Agriculture, Environment and Human Welfare in West Asia and North Africa: The Search for Sustainability

International Center for Agricultural Research in the Dry Areas

About ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based in Aleppo, Syria, it is one of 15 centers supported by the Consultative Group on International Agricultural Research (CGIAR).

ICARDA serves the entire developing world for the improvement of lentil, barley and faba bean; all dry-area developing countries for the improvement of on-farm water-use efficiency, rangeland, and small-ruminant production; and the Central and West Asia and North Africa region for the improvement of bread and durum wheats, chickpea, and farming systems. ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national agricultural research and development systems. These efforts are supported by seminars, publications, and specialized information services.

About IGBP

The International Geosphere-Biosphere Programme (IGBP), based in Stockholm, Sweden, was established in 1986 by the International Council of Scientific Unions (ICSU) to help the scientific community describe and understand the interactive physical, chemical, and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring, and the manner in which changes are influenced by human actions. A central objective of the IGBP is to establish the scientific basis for quantitative assessment of changes in the Earth's biogeochemical cycles, including those changes that control the concentration of carbon dioxide, a major greenhouse gas, and other chemicals in the atmosphere.

To achieve its objectives, the IGBP engages scientists from over 100 nations in interdisciplinary research on atmospheric chemistry: terrestrial ecosystems, biological drivers of the water cycle, coastal land-ocean interactions, ocean circulation, and past global changes.

About IDDC

Formerly called the International Desert Development Commission, the International Drylands Development Commission (IDDC) was established in Cairo in 1978 to promote research and education aimed at sustainable use of the dry areas of the world. A major focus of the work of IDDC has been the rehabilitation of degraded lands and mitigating future damage. One of the key activities of IDDC is to identify priorities for research on desertification in Central and West Asia and North Africa.

IDDC achieves its objectives through: organizing scientific conferences; establishing committees to deal with special problems; publishing proceedings of major conferences, and other publications; and establishing links with other international and national organizations involved in dryland studies.

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Proceedings of a workshop held at ICARDA, 5-7 May 2002

Abstracts

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Foreword

Much of the contemporary international development dialog focuses on the need to improve human welfare and alleviate poverty and malnutrition, while addressing global and local environmental issues within the context of globalisation. Given the increasing knowledge on global climate change, there is a need to provide the scientific underpinning for future rural development, while factoring in anticipated global change. Some organizations are making concerted efforts to extend the dialogue between international rural/agricultural research for development and the emerging environmental and global climate change agendas, and to reinforce their relevance to urban issues and needs.

There is an urgent need to explore, in detail, the links between agricultural land use and production systems and associated research, global climate change and human welfare, and poverty agendas on a regional basis. A more rigorous exploration of the economic, social and environmental exchanges between urban and rural populations and between the developed and developing world is also required. Nowhere are these issues of greater relevance than in the dry areas of West Asia and North Africa (WANA), part of the 'dry areas' mandate of the International Center for Agricultural Research in the Dry Areas (ICARDA).

As a contribution to this agenda, a working group has been set up to establish a firmer link between the agendas of the Consultative Group on International Agricultural Research (CGIAR) and the global environmental and climate change communities like the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environment Change (IHDP), and the World Climate Research Programme (WCRP). This 'global climate change community' has metamorphosed into the 'global change community' with a growing appreciation of the human dimension of environmental issues.

If the global marketplace, led by major multinational companies, becomes serious about decreasing carbon emissions, what would it mean to WANA? We must be aware of a number of possible scenarios and how they might interact. Climate change driven by current emissions might occur to the detriment of agriculture, human welfare and the natural heritage in the WANA region with its already limited industrial water resources. In turn, this may impact the socio-political stability of WANA and lead to massive migration to Europe.

The WANA region is the major center of biodiversity for several of the world's main crops such as wheat, barley, a number of forage and food legumes and tree crops such as olives, figs, and almonds, and also vegetable crops. What is the significance of climate change to the conservation of these biological resources, and equally, the importance of these genetic resources to the ability of the world community to respond to the triple challenges of climate change, poverty alleviation, and regional and global food production? What role[s] should ICARDA and its partners in research be playing? How can its unique germplasm collection be best utilized? What new strategic alliances need be established to focus on the region's most pressing livelihood, agricultural and environmental problems? What approaches can be developed to bridge the gap between the rural and urban agendas?

I am extremely happy that the workshop on "Agriculture, Environment and Human Welfare in West Asia and North Africa: The Search of Sustainability," held at ICARDA, 5-7 May 2002, was successful in promoting a dialog and developing a set of outcomes/recommendations which will help guide ICARDA's strategy and generate new partnerships to enhance the Center's contribution to human well-being in the region. We hope that this publication will prove useful to all the stakeholders involved in the development of agriculture, environment, and human welfare.

Prof. Dr Adel El-Beltagy
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ICARDA

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Session 1:

Setting the Scene

The Challenge for West Asia and North Africa within the Changing Global Context

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The world is going through a phase of transition in which social, political and economic realities are changing. Advances in science and technology and a growing recognition of collective responsibility are the driving forces for such changes. The objective of this workshop is to help us understand the likely changes in the region during the next 20 years and to shape our research agenda for poverty alleviation and environment protection.

The dry areas of the world are home to over one billion people. About 700 million of them live on 2 dollars a day. In Central and West Asia and North Africa (CWANA) alone, which we refer to as the ICARDA region, over 40% of the population, that is over 300 million people, live on less than 2 dollars a day. Women and children are affected the most by poverty. These statistics mask wide variations between regions, and between countries within regions. In CWANA, the rates of increase in poverty are now among the highest in the world, which is partly because of reduced agricultural production after the breakup of the Soviet the Union. In Tajikistan, for example, 68% of the population now lives in poverty. The poorest countries in CWANA are Eritrea, Ethiopia, Mauritania, Somalia, Sudan, and Yemen.

Poverty and the environment are closely linked. The poor are particularly vulnerable to environmental stresses, such as drought and water scarcity. To decrease poverty, appropriate interventions of science and technology are required to increase agricultural productivity, generate value-added products, develop rural industries, provide off-farm employment opportunities, and create an enabling environment for the implementation of new policies. This calls for alliances of many varied stakeholders including NGOs and the private sector.

The increasing population poses further challenges to poverty-stricken countries. The total population in CWANA alone is expected to rise from over 700 million in 2001 to approximately 1.15 billion in 2020. Of 163 million people living in countries that border the Mediterranean region between Morocco and Syria, a staggering 91 million, or 56%, are less than 24 years of age. The younger generation is growing. Lack of employment opportunities coupled with poor living conditions is driving a rural exodus and migration to industrialized countries, leading to economic and socio-political upheavals.

The population explosion is causing ever-increasing food deficits. The CWANA region is the largest food importer in the developing world. When Turkey and Kazakstan were excluded, and only a 27 country CWANA aggregate was considered, the 1995 grain gap was about 54 million tons. Using a conservative estimate, without considering any growth in per capita income or consumption, this deficit will easily reach up to 114 million tonnes by the year 2020. Therefore, the agricultural challenge of the region is to achieve a sustainable increase in the rate of food production at a faster rate.

The problem of malnutrition is another closely related aspect to hunger. A recent USDA study has found that currently some 700 million people are malnourished in 67 developing countries, many of which are located in North Africa, Central Asia, and the Nile Valley. It is predicted that nutrition deficits will intensify globally. Besides combating the menace of malnutrition, problems like land degradation, water scarcity, climate changes, and loss of biodiversity are also posing serious challenges.

The land area of CWANA covers some 1.7 billion ha. Of the irrigated crop land, 11.3 million ha or 33% of the total, is suffering from some form of degradation, 50 million hectares of the 73 million hectares (68%) of rainfed crop land is estimated to be degraded, and of the rangelands as much as 85% is degraded. This translates into an estimated 45% of the area under threat of some form of desertification. The WANA region faces the most serious threat of water shortages. The average annual per capita renewable supplies of water in WANA countries is now less than 1500 m^3, well below the world average of about 7000 m^3. This is expected to fall to less than 700 m^3 by the year 2025. Jordan faces a severe shortage with current per capita availability of just 230 m^3 water. It is projected that, by 2025, at least 19 WANA countries will be in the grip of severe water poverty. The surface temperature is projected to increase in the range of 1.4 to 5.8°C by the year 2100. The dry areas will get drier and face new challenges, and the crop varieties and agricultural technologies of today may become irrelevant to the changed climate of tomorrow.

CWANA is home to genetic resources of some of the most widely cultivated crops in the world. But this precious resource is under serious threat from desertification. For example, the Mouterde's Flora, published in 1953, reported 900 plant species in the Jabal El-Arab area of Syria, which is considered a treasure of biodiversity. An inventory carried out during 1996-2000 in the same area revealed that only 512 species were now available. The loss of over 50% plant species in just 50 years is truly alarming, and calls for immediate action.

Since its establishment in 1977, ICARDA has worked to meet these challenges through research to improve food production, protect the natural-resource base, and strengthen national programs. Following is a short account of impact of ICARDA in the region:

Introduction of improved varieties

Owing to ICARDA's wheat improvement research, jointly conducted with CIMMYT, over 80 improved wheat varieties are now grown in large areas of the region. For example, in Syria, about 90% of total wheat area is now under improved varieties. The productivity of wheat has quadrupled in Syria since the 1970s which has also helped spare about 3.5 million hectares of land for the cultivation of other crops. The gains from increased wheat productivity exceed US$ 500 million per year. Similarly, wheat production has shown substantial increases in Tunisia. The average contribution of new cultivars amounted to US$ 48 million annually, in the 1981-1991 period. For Morocco, the net present value of returns over the expenditure for the period 1970-1999 is estimated at about US$ 111 million.

