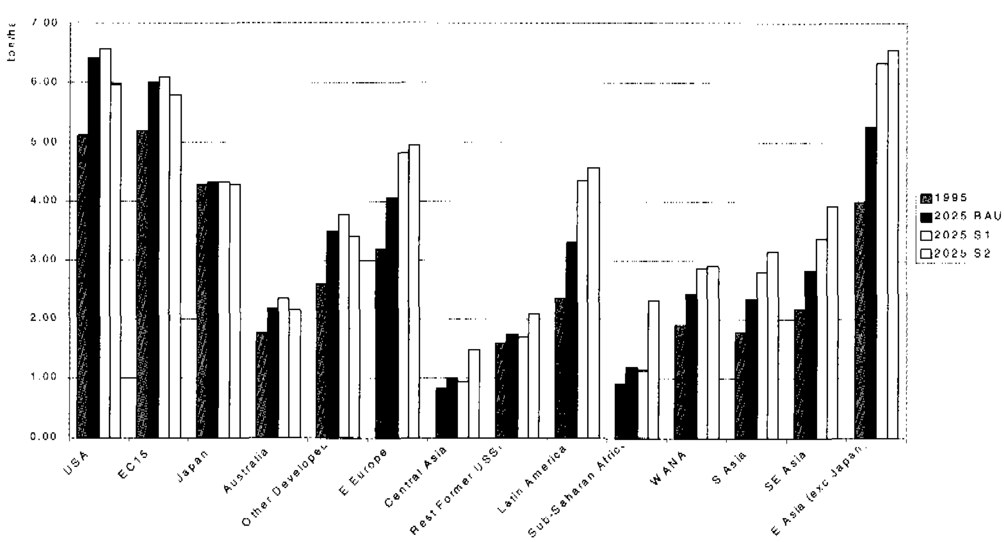

Figure A3. Cereal yields across regions according the Vision Unit Scenarios (IFPRI, 1999)

With global cereal crop area increasing only slowly, growth in crop yield will account for most of the projected production increases. However, although yield growth rates vary by commodity and country, there will be an overall decline in the rates of growth in crop yields compared to the already reduced rates in the post-Green Revolution period of 1982-94. Yield growth assumptions for the BAU scenario are very low and the effective yield growth rates during 1995-2025 present considerable slowdowns compared to historic and current trends[V]. Yield growth will be lowest for the low-income developing countries, at 0.48 percent per year. Achieved yield growth for these least developed countries is actually higher under BAU than under S1 – contrary to scenario input assumptions - because the price effects under BAU – where cereal prices are driven very high by slow production growth – slightly boost yield growth under BAU through feedback effects, compared to S1[vi]. However, under both BAU and S1, effective yield growth for these countries remains low. Under S2, on the other hand, where investments are concentrated on efforts towards closing the yield gaps for cereals across countries and regions, yield growth more than quadruples in the group of least developed countries.

Under BAU, and particularly, under the S1 scenario, where the focus is on expanding the yield potential, the yield gap between the developed and the least developed countries actually widens. However, even under the very optimistic S2, where an active effort is made to raise cereal yields in low-income developing countries closer to the levels achieved in the more developed countries, the cereal yield gap cannot be eliminated. Cereal yields in the least developed countries will almost double to 2.4 ton/ha by 2025. This is still less than half of the yield level in the most developed countries. Cereal yields in the group of less developed countries, on the other hand, reach levels close to the developed countries group.