In the case of barley, for which ICARDA has a global mandate, adoption of new varieties ranges between 20-40% in the Mashreq and Magreb countries. In Iraq, the area planted with 'Rihane-03', a new ICARDA-germplasm-based barley variety, increased from 5000 ha in 1994/95 to more than 250,000 ha by 1999, i.e., a fifty-fold increase within a five-year period. This barley variety outyields the commonly grown local variety Arabi Aswad by up to 20%.

ICARDA also has a world mandate for the improvement of faba bean, which, like lentil, is an important source of protein in the diet of the poor. The Center has been working in several countries on packages of faba bean technology, based on new cultivars and improved agronomic practices. Studies conducted in partnership with Egypt's national agricultural research system in the Nile Valley and Red Sea Region show that farmers in Egypt, Sudan, and Ethiopia are enjoying yield increases of up to 200%. The technology has been adopted by 63% of farmers in the target areas. The new cultivars are disease-resistant, so they have contributed to reduction in the use of pesticides and fungicides, which in turn reduces environmental pollution.

Mechanization of harvesting

Harvest cost, which has long been a barrier to lentil production, has been significantly reduced through the introduction of low-cost machine harvest systems. Mechanical harvesting has enhanced adoption of new lentil varieties, checking the decline of the lentil production area. In the Urfa province of Turkey, a major lentil-producing province, 78% of the 150,000 ha of lentils are now harvested mechanically. In Hassake province in Syria, nearly two-thirds of the 25,000 ha grown annually are harvested mechanically.

Introduction of winter sowing technology for chickpea

Chickpea is an important source of protein in the region. ICARDA has developed improved lines of chickpea, which can be sown in late winter, instead of the traditional spring sowing in the CWANA region. This has helped to double chickpea yields, and a large number of lines for winter sowing have been released in the ICARDA region, and Mediterranean Europe. Estimates indicate that about 150,000 hectares are now sown with winter chickpea, and provide an additional income of US$ 75 million in the region. The annual global benefits of ICARDA's chickpea improvement research are estimated at US$ 29 million. In recent years, ICARDA material has also been widely used in Australia, Canada and the U.S.

Crop/livestock integration

ICARDA's work with the National Agricultural Research System (NARS) in crop/livestock integration has been successful in developing alternative feed sources that provide better nutrition to livestock, particularly during periods of feed shortages. Feed-block technology that makes good use of agricultural by-products is being widely adopted by farmers in CWANA, and is providing new opportunities for employment, income generation, and linkage with the private sector. In Iraq, feed-block production increased over five-fold between 1995 and 2000, and spawned 20 private semi-industrial enterprises. A similar trend is being observed in Jordan, Morocco, Tunisia, Algeria, and Syria.

New forage legume production systems

A new crop rotation system based on vetch-cereal rotation has been developed. In this, vetch provides good quality feed for sheep and goats, while yield of the following barley or wheat crop is increased by as much as 50%, and the rotation breaks the cereal disease and pest cycles.

Cash crops

Strategic interventions in cropping systems can play a major role in protecting income and food security. For example, figs are a high-value cash crop to resource-poor farmers on the northwest coast of Egypt. This crop has been deteriorating in many locations over the last few years. A preliminary survey conducted by ICARDA and the Matrouh project in Egypt suggested that the fig dieback in that region is most likely caused by a combination of stresses, namely, viruses, insect pests, and drought. In collaboration with the Agricultural Genetic Engineering Institute, Egypt, ICARDA has started work to produce virus-free fig seedlings through meristem tip culture.

Natural resources management

ICARDA is conserving genetic resources of rangeland vegetation, and has adapted environment-friendly technologies based on a systems approach to range management. A pickup driven pitter has been very successful in creating micro-catchments to collect rainwater and seeds and to aid in seedling establishment.

Dairy products

By combining indigenous knowledge with modern dairy technology, ICARDA researchers are helping farm-family enterprises to increase their production. These endeavors also generate new employment opportunities and reduce poverty.

Water harvesting and irrigation technologies

Water harvesting is an approach to maximize the benefit from the limited rain in dry areas. ICARDA is leading an eco-regional project on water harvesting that involves Egypt, Iraq, Jordan, Libya, Morocco, Oman, Pakistan, Syria, and Tunisia. Among its outputs, the project has developed field equipment to make microcatchment systems of semi-circular bunds to trap rainwater. ICARDA's research on supplemental irrigation is designed to determine the optimum amount of irrigation water to apply at critical stages of crop growth. Crop-water modeling techniques are being used to develop highly efficient supplemental irrigation strategies.

Use of marginal-quality wastewater

To offset the declining availability of water for irrigation in dry areas, use of marginal-quality water, such as treated sewage effluent, drainage and brackish water, is being evaluated. Modeling tools are being used for ex-ante assessment of the long-term effects on soil health and crop productivity.

Gene bank

ICARDA holds 127,000 plant accessions in its gene bank. It is also working with partners in the region to help conserve landraces and their wild relatives in their native habitat.

Future directions

DNA marker

The Center has successfully integrated biotechnological tools with conventional breeding. Such an example is the use of DNA-marker techniques to characterize the population structure of *Ascochyta rabiei* in Syria, which causes ascochyta blight. As a result of these efforts, multiple resistance has been developed for several diseases in both cereals and legumes, and incorporated into high-yielding cultivars. New protocols for making interspecific hybrids enabling the introgression of desirable genes from wild relatives have also been developed.

Microarray-based genotyping/links with TIGR

Biotechnological tools are now available to develop drought and heat tolerant varieties. ICARDA, in collaboration with advanced research institutes in genomic research, is developing drought microarrays to help characterize the different pathways to stress tolerance, and elucidate their interdependent genetic control. We believe this will enable us to pyramid several unique mechanisms of drought tolerance in our facultative winter wheat and barley germplasm pool for the rainfed regions of CWANA leading to improved crop durability and reliability.

Remote sensing

Remote sensing and geographic information systems can help in better management of land, water and biodiversity. To assess drought, ICARDA has been working with NARS to develop indicators based on water-balance, using remote sensing, GIS, long-term meteorological data, and spatial weather generators. ICARDA in partnership with CIHEAM of Morocco has used remote sensing to analyze the yield and production potential of cereals affected by drought.

Expert systems

Computer expert systems are another important tool that can help in transferring knowledge from agricultural researchers to the end-user. For example, NEPER, developed through outsourcing the Central Laboratory for Agricultural Expert Systems, Egypt, is an integrated bilingual (English and Arabic) expert system that addresses all aspects of irrigated wheat management in Egypt. Field evaluation has revealed that NEPER provided good economic returns and a positive impact on the environment. ICARDA is strengthening its work in this field by developing expert systems for other crops of economic importance.

Value added products for increased income

To achieve the goal of poverty alleviation, and increase the income, ICARDA encourages entrepreneurs in village-based agro-industries. Durum wheat, for example, is a major component of many foods, including burghul, pasta, couscous, frike, and various types of bread. By working with NARS to increase durum production, ICARDA has helped stabilize wheat supply, and has supported farm families and communities to earn extra incomes through production of value-added products.

Farmer to farmer technology transfer

In promoting village-based agro-industry, ICARDA promotes farmer-to-farmer technology transfer. The center also provides opportunities to farmers of the region to come in contact with each other, and share their experiences.

Food security

Food security requires continued research and development efforts. Therefore:

- the role of land registration and more secure property rights needs critical examination. Agropastrolists and farmers cannot be expected to take long term responsibility for the natural resources they use in situations where they are insecure tenants, or where range and water rights are not well defined.
- the development of policy options is needed to encourage communal and private investments to enhance and stabilize food production, and promote social development.
- the involvement of communities and resource users in the research process is to be promoted.

Global alliances

In closing, I want to reiterate the aim of our meeting. We are here to analyze the implications of the current and future trends in agriculture, environment, and human welfare for the future of the region, and to evolve a strategy for poverty alleviation and improved livelihoods through a collective research agenda. To achieve this, ICARDA must continue to establish and broaden strong partnerships to develop sustainable technologies. The key to this lies in research. The knowledge generated from agricultural research can provide the basis for the development of technologies and improved policies that will not only help in increasing production, but also in generating increased income. This will have a direct bearing on poverty alleviation and protection of the natural resource base.

Global Change and the Earth System

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The past decade of global change science has led to a remarkable improvement in our understanding of the life support system of our home planet. The scientific landscape is very different now from that of the late 1980s. Global change research has confirmed that the Earth works as a single, interlinked system. The work has added a wealth of quantitative detail and process-level understanding at all scales. Through a significant increase in the ability to unravel the past, the understanding of the natural dynamics of the Earth System has advanced greatly. It is now clear that global change is one of the paramount environmental issues facing humankind at the beginning of the new millennium.

The work presented here is based on a decade of research carried out under the auspices of the International Geosphere-Biosphere Program (IGBP), and of our sister global change programs, the World Climate Research Program (WCRP), the International Human Dimensions Program on Global Environmental Change (IHDP), and DIVERSITAS, an international program of biodiversity science. Rather than being comprehensive and all-encompassing, specific examples are used here to highlight the major new understanding of global change and the Earth System achieved over the past decade.

The major findings of IGBP and related research over the past decade are:

The Earth is a system that life itself helps to control. Biological processes interact strongly with physical and chemical processes to create the planetary environment, but biology plays a much stronger role than previously thought in keeping the Earth's environment within habitable limits.

Global change is much more than climate change. It is real, it is happening now and it is accelerating. Human activities are significantly influencing the functioning of the Earth System in many ways; anthropogenic changes are clearly identifiable beyond natural variability and are equal to some of the great forces of nature in their extent and impact.

The human enterprise drives multiple, interacting effects that cascade through the Earth System in complex ways. Global change cannot be understood in terms of a simple cause-effect paradigm. Cascading effects of human activities interact with each other and with local- and regional-scale changes in multidimensional ways.

The Earth's dynamics are characterized by critical thresholds and abrupt changes. Human activities could inadvertently trigger changes with catastrophic consequences for the Earth System. Indeed, it appears that such a change was narrowly avoided in the case of depletion of the stratospheric ozone layer. The Earth System has operated in different quasi-stable states, with abrupt changes occurring between them over the last half million years. Human activities clearly have the potential to switch the Earth System to alternative modes of operation that may prove irreversible.

The Earth is currently operating in a no-analogue state. In terms of key environmental parameters, the Earth System has recently moved well outside the range of the natural variability exhibited over at least the last half million years. The nature of changes now occurring simultaneously in the Earth System, their magnitudes and rates of change are unprecedented.

Although all of these findings relate to the Earth System as a whole and to its functioning in a fundamental way, there is a strong intersection with the agricultural enterprise and, in particular, with the challenge of feeding an expanding human population while maintaining or improving the global environment. A significant number of the global changes that the planet is experiencing now - changes in the carbon, nitrogen and water cycles; changes in the Earth's land cover; changes in the composition of the atmosphere - have a direct link to our need to grow and consume food. The next 50 years will be crucial. Food production will have to continue to rise at about 2% per annum, while at the same time the impact of such food production will need to decrease. Our current and evolving understanding of the Earth System provides useful guardrails that can help guide the human enterprise over this daunting transition to sustainability.

Productivity Growth in World Agriculture: Sources and Constraints

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Prior to the beginning of the twentieth century, almost all increases in crop and animal production occurred as a result of increases in the area cultivated. By the end of the century the increases were coming from high output per hectare. The world population is projected to grow to between 9 and 10 billion people by 2050, which would almost double the demands placed on the world's farmers. Most of the growth is expected to occur in poor countries where the income elasticity of demand for food remains high. Therefore, very substantial increases in scientific and technical efforts will be required, if growth in food production is to keep pace with growth in demand.

Agriculture in development thought

In the early post-World War II literature, growth in agricultural production was viewed as an essential condition, or even a precondition, for growth in the rest of the economy. By the early 1960s it had become increasingly clear that much of agricultural technology was 'location specific'. Techniques developed in advanced countries were not generally directly transferable to less developed countries with different climates and resource endowments. Evidence had also accumulated that only limited productivity gains accrued from the reallocation of resources within traditional peasant agriculture.

Measuring the rate and direction of productivity growth

Early productivity studies identified exceedingly wide differences in land and labor productivity both among countries and major world regions. Recent trends in land and labor productivity indicate that these wide differences have persisted. Within the group of developed countries, except for continuing divergence between northern and southern Europe, productivity levels have converged modestly. Developing countries, as a group, experienced declining total factor productivity relative to the frontier countries. Similar trends have taken place in some of the more land-constrained, labor-intensive agricultural systems in Africa and Latin America.

Transition to sustainability

Growth of land and labor productivity has led to substantial poverty reduction. Productivity growth has also released substantial resources to the rest of the economy and contributed to reductions in the price of food in both rural and urban areas. The decline in the price of food has been particularly important in reducing the cost of industrial development in a number of important emerging economies. These price declines have also meant that in countries or regions that have not experienced such gains in agricultural productivity, farmers have lost competitive advantage in world markets and consumers have failed to share fully in the gains from economic growth. It is, therefore, important to study the environmental, resource, scientific, and technical constraints that will confront the world's farmers as they attempt to respond to demands that will be placed on them.

Resource and environmental constraints

The leading resource and environmental constraints faced by the world's farmers include soil loss and degradation; water logging and salinity; the co-evolution of pests, pathogens and hosts; and the impact of climate change. Soil degradation and erosion have been widely regarded as major threats to sustainable growth in agricultural production in both developed and developing countries. It has been suggested, for example, that, by 2050, it may be necessary to feed "twice as many people with half as much topsoil."

During the last half-century, water has become a resource of increasing value in many countries. In the past 50 years, the irrigated area in developing countries more than doubled, from less than 100 million hectares to more than 200 million hectares. About half of developing country grain production is grown on irrigated land. The International Water Management Institute has projected that by 2025 most regions or countries in a broad sweep from north China across East Asia to North Africa and northern sub-Saharan Africa will experience either absolute or severe water scarcity.

Pest control has become an increasingly serious constraint on agricultural production in spite of dramatic advances in pest-control technology. For much of the post-World War II era, pest control has meant application of chemicals. By the early 1960s, an increasing body of evidence suggested that the benefits of the synthetic organic chemical pesticides introduced in the 1940s and 1950s were obtained at substantial direct and indirect effects to wildlife populations and human health, also leading to the destruction of beneficial insects and the emergence of pesticide resistance in target populations. The solution to the pesticide crisis offered by the entomological community was Integrated Pest Management (IPM). However, exaggerated expectations that dramatic reductions in chemical pesticide use could be achieved without significant decline in crop yields, as a result of IPM, have only been partially realized. The co-evolution of pathogens, insect pests, and weeds, in response to control efforts, will continue to represent a major factor in directing the allocation of agricultural research resources to ensure that agricultural output can be maintained at present levels or continue to grow.

During the early 1980s, a fairly broad consensus had emerged in the climate change research community that energy production and consumption from fossil fuels could, by 2050, result in a doubling of the atmospheric concentration of CO_2, a rise in global average temperature by 2.5-4.5°C (2.7-8.0°F), and a complex pattern of worldwide climate change. This followed a number of studies to assess how an increase in the atmospheric concentration of greenhouse gases could affect agricultural production. Early assessments of the impact of climate change on global agriculture suggested a negative annual impact in the 2.0-4.0 % range by the third decade of this century. Efforts to incorporate how public and private suppliers of knowledge and technology might adjust to climate change are just beginning. It is certain that a country or region that has not acquired substantial agricultural research capacity will have great difficulty in responding to anticipated climate change impacts.

Scientific and technical constraints

The achievement of sustained growth in agricultural production over the next half century represents at least as difficult a challenge to science and technology as the transition to a science-based system of agricultural production during the twentieth century. Owing to new types of constraints, it is much more difficult to tell about the likely sources of increase in crop and animal production over the next half century. The yield increases from incremental fertilizer application are falling, the share of research budgets devoted to maintenance research has risen relative to total research budgets, and cost per scientist per year has been rising faster than the general price level. Both public and private sector agricultural research, in those countries that have achieved the highest levels of agricultural productivity, have begun to experience diminishing returns. The optimism that advances in molecular biology and genetic engineering will relieve the scientific and technical constraints are shadowed by the concerns about the possible environmental and health impacts of transgenic plants and foods.

Agricultural research systems

The establishment of the Consultative Group on International Agricultural Research (CGIAR) during 1971, is an example of institutional arrangements to support agricultural research. From the 1950s through the 1980s, the resources available to the new national and international research institutions from national and international sources expanded rapidly, leading to dramatic success in the form of the "green revolution." But during the 1990s, growth of public sector support for research has slowed substantially. However, an active and vibrant global agricultural research system will be needed to sustain growth in agricultural productivity into the twenty-first century.

Perspective

In developed regions in which land and labor productivity are already at or approaching technical frontiers, it will be difficult to achieve growth in agricultural productivity comparable to the rates achieved in the past. But, because of the slow rise in food demand in these countries, except perhaps those that are most land-constrained, they will have little difficulty in achieving desired rates of growth in agricultural production. In sub-Saharan Africa, where land and labor productivity levels are furthest from frontier levels, opportunities exist to enhance agricultural productivity substantially. Land constrained countries, such as India, can be expected to depend on biological technology. In contrast, Brazil, which can still expand its agricultural land frontier, can be expected to follow a more balanced productivity-growth path. Most of the poor countries or regions that find it advantageous to follow a biological-technology path will have to invest substantially more than in the past to acquire capacity for agricultural research and technology transfer.

It is difficult to anticipate the productivity paths that will be followed by countries of the former USSR, West Asia, North Africa and other arid regions. The major oil-producing countries and a number of tropical or semitropical developing countries will continue to expand their imports of food and feed grains. Many of the constraints on agricultural productivity discussed here could become a threat to the growth of agricultural production in a number of the world's poorest countries. A primary defense against the uncertainty about resource and environmental constraints is agricultural research capacity. Thus, erosion of capacity of the international research system will have to be reversed, the capacity of developed countries will have to be maintained, and the capacity of developing countries will have to at least be substantially strengthened. It is emphasized that more secure bridges must be built between the research systems of what have been termed the "island empires" of the agriculture, environment, and health sciences.

Research Developments in Global Environmental Change and Food Systems

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In coming decades, human welfare will largely depend on finding answers to questions such as: given changing demands for food, how will Global Environmental Change (GEC) additionally affect food provision and vulnerability in different regions and social groups? How might different societies and categories of producers adapt their food systems to cope with both GEC and changing demands? And what would be the environmental and socioeconomic consequences of adaptations to these changes?

These issues are of interest to policymakers and society at large. The research agenda they prompt is also of particular interest to the international GEC research community, notably the International Geosphere-Biosphere Program (IGBP), the International Human Dimensions Program on Global Environmental Change (IHDP) and the World Climate Research Program (WCRP). It is also of growing interest to NARS and the Centers of the CGIAR, especially in relation to their developing Challenge Program on Climate Change.

Recent years have seen considerable advances in understanding both how the biophysical aspects of GEC will affect food productivity, and how institutions and other socioeconomic factors influence vulnerability and adaptive flexibility of societies in response to GEC. Nevertheless, many issues of great interest to science remain, and warrant continued research efforts. Of more general interest to society at large is the complex question of how GEC will affect food provision, a concept that considers notions of availability and access, in addition to productivity and overall production. Access to food is a function of economic potential and food availability, which depends on production and distribution. Food production is a function of yield per unit area, and the area from which harvest is taken. The interactions between GEC and this broader concept of food provision involve many complex issues spanning natural, social and climate sciences and an innovative, interdisciplinary approach - "Global Environmental Change and Food Systems" (GECAFS) - is now emerging.