Growth in cropped area

Increases in irrigated area vary substantially by region and country grouping. Figure A4 shows that under BAU, growth in irrigated cereal areas is virtually stagnant as increases in the group of more developed countries are balanced by declines in irrigated cereal areas in the group of most developed countries. Under the S1 scenario, on the other hand, cereal irrigated areas expand most rapidly in the group of more developed countries (with the largest absolute increase in India), but are also substantial in other countries and regions. Under the S2 scenario, on the other hand, irrigated cereal area is taken out of regions where irrigation is considered to be highly unsustainable due to water stress like areas in West and Central Asia and North Africa. However, rapid increases take place in low-income developing countries, particularly Sub-Saharan Africa, which will also experience the largest increases in rainfed cereal areas. The effective increases in irrigated areas were achieved after implementing rates of irrigation growth that would have totalled in increases of 3.7 percent and 40.0 percent as specified for the BAU and S1 scenarios, respectively, and 8.4 percent for the S2 scenario.[vii]

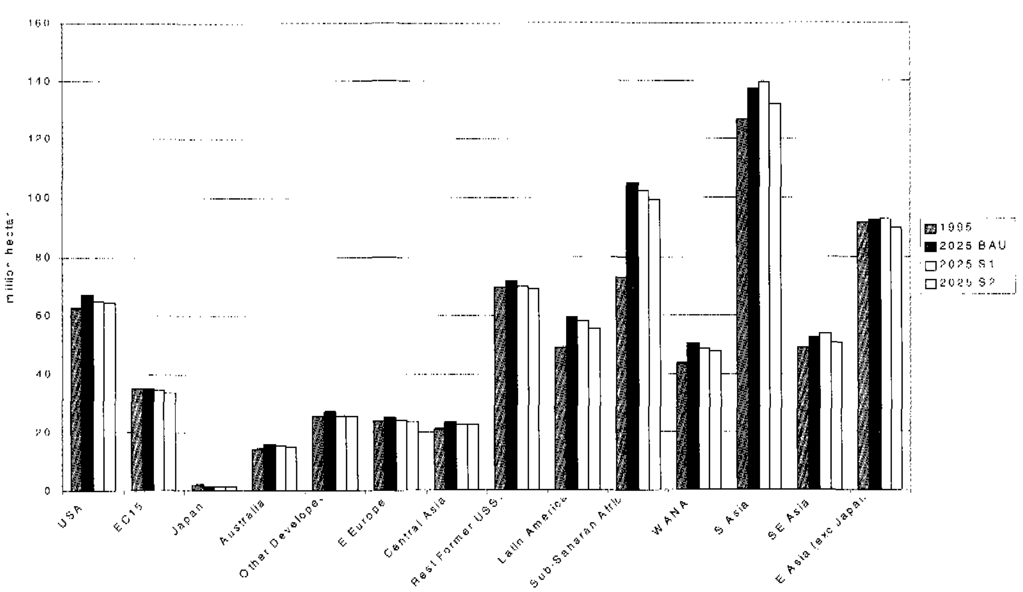

Figure A4. Development of cropped area under the Vision scenarios - IMPACT simulations, (IFPRI. 1999)

Growth in area will contribute little to future cereal production growth. Between 1995 and 2025 the cereal cropped area will increase by 77 million ha (0.36 percent per year), 66 million ha (0.31 percent per year), and 34 million ha (0.16 percent per year) under the BAU, S1 and S2 scenarios, respectively. This compared with an annual rate of growth of 0.37 percent during 1967-82 and a decline in area of 0.24 percent per year during 1982-94. The world market prices for cereals directly influence realised area growth across scenarios. Thus, under BAU, where world market prices are highest and yield growth is lowest, the highest growth in cereal area is realised. On the other hand, under S2, world market prices in 2025 are lowest, and increases in cereal area are comparatively low. Most of the cereal area growth takes place in like Sub-Saharan Africa. Under BAU, for example, Sub-Saharan Africa accounts for 60 million hectares or 83 percent of total harvested cereal area increase. The area expansion under S1 (and to a lesser degree under the other scenarios) also increases by growth in irrigated area as only part of the new irrigated area is conversion from previously rainfed areas. The remainder is expansion of harvested area through double/triple cropping or through irrigation of previously fallow land. This can be seen in particular for the cereal area growth rate of the group of medium income countries, where irrigated area increases significantly under S1, particularly in India and, to a lesser degree, in China (see also Figure A4).