In response to the three fundamental questions which introduce this paper, GECAFS is designed to address three interrelated science themes derived from them, and has the goal: "to determine strategies to cope with the impacts of global environmental change on food provision systems and to analyze the environmental and socioeconomic consequences of adaptation."

Though disciplinary studies of GEC impacts continue to be important, GECAFS will be broader in scope, and explicitly include studies on how food provision systems could be adapted to the additional impacts of GEC, and the consequences of different adaptation strategies for both socioeconomic conditions and environment. By including considerations of both "impacts" and "feedbacks" there is a strong link to the "Earth System Science" of the international research community. This link would be further consolidated by designing and undertaking the research program in close collaboration with the CGIAR, thus establishing a formal research partnership between GECAFS and the CGIAR. The specific role that each community of researchers can play needs to be clearly defined to show how collaboration will lead to more effective use of research investment and findings.

GECAFS is a new approach to global change science. Building on work within the three sponsoring programs (IGBP, IHDP and WCRP), and linking it to the strengths within the CGIAR and beyond, it offers prospects for significant scientific advances as a consequence of its interdisciplinary approach. The juxtapositioning of social, economic, climate, and biophysical sciences in GECAFS offers a fertile prospect for developing the following new areas of science as these often develop at the boundaries of supposedly "separate" sciences:

- Analyses of changing human wealth and food preferences, and interactions with biophysical models of GEC to produce new insights of regions where food provision may be sensitive to GEC.

- Methodologies that allow the appropriate level of aggregation of small-scale food production systems and disaggregation of global-scale scenarios and datasets to address regional and sub-regional issues.

- Comprehensive scenarios of future socioeconomic and environmental conditions.

- Use of past records of societal adaptations to biophysical changes to provide inputs to scenario-based models of the future.

- New analysis and insights into the institutional factors that can reduce societal vulnerability to GEC.

GEC and the food system in the WANA region: the role of changing land management aimed towards multiple goals

In addition to changes in climate, GEC includes changes in several other key issues including land management - which is often the predominant current aspect of GEC. To complement GECAFS studies elsewhere in the world, it would be valuable to develop a project in more arid regions where grazing systems are often very important. This would be especially so if the project were to concentrate on a particular aspect of changing land management aimed towards multiple goals including improving food provision by increasing fodder supplies. A GECAFS study based on livestock-pasture-crop systems of WANA, including the potential role Atriplex could play in the system (given its potential for fodder supply, and carbon sequestration and other environmental considerations), would provide an excellent contribution to many aspects of the GEC agenda.

There is increasing interest in the use of various Atriplex species for arid-land development projects related to carbon sequestration. Research in Australia has shown that carbon sequestration potential can be as high as 20 t C/ha over a 3-5 year period, but even a figure of 10 t C/ha would be very significant, especially when extrapolated over the large areas potentially available in the Middle East and other arid and semi-arid parts of the world. The potential for Atriplex to sequester carbon is also of interest as a possible source of credits in any carbon trading scheme. Such credits might help offset any possible changes in rural livelihoods discussed in the background papers for this meeting.

While land management for carbon sequestration could be a central goal, there will be concurrent effects on fodder and water supplies, biodiversity enhancement and land degradation. The GECAFS approach would allow development of tools to analyze the "trade-offs" between socioeconomic and environmental goals at a range of spatial and temporal levels so that the overall potential value of investment in Atriplex-based land management projects could be assessed.

GECAFS is designed to be applicable to a wide range of issues and regions, including drylands. Although drylands cover one third of the earth's surface, little work has been done to determine the impacts of GEC in these regions, the nature of institutional and agronomic responses including mitigation options, and the potential feedbacks of possible management options to socioeconomic and environmental conditions. A GECAFS approach would allow these three areas to be researched in an integrated manner.

Perspectives on Social and Economic Evolution in West Asia and North Africa

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Past agricultural policies in the West Asia and North Africa (WANA) region have been dominated by heavy-handed interventions by governments, ranging from macroeconomic, trade and sector policies that discriminated against agriculture; state ownership of agro-business enterprises and land; price controls; import and export controls; market regulation; and even the planning of production, distribution, and consumption of important foods and agricultural export commodities. Farmers and communities have typically had little voice in agricultural development and resource-management decisions, and there have been few attempts to create institutional structures that would promote investment and sustain the resource base. These policies have promoted patterns of agricultural growth that have proved disappointing in terms of growth in rural per-capita incomes, and have led to severe environmental degradation in the dry areas. They have also proven costly to governments and consumers alike because of the labyrinth of subsidies, price supports, and trade barriers that they involve.

The farming systems promoted by past policies are not sustainable from an environmental or fiscal perspective, and there is urgent need for change. Future polices need to strive for much greater cohesion between agricultural growth, poverty reduction and sound environmental stewardship. WANA countries have already endorsed such changes by devoting new efforts to reforming their policies and by ratifying the UN Convention to Combat Desertification and the recommendations of the Rabat Ministerial Meeting.

This paper discusses options for policy change to achieve these objectives in the dry areas of WANA (defined as receiving less than 400 mm mean annual precipitation). These areas embrace a significant share of the arable land in the region, virtually all of the steppe rangelands, and much of the upland watersheds. In addition to being the main locus of rural poverty, they are severely degraded, largely as a result of human activity. While degradation is not solely of recent origin, there is strong evidence that it is accelerating. The paper draws on the experience in eight WANA countries (Algeria, Libya, Morocco, Tunisia, Syria, Iraq, Lebanon, and Jordan) and on recent research undertaken within those countries as part of the Mashreq and Mahgreb (M&M) project led by IFPRI and ICARDA in collaboration with the national agricultural research systems in all eight countries.

Reforms are needed to correct existing policies that distort economic incentives and encourage farmers to overstock and over-cultivate the range, to pursue excessively capital intensive production practices, and to waste water. This will require reducing, even removing, many of the output support and input subsidies that benefit the dry areas. The transition from the planned agricultural sector, typical of WANA countries until very recently, to a dynamic agro-food system closely integrated within a global and open market economy, involves a complex process of institutional, structural, and behavioral changes in both the private and public sectors. The standard Agricultural Sector Adjustment Package (ASAP) seeks to promote this transition and includes policy-reform provisions related to domestic pricing, trade, marketing, property rights, investment, and natural resource conservation.

The eight M&M countries have moved along this transition at different paces and to varying degrees. Algeria, Jordan, Morocco, and Tunisia have initiated and/or implemented market liberalization, while Iraq, Lebanon, Libya and Syria have started reforming their agricultural sectors, but within less ambitious structural adjustment packages. Property rights reforms have also been implemented to promote privatization of croplands, land distribution, and improved management of rangelands. But again the degree of implementation varies across countries. Algeria, Iraq, Jordan, Syria, and Libya continue to treat rangelands as state lands under the control of the government with very limited involvement of pastoral communities in the management of these resources. However, in other countries, especially Morocco and Tunisia, the rights of tribes and communities have been recognized and efforts are being made to improve the capacity of the communities to better manage their resources.

The results of the multi-market modeling confirm the desirability of market and trade liberalization policies from a national perspective for promoting growth and better environmental management. However, the income losses borne by the agricultural sector are quite severe, particularly in the dry areas, and this would inevitably adversely impact the poor. These losses arise from a) the huge loss in government subsidies and output supports that currently benefit the agricultural sector, and b) the limited opportunities for developing alternative sources of agricultural income in the dry areas given available technology and land-use options.

In order to capture the growth and environmental benefits of market liberalization, while buffering the potentially negative impacts on farm incomes and the poor, it will be necessary to manage the transition carefully. Farmers need time to adjust their farming systems to the new economic regime. For example, they need time to develop and adopt less-input intensive feeding systems, to rehabilitate rangeland, and to invest in alternative land uses such as tree crops and dairying.

Therefore, there is good reason to phase out existing subsidies over a number of years rather than in one abrupt step as has sometimes been tried. The modeling results suggest that this phasing may be more important for removing output rather than input supports, though important exceptions arise such as feed subsidies in Jordan.

The property rights research found that strengthening property rights and markets for cropland would provide additional incentives to farmers for improved stewardship of their resources. It would also enable farmers in the dry areas to better respond to the changing economic environment as market liberalization proceeds. However, these changes should be undertaken in close consultation with local communities to identify options and mechanisms that would ease some of the constraints they face.

On rangelands, there are many promising examples of institutional options for improving range management, but their success ultimately depends on the extent to which herding communities have control over their resources and are aware that they will be the primary beneficiaries of any investment they make in rehabilitating pastures. The recognition of these rights would also favor retention of traditional livestock mobility systems that are so critical for extensive livestock production in drought-prone areas. But Bedouin communities have undergone many transformations in recent decades and it is not always feasible to reconstruct traditional management institutions, however attractive they may have been.

Session 2

Cradle of Civilization: Crucible of Land Degradation?

Climate Change in West Asia and North Africa in the Period of Human Settlement

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Models predicting future environmental changes should take into account the interactions of natural climate dynamics with anthropogenic forcing factors. Instrumental records are too short to represent the full range of natural climatic variability. There is no doubt that climate changes that have occurred during the Holocene period, the past 11,500 years, in West Asia and North Africa (WANA) have been more dramatic and persistent than those of the last century. It is thus crucial to study the past to understand how regional environmental changes are related to changes in the Earth's climate.

In WANA, fluctuations in rainfall, landscape and water resources of impressive amplitude are documented by numerous geological, historical and archaeological data. These climatic changes have different causes and have occurred at different time-scales. These facts are illustrated here with some selected records based on different types of archives taken from the Sahara-Sahel of West Africa to Western Tibet.

Climatic changes at the millenial scale: The wet early Holocene period in WANA

One of the most spectacular features of past climate changes is the wetting/greening of the WANA deserts that took place from ca. 10-5 ky (ky means 1000 calendar years before present). This wet period was preceded and followed by generally dry conditions.

From ca. 11-10 to 6-4 ky, there were numerous freshwater lakes in the Sahel and in the Sahara which supported savannah and steppe vegetation, large mammal fauna and human populations. This period also saw an intensive recharge of the Saharan deep-water reservoirs which are today's unique and non-renewable water resource in the region. In North East Africa, many tectonic or volcanic basins which are presently almost dry were occupied by large freshwater lakes. Some of these were up to 300 m deep (e.g. L. Asal, Djibouti) and 6000 km^2 in area (L. Abhé, Ethiopia). A very similar evolution was recorded from lake records in the present-day arid western Tibet. The wet early Holocene period is also documented by speleotherm records from Oman and Israel. Using different proxies and methods, palaeoprecipitation has been estimated at 10-40% higher than today in different regions of WANA.

The early Holocene wetting in most of WANA can be primarily attributed to the Earth's orbital changes that increased summer insolation in the Northern Hemisphere, inducing an intensification of the monsoon circulations. However, global-circulation climate models show that global-scale atmospheric circulation, feedback mechanisms from the ocean, vegetation cover and soil are also required to account for the amplitude and the abruptness of the onset (ca. 11-10 ky) and termination (ca. 6-4 ky) of this generally wet period which spanned several thousands of years.

Climate changes at the centennial to interannual time scales: Short-term Holocene climatic events in WANA

Dry or wet spells spanning a few decades or centuries are superimposed to the general trends from usually wet early Holocene conditions to generally dry climate after ca. 5 ky. Attention is paid here to well identified severe droughts.

A dry spell between ca. 9 and 8 ky was evidenced in lake and pollen records from western Sahara-Sahel and western Tibet, and a sharp weakening in precipitation was recently precisely dated at 8.2 ky in Oman speleotherms. A dry event around 7-6.5 ky was recorded in West Africa and West Asia. At many sites of the African and Asian monsoon domains, a maximum in aridity is observed at 4.5-4 ky. It coincides with an unusual dust event identified at 4.2 ky in the eastern Mediterranean, and across Mesopotamia. The Sahel experienced a drastic drought at 1.5-1.2 ky. The well-resolved 2000 year record from Lake Naivasha (Kenya) shows a succession of at least seven decade-scale episodes of aridity more severe than any drought recorded during the 20th century, especially between 870-1270 AD.

The instrumental record of the Nile River discharge at Cairo, which covers the past 1400 years, shows several periodicities from 220 to ca. 4-7 years in the summer discharge which mainly depends on the Blue Nile flowing from the Ethiopian Plateau.

The causes of these abrupt Holocene events are still poorly known and are probably multiple. Several authors hypothesize that the 8.2 and 4.5 ka dry events in the tropics and subtropics are linked to cooling events in the North Atlantic. High resolution records of the recent past, e.g., the L. Naivasha and the Nile records, strongly suggest that the decade to century-scale episodes of aridity/wetness represent the regional response to changes in solar activity, as the European "Medieval Warm Period" and "Little Ice Age". High frequency, interannual variability of the Nile record has been associated with the El Nino-Southern Oscillation.

Potential impact of climate changes on human societies in WANA

Natural climatic changes may have considerable impact on biological and human activities, as illustrated here with some examples from the western Sahara and Sahel.

Human migrations into and out of the Sahara are obviously linked to the onset and retreat of generally wet early-mid Holocene conditions. From about 10 to 5 ky, Neolithic civilizations flourished in an environment with accessible water and substantial food even in the heart of the Sahara that today has almost no measurable precipitation. But these populations experienced severe droughts, e.g., at ca. 8 ky. Lake records show that freshwater lakes dried or turned to saline ponds unsuitable for water consumption in a few decades. Such dramatic events may have been socioeconomically destructive and induced southward migration, such as during the 1970-80s Sahel drought. They also might have generated inventive adaptations to new socioeconomic situations, as suggested from archaeological data in western Fezzan. The major desertification phase around 5-4.5 ka was associated with large cultural changes; e.g., agriculture development and changes from fish and meat to cereal food in Niger. From about 4.5-4 ka, classical Neolithic civilization in the central Sahara collapsed, but was probably replaced by nomadic or semi-nomadic populations coming from the East or the Northeast. This change coincided with the mysterious collapse of the advanced urban civilizations in Egypt, Mesopotamia and India, and a severe dry spell in the eastern Mediterranean.

Over the past thousands of years, climatic changes in WANA have occurred on millennia to interannual time scale. Although their causes and mechanisms are not fully understood, these changes appear to be linked to the Earth's climate system and its major forcing factors, e.g., insolation or general oceanic circulation. Whatever the time scale, such natural climatic changes may have considerable social impact and should be considered in forecasting regional environments.

Historic Impact on Terrestrial Ecosystems and Land Use Patterns in West Asia and North Africa

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It is now half a century since modern scientific studies of the history of terrestrial ecosystems began, notably with the application of radiocarbon dating to organic remains. Progress in WANA over the first ten years was reported by Butzer, Whyte, Hamdan and Despois to a UNESCO meeting in Paris on the History of Land Use in Arid Regions (Stamp 1961), by which time several thousand radiocarbon dates had become available. Since then, Brice (1978) has edited 'The Environmental History of the Near and Middle East since the Last Ice Age' and Roberts (1998) has summarized new material. In addition there have been numerous books and papers on individual areas where archaeological or historical studies have been made.

As a result we now have somewhat more reliable accounts of the climatic history of WANA. Some progress has also been made on reconstructing vegetation history, though this is a more difficult area of study. To trace the effects of the activities of people - governments, landowners, cultivators and pastoralists- is still more difficult. Let us examine these three in turn:

1. Climatic history: Climates with dry summers and rainfall mainly in the winter half of the year are very unusual, probably occupying less than one percent of the world's surface. Such regions were probably cooler during the last Glacial maximum by about 6 degrees, but in many WANA regions it was probably not much rainier than now, though evaporation losses must have been lower. The flow of the Blue and White Nile was very much less than it is now, but that, of course, depends on precipitation in the equatorial regions, so it is a special case. The early and middle Holocene were, at intervals, markedly wetter than now in the northern tropical zone (on account of solar precession) and the increased rainfall may have extended at times into the WANA region. Certainly, the Nile's discharge into the Mediterranean was much influenced, as anoxic sediments on the sea floor indicate. Glacier and other records suggest that the climatic sequence has been complex in the historical period with individual cooler and warmer intervals possibly associated with varying solar activity, and occasional individual or clusters of wetter and drier years result-

ing from volcanic eruptions. Current warming, following a millennium characterized by 'The Little Ice Age,' is likely to be mainly the result of increasing carbon dioxide and methane pollution of the atmosphere.

2. Vegetation history: Reliance for reconstructing vegetation has to be placed mainly on pollen analysis. Sites suitable for coring are relatively rare in WANA and the picture we have is still rather sketchy. Local absence or presence of species can be deduced, but the height and density of the regional cover over extensive areas is much more difficult to assess. Many of the earlier reconstructions were based on Clementsian ideas of plant succession which Blumler (1993), for instance, would now regard as misleading. An interesting attempt has been made to reconstruct the climate of Roman times on the assumption of a more complete plant cover in those times than now.

3. Land-use history: Rackham and I have criticized the view that landscape degradation characterizes Mediterranean Europe. As my field experience of WANA is very limited, I would hesitate to make a similar criticism here, because the prevailing climatic, economic and demographic conditions are so different. Much Ottoman archival material relating to WANA land-use history is in a script not easily read and interpreted even by Turkish and Arabic scholars. More attention to this source of information is required. Landscape observation indicates the abandonment of terraced slopes where cereals were traditionally grown under perennial tree crops. The decay of nomadic pastoralism has important implications for future vegetation cover. Building dams presents obvious risks of flooding formerly productive areas and of depriving downstream areas of the floodwaters on which they depend. Tapping subterranean water threatens the exhaustion of groundwater supplies. Currently rising Northern Hemisphere temperatures are reducing the natural storage of glaciers and snowfields in the headwaters of large rivers, and may cause the lower limit of tree growth to rise. It can be argued that the limited water supplies are needed for direct use by the population of the region which is increasingly concentrating in a relatively small number of urban areas.

Finally, mention should perhaps be made of environmental catastrophies which had long lasting consequences: the flooding of the Black Sea by the Mediterranean about 6000 BC, a hypothetical great drought about 2000 BC, a series of disasters including earthquakes, volcanic eruptions about 540 AD in the reign of Justinian, and the fourteenth century Black Death and Mongol invasion. In conclusion, lessons from history coupled with modern research findings could provide a better way to achieve the goal of sustainability.

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Session 3

Some Challenges Currently Facing the WANA Region

Exploitation Potential of Renewable Natural Resources in West Asia and North Africa

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After millennia of food self-sufficiency, the region of Central and West Asia and North Africa (CWANA) is no longer capable of feeding itself. Population growth (up to 3.6%) has already considerably outpaced agricultural production. The total population in West Asia and North Africa (WANA) alone is expected to more than double, approaching 930 million by 2020. The deficit between the demand and supply of food is bound to widen even more in the years to come.

The land area of CWANA covers some 1.7 billion ha. Soil degradation and water scarcity characterize much of the region and an estimated 45% of the total area irrigated and rainfed arable land together with rangelands is subjected to some degree of land degradation.

Erosion-promoting and nutrient-mining cropping systems, due to demographic and economic pressures, are having detrimental effects on the environment and have generated serious problems associated with declining soil fertility and inadequate feed supply for livestock. Scarce water resources are being rapidly depleted.

Water poverty is widespread in the WANA region. In 1990, only 8 of the 23 WANA countries had per capita water availability of more than 1000 m^3, the threshold water-poverty level. Water scarcity in this region has already hampered development in the Arabian Peninsula, Jordan, Palestinian territories, Egypt, Tunisia and Morocco. Other countries of the region such as Syria, Iraq, Algeria and Lebanon are increasingly affected each year. Clearly water must be managed differently.