Water implications

In the BAU scenario the primary water diversions increases only 6%, a very modest increase because of very restricted investments in new water infrastructure (Tables A2-A4). Most of the growth takes place in developed countries in the domestic and industrial sector[viii], especially in low-income developing countries where 1995 levels are very low. Out of the IWMI set of 45 countries[ix], absolute water scarcity (i.e. degree of development higher than 60%) occurs only in the 12 countries that were already water scarce in 1995. There are some 22 countries mainly in South America and Sub-Saharan Africa that will be economic water scarce meaning an increase of primary water supply by 25% compared to 1995 levels, implying substantial investments in water infrastructure. However, most countries fall in the category of production scarce, meaning that they face no water but cereal shortage. This is not surprising in view of the low yield levels and limited investments in irrigation infrastructure.

In the S1 scenario the primary water supply increases by 24% worldwide. The biggest growth takes place in the higher-income developing countries that have the opportunity to benefit most from irrigation development. Consequently the number of countries facing absolute water scarcity is higher compared to the BAU scenario. For example both India and China will be water short due to large irrigation expansion. The biggest group of countries will face economic water scarcity. Because of more intensive water use they have to develop 25% more water between now and 2025 resulting in high investment requirements. The number of countries facing production scarcity is low compared to the BAU scenario.

In the S2 scenario primary water supply increases with 23%, with the biggest increase takes place in the low-income developing countries. Here an increase of 50% compared to 1995 level takes place. Due to higher income levels the per capita consumption of water in the domestic and industrial sector increases. This scenario is geared towards closing the production gap between rich and poor countries, which requires a substantial expansion of the irrigated area, especially in Africa. Not surprisingly, in this scenario many countries in the low income developing groups will face economic scarcity while absolute and production scarcity are relatively few

Global cereal trade

One of the major trends influencing future food supply and demand will be the rapid increase in global cereal trade, with the primary impetus for expanded trade being generated by the group of middle and lower income countries increasing its food imports from the group of high income countries. Total cereal trade is projected to increase from 172 million ton in 1995 to 325 million ton under BAU, 348 million ton under S1, and 342 million ton under the S2 scenario (Figure 12). The cereal trade volume is slightly lower under the S2 scenario, compared to the S1 scenario, due to the lower population in 2025. Rapid increases in the trade of agricultural commodities will not only influence food but also future water security.

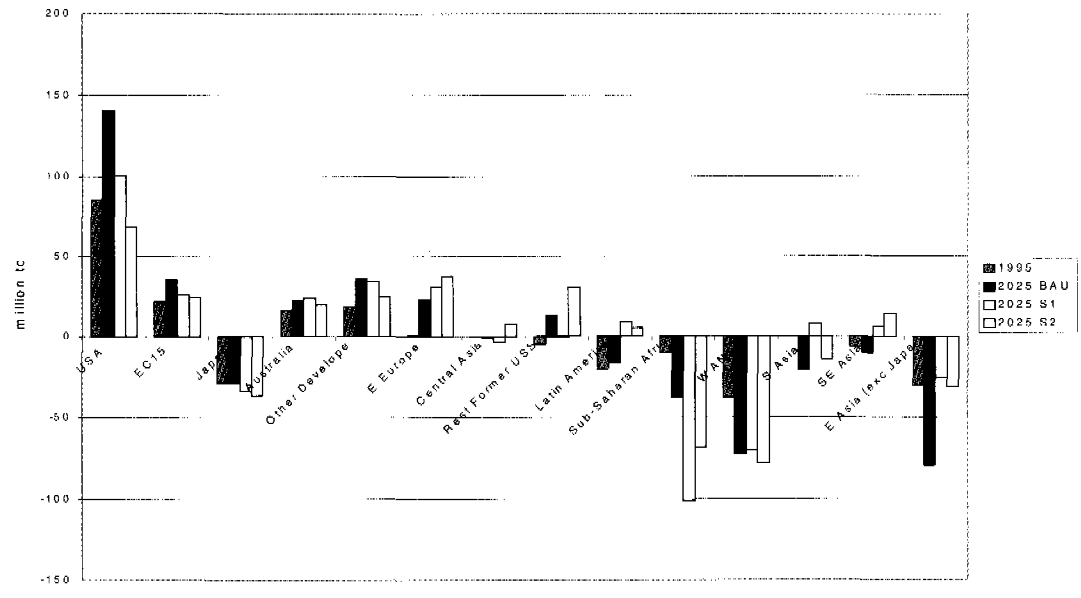

Figure A5 Global cereal trade according the Central Vision Unit scenarios (IFPRI 1999).