The CWANA region contains three of the eight centers of plant genetic diversity identified by Vavilov, with many key crops domesticated here. Small ruminants have been a part of farming systems since early times. But the rich biodiversity, which is key to future food security, is being lost through habitat degradation, agricultural expansion and intensification, and overgrazing.

Arable Lands

Technologies to recuperate degraded lands are now available and range from the application of soil and water conservation measures, diversification and intensification of production systems, integrated nutrient management, improved water-use efficiency, appropriate tillage, and residue management practices. These promising options explored by ICARDA require local refinement and increased efforts to improve the adaptive capacity of the national agricultural research systems and the land users in the region.

Because of the vast land area of CWANA, changes in land-use patterns are likely to have a global impact. A focus on the carbon sequestration potential can help to illustrate this point. Estimates of the likely losses of soil carbon as a result of agriculture in the region are in the range of 6-12 Pg C. It is assumed that up to 60% of this loss can be recovered. A further analysis of the potential for carbon sequestration through the adoption of technologies mentioned above suggests that up to 0.2-0.4 Pg C per year can be accumulated in the soil in the CWANA region.

Water must be more effectively managed in the region. Water cost-recovery is one avenue. Although water is extremely valuable in the region, it is generally supplied free or at low subsidized costs, giving little incentive to farmers to increase water-use efficiency. There is a major campaign to adopt pricing schemes for water services based on total operational costs. The concept is seriously challenged in many countries of the region, and innovative solutions are desperately needed to put a real value on water for improving efficiency, while continuing to protect the right of people to access water for their basic needs.

A second avenue is through improved water productivity. Research at ICARDA has shown that a cubic meter of water can produce several times the current levels of agricultural produce by adopting efficient water-management techniques. In supplemental irrigation, a limited amount of water is applied to rainfed crops during critical stages resulting in substantial improvement in yield and water-use efficiency. Water application based on deficit irrigation can maximize the return per unit of water rather than per unit of land. Application of water to satisfy less than full water requirement of crops was found to increase water productivity and spare water for irrigating new lands. Such strategies are important in the dry areas because water, not land, is the most limiting factor in agricultural production. As scarcity is growing this situation requires, an immediate adjustment to the conventional guidelines of irrigation in this region.

Optimizing agribusiness practices and inputs such as selection of appropriate cropping patterns and fertility can also increase the water-use efficiency. Selection of crops should ensure that water used in its production is cost-effective in terms of social and economic considerations. It is, however, a dynamic process since the land-use in this area will be affected by globalization and the new world trade agreements.

Using both Mendelian breeding and genetic engineering, new crop varieties can be developed to increase the water-use efficiency while maintaining or even increasing the yield levels. For example, through breeding we have developed winter chickpea and drought resistant barley, durum wheat and lentil varieties that use substantially less water to produce normal or higher yields. More work is, however, needed to integrate all the above-mentioned approaches in practical packages to achieve the largest return from the limited water available.

Participation of all concerned in the management of scarce water resources is the key to successfully implementing more effective measures of water management. Users cannot, without appropriate policies, achieve the objectives of effective water management. It is widely agreed that lack of proper policies in this region is the main constraint to improved water use.

Rangelands

The areas of rangeland in CWANA between 400 and 100 mm isohyets are huge with 270 Mha in WANA and 250 Mha in CAC.

Within only four decades, rangelands in Central Asia have evolved from a state of over-exploitation to a state of under-utilization. During the Soviet time, rangeland degradation due to high stocking rates was widespread and millions of hectares of dry steppe were plowed in northern Kazakhstan to meet the grain production goals of the Soviet Union. After the breakup of the Soviet Union, lack of infrastructure maintenance, operating capital, and loss of traditional markets for wool and karakul pelts rendered vast areas effectively ungrazeable or unattractive.

Studies in West Asia and North Africa clearly show that in most countries of the region the contribution of rangelands to livestock feeding is diminishing. To meet increasing demands for food and feed in WANA, there is an obvious expansion of rainfed crops (mainly barley) onto the best range in the 150-250 mm zone, as well as an increase of irrigation activities wherever it is possible to establish a water source. The area available for grazing is becoming smaller with more animals grazing fewer hectares. The perennial vegetation has been almost totally destroyed by overgrazing and firewood collection, leaving the soil exposed. And the ever-decreasing biomass available for grazing encourages land users to plough and grow barley instead, thereby destroying the last vestiges of any dry-season soil cover.

Attention to policy on property rights is fundamental to the future of rangelands in the region. ICARDA has been actively promoting the use of a community approach to the rehabilitation of degraded rangelands. On the technical side, alternative feeds such as cactus are showing promise, as is fodder shrub establishment, and in the wetter areas, alley cropping of saltbush with barley. Grazing management is also an important intervention. Rainfall water-harvesting is being used to improve natural resource management and production using micro-catchment systems, collecting surface runoff locally. Other successful water-harvesting techniques that have for centuries sustained the population in the dry areas of WANA include the well-known cisterns. Qanats, traditional underground canal systems that guide groundwater by natural gravity flow to the surface, have been used as irrigation and drinking water sources for many centuries in WANA. A current study at ICARDA is assessing the potential for renovation of these ancient water supply systems in Syria. Machines and tillage implements have been introduced and developed by ICARDA and her cooperators for the mechanical construction of micro-catchments. These machines include a camel pitter and land imprinter for the reseeding of degraded rangeland. The micro-depressions created by these machines induce not only the collection of water, but also of soil particles, organic matter, and seeds. In short, the future of rangelands in CWANA hangs on policy issues combined with the community use of the various technical options for intervention.

Desertification

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Increasing desertification is one of the biggest challenges posed to international development agencies. In view of the global consequences of desertification and drought, a collective approach is required. There is a pressing need to develop and strengthen partnerships among various stakeholders, and to make maximum use of existing, and newly emerging opportunities. This presentation intends to highlight the following aspects:

- Linkages between desertification, poverty, and food security
- Assessment of land degradation
- Land degradation and drought
- Approaches being promoted by FAO through the Global Mechanism
- Challenges to the successful implementation of the Convention on Desertification.

Seventy percent of the drylands, which constitute 25% of world agricultural land, are used for agriculture. Dry areas, including arid, semi-arid, and dry sub-humid areas, provide habitat and livelihoods for more than one billion people. But these regions are extremely susceptible to desertification owing to extreme difficulties involved in restoration of protective vegetative cover, soil health and nutrient status. A key to stopping desertification is to check it while continuing to provide inhabitants with their needs such as food, fiber, regular income, and a clean environment.

Food security, poverty and desertification are strongly interlinked. Availability of food is the first step towards poverty reduction, but it is very quickly and crucially affected by desertification. Food security can be achieved through understanding local livelihood strategies, and using innovative ideas of local people. Current practices in agriculture show very little use of local or traditional knowledge and wisdom. We need to capitalize more on indigenous knowledge as we implement the Convention on Desertification, in order to promote food security in the dry areas.

Implementation of the Desertification Convention is slow largely due to lack of awareness, absence of proper policies, limited scientific partnerships and extremely poor organizational capacities. Aid to agriculture is steadily declining, contributing to more and faster desertification. Recently, the Global Environmental Facility Council (GEF) declared the problem of land degradation as a new focal-area. Its forthcoming approval will provide a new window to cover the incremental cost of achieving global benefits in combating desertification. In the current circumstances, attention on economic aspects of investing in land degradation at local, national, and international level would be extremely useful.

The GEF financial support compliments the efforts of the Global Mechanism, which was established as a financial system by the Convention on Desertification to meet national and local costs. Such a partnership backed by a facilitation committee of the Desertification Convention, could prove very effective in tackling the problem. Besides the secretariat of the Convention on Desertification, the Food and Agriculture Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD), the United Nations Environment Program (UNEP), the United Nations Development Program (UNDP), the World Bank, GEF and Regional Development Banks are also members of the Facility Council. The Global Mechanism, by investing little catalytic money, has managed to help countries to develop partnerships with bilateral donors, banks and GEF.

The FAO is working with GEF and hopefully will act as one of the implementing agencies, taking advantage of its expertise in the following areas:

- Soil, water, and biological resource management
- Technology transfer
- Water-use efficiency
- Soil-productivity improvement through farmers' participation
- Biodiversity of plant and animal genetic resources
- Ecosystem services
- Soil biodiversity management
- Carbon sequestration
- Organic matter management
- Biological nitrogen fixation
- Macro fauna to improve water infiltration and moisture retention.

A new program, Land Degradation Assessment in Drylands (LADA), has been introduced and will be executed by FAO in collaboration with a number of partners. The aim is to find comparable information across the countries and determine easily measurable aggregate indicators of soil degradation and rehabilitation based on the perception of local communities and their environment and historical backgrounds. Possibilities have to be explored if assessments and experiences from one region can be applied to similar farming systems in other countries. A number of pilot countries are now developing the methodologies for LADA, while others like Argentina, Brazil, China, India, Kenya, Senegal and Tunisia, have shown interest. To implement and streamline the Convention on Desertification, and others like conventions on biodiversity and climate change, better investment and resource-targeting is required to fully utilize the scarce resources. This requires identification of new partnerships and strengthening of existing ones.

FAO, with other partners like IFAD, is also working on capacity building through various training programs, while continuing to explore possibilities of disseminating the use of proven technologies and farming innovations. It is important that agricultural systems are developed by taking into consideration the knowledge and experiences of governments, donors, farmers, local communities and other stakeholders. This will increase the diversification in the system making it more sustainable and fool proof in case of some climatic and biotic disasters. The scientific community has to encourage governments to adopt policies to restore the fertility of degraded lands and to follow good principles of organic agriculture like, crop rotation, cover crops, and no-tillage. An alarm has to be raised against non-sustainable agriculture systems, like mono-cropping, that is being promoted by the private sector. Organic agriculture and setting up of agricultural oases are other emerging areas that require further study.