Figure A5 shows the volume of net cereal trade by region. The most striking outcome is the large net cereal imports for the group of lowest income countries under the S1 scenario. This is due to the combination of very low yield growth rates assumed under this scenario – for Sub-Saharan Africa, for example, 0.75 percent per year during 1995-2025 – and very rapid income growth, of 5.7-6.5 percent per year, depending on the region within Sub-Saharan Africa. High growth in income fuels rapid increases in cereal demand. This demand cannot be satisfied locally due to low increases in cereal yields. As a result, net imports by the group of lowest income countries countries increases; the growth in income implicitly assumes that these countries will have the foreign exchange to finance these imports.

Under S2, on the other hand, net imports by these low income countries are much lower. This time, the assumptions specify rapid growth in cereal yields combined with even faster growth in incomes. The even higher cereal demand under this scenario will be met mostly by local production, or intra-regional trade, and thus, the net imports from the developed countries is much lower.

Annex A1. Assumptions used for the World Water Vision Scenarios.(IWMI, 2000)

Variables		BAU		S1		S2	
Population	G1 countries	UN MED		UN MED		UN LOW	
	G2 countries	UN MED		UN MED less 2%		UN LOW	
	G3 countries	UN MED		UN MED less 2%		UN LOW	
Country consumptive use factor (E/PWS)	All countries	Can be above 70%		Less than 70%		Less than 70%	
Degree of Development (PWS/UWR)	All countries					Less than 60%	
		Growth Rates 1995 - 2025					
		BAU		TEC		VAL	
		Annual	Total	Annual	Total	Annual	Total
GDP - Regions	N America	2.10%		3.32%		0.98%	
	W Europe	2.10%		3.32%		1.53%	
	Australia	2.05%		3.27%		1.21%	
	E Europe	1.89%		1.42%		4.37%	
	Japan	0.96%		2.17%		0.12%	
	CIS	2.15%		2.13%		5.13%	
	Aral Sea	2.17%		2.34%		4.50%	
	Cent America	1.77%		1.12%		5.18%	
	South America	1.95%		1.80%		4.07%	
	Mid East	1.40%		1.31%		3.89%	
	China	4.20%		4.02%		7.69%	
	N Africa	2.06%		4.07%		6.73%	
	Cent Africa	1.92%		3.74%		5.18%	
	E Africa	1.83%		3.77%		5.92%	
	W Africa	1.96%		3.92%		6.11%	
	S Africa	1.69%		3.54%		5.20%	
	S Asia	3.49%		3.81%		6.65%	
	SE Asia	2.98%		3.35%		6.01%	
Total irrigated area	Global	0.22% Brazil, India, Turkey	1.5%	IWMI base adjusted	25%	IWMI base adjusted	5%
Total cereal area	Global	0.36%		0.31%		0.16%	
Irrigated grain yield	G1	0.88%		1.50%		1.50%	
	G2	1.00%		1.80%		2.30%	
	G3	0.79%		1.00%		2.30%	
Rainfed grain yield	G1	0.30%		0.60%		0.40%	
	G2	0.30%		0.45%		0.80%	
	G3	0.30%		0.30%		1.00%	
Irrigation Efficiency2	G1 countries		10%		20%		30%
	G2 countries		10%		20%		30%
	G3 countries		10%		10%		30%

Table A2. Growth in primary diversions by scenario.(IWMI, 2000)