The Effects of Large Dams on Environment and Human Welfare: the Experience of South Eastern Anatolia Project

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Water is not just a basic human need. It is also a basic constituent for the development, management, restoration, and enhancement of ecosystems, of which people and their cultures are just one component. In many parts of the world, the sustainability of development is threatened by the imbalance between the demands and available supplies of water, food and energy. This paper reviews the overall water scenario, and the attempts to address water scarcity and increase food and energy production by building large dams. The positive and negative effects of these water-harvesting structures on humans, and the natural environment are also examined, with special reference to the South Eastern Anatolia Project.

During the 20th century, large dams emerged as one of the most significant and visible tools for the management of water resources. More than 45,000 large dams around the world have played an important role in helping communities and economies harness water resources for food production, energy generation, flood control and domestic use. From the 1930s to the 1970s, the construction of large dams became synonymous with development and economic progress. Viewed as symbols of modernization and humanity's ability to harness nature, dam construction accelerated dramatically.

While the immediate benefits were widely believed sufficient to justify the enormous investments made (total investment in large dams worldwide is estimated at more than $2 trillion), secondary and tertiary benefits were also often cited to prove the point. These included food security considerations, local employment and skills development, rural electrification, and the expansion of physical and social infrastructure such as roads and schools. The benefits were regarded as self-evident, while the construction and operational costs tended to be limited economic and financial considerations that justified dams as a highly competitive option.

For most of the 20th century, water managers and engineers have focused on building irrigation hardware. The development of rules, on the other hand, lagged behind, causing many discussions on the effects of large dams on development. Regarding water development projects, sustainability may depend on how economic, social and environmental issues are approached during the planning, construction, and operation of the projects. In order to ensure that the environment and the well-being of the populations are protected, or even enhanced, environmental impact assessment (EIA) studies have to be prepared for all present and future development projects. However, it has not been easy to define how and when water projects could be considered to be sustainable or unsustainable because of many reasons, among which are the difficulties to define sustainability in operational and quantitative terms.

The South Eastern Anatolia Project (GAP) aims to develop water resources for poverty alleviation and balanced regional development. It was formulated as a package of water and land resources development project in the 1970s, which in the early 1980s was transformed into a multisectoral, socioeconomic regional development program, and then into a sustainable human development project in the 1990s. This massive launch for development has special emphasis and priority for the economic, social, and cultural advancement and well-being of the whole country, and of the people of the South Eastern Anatolia region (the Upper Mesopotamia or Fertile Crescent) in particular. The basic objectives of the GAP are to remove interregional disparities in the country by alleviating conditions of abject poverty and raising the income levels and living standards in the region, to enhance productivity and employment opportunities in rural areas, and to improve the population-absorbing capacity of larger cities.

The main environmental benefits of the project that have been identified are the control and use of flood waters mainly for energy and agricultural purposes, availability of a regular supply of high-quality water for human and industrial use, preservation of natural flora, increase in the aquatic fauna, and creation of recreation facilities.

The main impact of the construction of the Atatürk Dam to the population living in the project area and beyond is employment generation, resettlement, and rehabilitation. The project aims to increase GRP by 445%, per capita income by 209%, and create new employment opportunities for 3.8 million people.

The importance of water development projects for the socioeconomic development is often ignored. However, there are other equally important issues that need attention. Many governments have failed to identify and minimize the negative social and environmental impacts resulting from the construction and operation of large water projects. In spite of the importance and necessity of actively engaging the affected populations in the decision-making processes, they have been repeatedly ignored. It is only recently that involuntary resettlement is being recognized as a development issue, and not simply as a salvage operation. Participatory resettlement, as initiated in the Birecik Dam, is a step in the right direction and needs to be replicated elsewhere.

GAP has been conceived and implemented as a means of integrating water resources development with overall human development in the poorest and most backward regions of Turkey. The strategy aims at bridging the hiatus between physical and spatial development, and human development. Despite the many constraints and challenges, initial results have justified the strategy not only as a tool for meeting physical progress, but also as an instrument of Social Engineering. It has sought to resolve the dichotomy between the dominant interventionist paradigm of development, and the participatory and decentralized model, by using a balanced sustainable strategy of integrating water resources development with overall socioeconomic development of the region.

Habitat Degradation and Agrobiodiversity Loss in the Drylands of West Asia

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The drylands of West Asia are a center of diversity for many crops of global importance such as wheat, barley, lentil, many forage legumes and fruit trees. The alarming depletion of natural resources, including land degradation and loss of local agrobiodiversity, are threatening the livelihoods of local communities in these fragile environments. The GEF/UNDP funded project on conservation and sustainable use of dryland agrobiodiversity is promoting the in situ conservation of wild relatives of major crops through demonstration of appropriate techniques for the rehabilitation of degraded natural habitats.

Eco-geographic surveys show that overgrazing, the destruction of natural habitat through land reclamation, agricultural encroachment along with quarries, are the major causes of the degradation of local agrobiodiversity. GIS/RS techniques were very instrumental in assessing the degradation of natural habitats and the temporal change in land use. These surveys have allowed the selection of areas rich in targeted wild species. Management plans were developed together with local communities.

The value of water harvesting, reseeding and reforestation with native species were demonstrated to local communities. Alternative land use by planting barley, olive and apple trees to replace rangeland and forests has shown limited long-term economic benefit in most harsh environments. On the contrary, it has resulted in abandoned fields and severe land degradation.

The project is also investigating ways to add value to the wild fruit tree species (processing) and diversify the incomes of local communities (eco-tourism). It is working on increasing public awareness within an integrated approach based on community participation, sustainable livelihoods, and ecosystem management. This paper highlights the technological, institutional and policy options for preventing further land degradation and loss of local agrobiodiversity.

Evolution of Sahara Oases: A Case Study in Tidikelt, Algeria

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For more than 40 years, I have been engaged in field studies of the Foggara-Oasis in the Algerian Sahara. The purpose of this research was a comparative study of Qanat-Foggara systems in the world. The main academic interests were a comparison between similar underground water irrigation systems in dry areas of the world, such as North Africa, Western Asia, Central Asia and China. I chose the Sahara oasis because no one had tried to compare Qanat in Iran and Foggara in the Sahara.

Between 1961-2002, I observed many socioeconomic changes of oases under dramatic political transitions after 1962 (independence of Algeria). As a research field, I chose one oasis called In-Belbel, 120 km north of Aoulef, capital of Tidikelt region. In-Belbel is located at the south-edge of Tademait Plateau in the center of the Algerian Sahara. It was probably established by a marabout that visited there in the 17th century and constructed an underground canal to feed nomads around the oases. As there are no historical documents, it is very difficult to follow chronological evidence. However, it is very clear for visitors to see at least three stages of habitat evolution.

An initial fundamental comparative survey provided basic information, a village map (1/5000), and a water distribution system. At the beginning of this study the total population of the area was around 300 people. Most of them were peasants, with a small number of nomads. Before the Sahel drought of 1968 to 1972, there were Tuareg camel breeder caravans from Mali to Niger who traded traditional goods and dates between the Sahara and Sahel zones. However, after the drought, the Tuareg disappeared because of the diminished grasslands. There is no scientifically recorded data on the precipitations of the area but it might have been 0 to10 mm/ year.

Covering a period of 20 years (1980 - 2002), we have observed changes in the daily lives of the inhabitants. Their income is principally from date palm gardens and vegetables. In the 1980's, they were obliged to import necessary fruits and vegetables from Aoulef and other areas. For primary education, there was only a small Koranic school with one teacher and less than a dozen pupils. Most of the children were just learning Arabic and the Koran, and young girls were not allowed to attend the school. There were only two or three cars, and accessibility to central cities, such as Aoulef, was very difficult. There was no electricity and potable water supply in the area.

In 1980, the central government introduced solar-energy systems to the village that made availabble 18 watts of electricity per household. These systems served the community until 1999. However, during this period, they faced several problems. Forced by a strong demand from inhabitants, the government constructed a central energy station near the oasis, and from July 2001 they could get electricity for domestic use. Later, construction of a new electricity generation center made it possible to operate a 160 m deep well. Date palm farming increased three times, as compared to 1970, because of a sufficient electricity supply and use of ground water. By the end of 1980, greenhouse systems for production of vegetables and fruits had been introduced. The systems gave significantly higher yield than farm fields due to the higher temperatures.

In parallel with this sustainable development of technology, the central government introduced locally-made, but very advanced irrigation technologies, such as central pivot irrigation systems. The irrigated area was used for cultivation of wheat imported from Mexico. The central government's goal was to develop this new technology outside the date farm gardens where the traditional irrigation systems such as Foggara are used. The government attempted to replace the less productive traditional technology with the new one but could not achieve the desired success. The main reasons for the failure were the huge evaporation, rates that led to land salinization, the very high cost of electricity coupled with the expensive maintenance of the system.

The region continues to make steady progress. There is now a big primary school with seven teachers and 150 pupils, half of whom are girls. Irrigation and drinking water is provided by new artesian wells. The population has now increased to around 800 individuals, and the community sells extra products in the local markets. However, old water channels and traditional customs of water division are still in use.

This experience demonstrated that a dramatic evolution of the oases' agriculture in the central Sahara using alien and advanced technologies may not be suitable. On the contrary, enhancing endogenous and traditional techniques incrementally might be more adaptable to local conditions, and yield better results.

Migration Patterns

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International migration, which is now at an all-time high, has emerged as a major issue in international relations. About 130 million people live outside their native countries, and the number is increasing by two to four million each year.
There are three major trends in international migration:

- Acceleration: for all categories of migrants, along with a diversification of forms (labor migration, family reunification, asylum-seekers, refugees, and illegal migration)
- Globalization: all continents are concerned at various degrees
- Strong regional trends and specificities: migrant workers today are structurally embedded in the economies of industrial democracies. While uneven population growth and demographic trends can contribute to pull (demand) as well as push (supply), the global economic restructuring that is shifting jobs from agriculture to industry and service sectors contributes to migratory pressure worldwide.