Group/ Region/ Country	1995 Primary Water Supply km3	BAU Primary Water Supply km3	BAU Growth 1995-2025 %	TEC km3	TEC Growth 1995-2025 %	VAL km3	VAL Growth 1995-2025 %
World							
All countries (100)	2363	2499	6%	2929	24%	2904	23%
OECD Countries	753	830	10%	850	13%	800	6%
High income Developing countries	1324	1372	4%	1727	30%	1677	27%
Low income developing countries	286	297	4%	352	23%	427	50%
Regions							
N America	437	500	15%	510	17%	480	10%
W Europe	190	197	4%	201	6%	197	4%
Australia	24	26	8%	34	40%	29	19%
E Europe	36	39	7%	39	7%	63	75%
Japan	61	58	-4%	55	-9%	54	-12%
CIS	76	90	18%	88	16%	167	121%
Aral Sea	80	76	-5%	89	12%	96	20%
Cent America	54	57	5%	71	32%	87	61%
South America	72	88	23%	98	36%	124	73%
Mid East	134	127	-6%	144	7%	143	7%
China	359	369	3%	488	36%	450	25%
N Africa	69	70	1%	103	49%	110	58%
Cent Africa	1	2	106%	2	91%	3	167%
E Africa	8	9	12%	12	41%	13	59%
W Africa	10	12	16%	14	39%	16	58%
S Africa	14	17	18%	23	64%	18	25%
S Asia	622	626	1%	813	31%	661	6%
SE Asia	115	135	17%	145	26%	193	68%

Table A3. Growth in total diversions (IWMI,2000)

Group/ Region/ Country	1995 km3	BAU 2025 km3	BAU Growth 1995-2025	S1 2025	S1 Growth 1995-2025	S2 2025	S2 Growth 1995-2025
World							
All countries (100)	3372	3779	12%	4072	21%	3972	18%
OECD Countries	935	1000	7%	1021	9%	938	0%
High income Developing countries	2043	2315	13%	2549	25%	2419	18%
Low income developing countries	394	464	18%	502	27%	616	56%
Regions							
N America	510	563	10%	571	12%	529	4%
W Europe	239	248	4%	260	9%	244	2%
Australia	27	29	5%	38	37%	31	14%
E Europe	55	67	23%	62	13%	108	97%
Japan	109	101	-7%	90	-17%	87	-20%
CIS	126	171	36%	168	33%	313	149%
Aral Sea	102	108	6%	112	9%	110	8%
Cent America	67	78	17%	88	31%	117	76%
South America	108	150	39%	171	58%	194	79%
Mid East	169	173	2%	169	0%	163	-4%
China	582	683	17%	765	31%	712	22%
N Africa	97	108	12%	135	40%	141	46%
Cent Africa	1	4	166%	4	187%	4	191%
E Africa	11	14	29%	18	59%	18	62%
W Africa	15	21	36%	25	61%	25	65%
S Africa	16	19	13%	26	56%	19	14%
S Asia	954	1003	5%	1109	16%	860	-10%
SE Asia	184	239	30%	263	43%	297	62%

Table A4. IWMI's Water Scarcity Indicators by Scenario (IWMI 2000).

Group/ Region/ Country	Degree of Development (PWS/UWR)				Country Consumptive factor (E/PWS)			
		BAU	**S1**	**S2**		**BAU**	**S1**	**S2**
	1995	1995-2025	1995-2025	1995-2025	1995	1995-2025	1995-2025	1995-2025
	%	%	%	%	%	%	%	%
World								
All countries (100)	11%	11%	13%	13%	64%	66%	65%	60%
OECD Countries	21%	23%	23%	22%	56%	56%	59%	58%
High income Developing countries	13%	14%	16%	15%	68%	71%	69%	62%
Low income developing countries	3%	4%	4%	5%	64%	67%	62%	55%
Regions								
N America	17%	20%	20%	19%	59%	59%	60%	60%
W Europe	26%	27%	28%	27%	55%	56%	59%	59%
Australia	12%	12%	16%	14%	57%	57%	65%	64%
E Europe	10%	11%	11%	17%	59%	63%	64%	55%
Japan	50%	48%	45%	44%	42%	43%	43%	44%
CIS	3%	3%	3%	6%	56%	58%	58%	49%
Aral Sea	23%	22%	25%	27%	67%	73%	64%	59%
Cent America	7%	7%	9%	11%	64%	67%	69%	58%
South America	1%	2%	2%	2%	57%	57%	67%	52%
Mid East	88%	83%	94%	94%	66%	73%	67%	62%
China	44%	46%	60%	56%	70%	74%	70%	67%
N Africa	38%	38%	56%	60%	70%	73%	61%	57%
Cent Africa	0%	0%	0%	0%	49%	44%	52%	39%
E Africa	1%	1%	1%	1%	57%	58%	57%	54%
W Africa	2%	2%	3%	3%	61%	62%	63%	60%
S Africa	47%	55%	77%	59%	60%	59%	59%	45%
S Asia	44%	44%	57%	46%	71%	75%	69%	64%
SE Asia	5%	5%	6%	7%	55%	54%	61%	47%

[i] Opinions among the experts in the Scenario Development Panel differed with regard to the income, irrigated area, and yield growth assumptions through 2025 that reflect business-as-usual trends. IFPRI's IMPACT baseline results show an increasingly difficult, but still significantly more positive picture of future world food supply, demand, and prices, compared to the BAU scenario; see, for example, Pinstrup-Andersen et al. (1999).

[ii] GFAR (1999)

[iii] The original specification for effective growth in irrigated area was 5 percent.

[iv] The IFPRI IMPACT baseline projection results indicate that global food production will grow fast enough for real world prices of food to decline slightly, but at much slower rates than in the past two decades. Results indicate tighter global food markets, with greater susceptibility to year-to-year price fluctuations, but not the dramatic price increases resulting from the BAU specification.

[v] A comparison with the IFPRI IMPACT baseline global cereal yield growth – of 1.0 percent per year through 2025 – exemplifies the drop in growth in yields stipulated under BAU. The baseline projections already result in very substantial declines in yield growth relative to recent performance. To implement the specified irrigated and rainfed yield growth rates under BAU, a further large reduction from the baseline projection is required: a proportion of 72 percent to IMPACT baseline yield growth rates for G1, 63 percent for G2, and 45 percent for G3 countries was applied.

[vi] Under IMPACT, world market prices for cereals have feedback effects on both area and yield growth. Thus, for example, with assumed low yield growth under BAU, cereal prices begin to increase as demand outstrips production. As cereal prices increase to balance supply and demand, there are secondary positive impacts of prices on area and yields, thus somewhat increasing the originally specified low yield growth and bidding up area planted to cereals, partially compensating for the low yield growth.

[vii] The originally specified rate of growth for the S2 scenario was 10 percent. However, the rapid income growth assumed under this scenario, together with the more rapid slowdown in population growth, and the retiring of irrigated areas in Japan, Pakistan, and several countries of West Asia and North Africa, have contributed to the lower 8.4 percent.

[viii] The consumption rate is much lower since the consumption factors in domestic and industrial are much lower than in the agricultural sector.

[ix] IWMI used 45 countries for evaluation of its base scenario and grouped them in countries with physical, economical or little water scarcity. Countries classified as having physical scarcity are o.a.: Saudi Arabia, Pakistan, Jordan, Iran, Syria, Tunisia, Egypt, Iraq, Israel, South Africa and Algeria. Countries with economic water scarcity are Brazil, Turkey, Mexico, Philippines, Thailand, Ethiopia, Australia, Myanmar, Nigeria, Bangladesh, Argentina, Vietnam, Sudan, Morocco. Countries classified as having little or no water scarcity are: Kyrgystan, Canada, USA, Indonesia, Poland, Spain, France, UK, Italy, Germany, Uzbekistan, Turkmenistan, Romania, Tadjikistan, Japan, Kazahstan, Ukraine, Russian Federation.