The world's migrant population is not spread evenly. Non-economic factors, especially networks, explain why migrants do not move randomly around the globe, and are concentrated in relatively few countries. About half of the world's migrants live in the developing world. Seven of the world's wealthiest countries (Germany, France, the United Kingdom, the United States, Italy, Japan, and Canada) have about one-third of the world's migrant population, but less than one-eighth of the total world population.

In the mid-1990s, the largest number of immigrants moved from Latin America and Asia into North America, and from Eastern Europe, the former Soviet Union, and North Africa into Northern and Western Europe. The Middle East draws migrants from Africa and Asia, and hosts millions of refugees from within the region. There is considerable migration within Asia, Africa, and Latin America as well. The WANA region has both sending and receiving countries.

The Middle East and North Africa

- The Middle East has witnessed dramatic and extensive population movements in the past half-century. The region exports and imports hundreds of thousands of labor-migrants. It also produces and hosts one-third of the world's refugee population. Palestinians are the largest refugee group, followed by Afghans, in Iran. While there are almost 1.5 million foreigners- mainly Arabs and

Africans- in Libya, a country of 4 million, most of the foreign workers in the Middle East are Asians or Arabs from neighboring countries. Labor migration in the Middle East has differed from that in many other regions in that it embraced workers at all occupation and skill levels, and may reach up to 80% of the work force.

- Turkey and North Africa, mainly sending countries, have become migration transit areas and have entered into migration transition points.

Western Europe

Demographic realities, increasing prosperity gaps, and globalization have forced the issue of migration to the top of the political agenda across Europe. It has also emerged as a major challenge in EU relations with its partners, mainly in the Mediterranean Basin. To maintain its economic growth, fill in labor ranks and support the increasing number of pensioners, Europe will need massive imports of foreign labor. The UN estimate, of 159 million immigrants in Europe by 2025, has raised anger and concerns in societies anxious to preserve their cultural identity and economic prosperity in the context of rising unemployment figures, xenophobia, and racism. Many imbalances are at the origin of the migration movement, mainly the demographic patterns, and the prosperity gap along the Mediterranean and even within Europe.

While most observers confirm that movements of the population from southern and east Mediterranean towards Europe will only increase, there is a deep concern about adoption of new restrictive immigration laws and the declining development aid to support economic restructuring and transitions in the South and East Mediterranean. Direct foreign investment in non-European Mediterranean countries combined with the overall aid to these countries is inferior to the emigrant's remittances. All stakeholders have a vested interest to manage together migration issues which are a source of North/South, North/North, and South/South tensions.

Session 4

Possible Future—2025

Climate Change in the West Asia and North Africa Region

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Climate change poses a major challenge to social and economic development in the WANA region. The most thorough and up-to-date assessment of the science and predicted global and regional impacts of climate change have recently been published in the IPCC Third Assessment Reports (TAR). The latest IPCC projections of global surface-air temperature and sea-level rise, based on the SRES emission scenarios, will be presented. Based on the SRES scenarios, the estimated envelope of global surface temperature ranges from 1.4 to 5.8 °C above the 1990 level by 2100 (0.09 to 0.88m global sea level rise, IPCC 2001). Already, in 2001, 0.2 °C warming has occurred above 1990 levels although the associated impacts remain difficult to identify with certainty given the confounding factors of natural-climate variability and social change. The long-term impacts of climate change, however, will include shifting supply and access to key resources in the region, such as water, with important consequences for agriculture.

Complex physically-based global climate models are used to generate detailed estimates or scenarios of regional climate change. Uncertainty is inherent in the development of climate scenarios due to unknown future emissions of greenhouse gases and aerosols, unknown global climate sensitivity, uncertainties associated with clouds and their interaction with radiation, and to the difficulty of simulating the regional characteristics of climate change. Examples of the potential magnitude of climate change over the WANA region will be presented from recent experiments using the UK Hadley Center's fully coupled ocean-atmosphere general circulation model.

The uncertainty associated with projections is often manifest in ranges of estimates for certain climate parameters, particularly rainfall. For the agricultural and water sectors, for example, inter-climate model differences in rainfall change often remain a barrier to the effective use of climate change information by managers and stakeholders. Inter-climate model differences are, however, much smaller for temperature, particularly in the Northern Hemisphere. Table 1 highlights inter-model agreement in temperature change and disparities in rainfall change for the DJF and JJA seasons in the WANA region, represented by the Mediterranean and Caspian Sea regions as defined in IPCC (2001).

Table 1. A summary of inter-climate model consistency regarding future winter and summer temperature and rainfall change for the Mediterranean and Caspian Sea regions with different greenhouse gas emission scenarios.

	December to February		June to August	
	High emissions scenario	Low emissions scenario	High emissions scenario	Low emissions scenario
Temperature				
Mediterranean	Greater than average	Greater than average	Much greater than average	Much greater than average
Caspian Sea	Greater than average	Greater than average	Much greater than average	Much greater than average
Rainfall				
Mediterranean	No change	No change	Large decrease	Inconsistent
Caspian Sea	Small increase	Small increase	Inconsistent	Inconsistent

Source: Adapted from IPCC (2001).

Nevertheless, in spite of the uncertainty, it remains the case that the WANA region will experience climate change that will require adaptive responses in climate sensitive sectors. There have been many assessments of the potential impacts of future climate change from global through regional to country level across a range of sectors including agriculture, water resources, health, and tourism. Many of these are reviewed on a regional basis in the WGII contribution to the TAR, "Climate Change 2001: Impacts, Adaptation and Vulnerability." These reviews highlight key potential impacts and environmental and societal systems with particular climate sensitivities. For the WANA region, an important area where climate change is likely to require significant adaptive response is in irrigated agriculture due to the combined effects of rainfall change and increased evaporative demand for water.

Crop and Animal Production Potential of Drylands

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Agricultural systems first evolved in the Mediterranean basin over 10,000 years ago, mainly in the fertile crescent of West Asia. However, today the WANA region is facing the challenges of decreasing water availability, high population growth rates, and increasing globalization. These factors mean the countries in the region have to feed larger numbers of people with relatively less water resources, gradually reducing area of agricultural land per producer, and highly variable climatic conditions, while facing increasing globalization. This could have serious implications on the food security of the region.

Mixed crop-livestock systems are the predominant production systems of WANA. In cropping zones these systems are based on wheat in the wetter and barley in the drier areas in rotation with food legumes. The livestock component of these systems consists mainly of small ruminants, which prevail over crops as the areas become more marginal, determining a more pastoral production, though still heavily dependant on crop residues and agro-industrial by-products. The base of the main agricultural systems in the region are rangelands and croplands, both rainfed and irrigated, which cover only 6-8% of the total land that is suitable for crop production. The production of these areas is crucial to supply not only the needs of the increasing population, but also extra fodder for livestock, as the rangelands contribute to no more than 20% of the animal feed.

Drylands support the livelihoods of 60% of the total population living in the WANA region, but these are increasingly threatened by unsustainable use of the fragile natural resource base and ecosystem. Recent projections made by FAO indicate that 72% of the expected production gap between demand and supply will need to be met by productivity increases, 21% from the crop intensification and 7% only from additional land for cropping, which is only possible in Sudan. ICARDA has focused on the promotion of the sustainable development of drylands to increase productivity while mitigating the effects of climate change. This is being achieved through improved soil and crop management, appropriate crop rotations, improved crop cultivars, improved feeding systems, and better production of animal breeds, improved water-use efficiency, maintenance of soil fertility through soil-conservation practices, and the development of integrated crop/animal husbandry technologies that favor carbon sequestration while capitalizing on the added value of products to reap optimum benefits from enhanced market demands. These efforts are being extended throughout the region via a network of collaboration with the national agricultural research systems thereby enabling farmers to increase or stabilize their production. Parallel social studies seek to understand the region's agriculture from a human and institutional perspective.

Given its comparatively long history of research in the area of natural resources, it is instructive to highlight some of the concrete and tangible achievements in the areas of soil, water, and crop management practices that have resulted in better crop production in the region.

Phosphorus deficiency was identified as a major constraint to crops in WANA and the need for P fertilizer use was brought to the attention of the NARS through crop response trials in the region. Such fertilization practice is now commonplace. The necessity of using nitrogen fertilizers for cereals and other non-legume crops, even under low rainfall was clearly demonstrated. This has contributed a 10 to 20-fold increase in N fertilizer use and to increased crop yields both in rainfed and irrigated crops. For efficient fertilizer use, the extent of biological nitrogen fixation for cool-season legumes was quantified, and valid and reliable soil tests were established. Agronomically and economically viable, water-use efficient cropping system components (feed or forage legumes) have also been identified and introduced in the region. This clearly showed that the enhanced output from cereal/legume rotations was also associated with improved "soil quality" as a result of increased organic matter or carbon sequestration. Thus, higher crop production can be compatible with environmental protection. The use of conservation tillage practices was promoted as a means of mitigating erosion and saving energy. Agronomic practices (sowing dates, method and depth, seeding rates, fertilization time and rate, weed control time and methods, etc.) were validated for technology transfer within the region. Supplemental or deficit irrigation was shown to be efficient in terms of water use while maintaining crop yields when compared to full irrigation. This has saved some 30-60% of water compared to full irrigation. Crop growth simulation models are now available to extrapolate site-specific research to similar environments elsewhere.

Critical challenges to livestock production that will affect the livelihoods of farmers, the nutrition and health of human, the market dynamics and the integrity of the resource base are expected in the next 20 years in the region. In spite of its implications to the quality of life, population growth and concentration around urban areas is expected to be the driving force determining, on the positive side, an enhanced demand of products of animal origin. This demand could be further enhanced if people's purchasing power is also improved. Such a condition will establish demanding markets that will require year-round supplies of milk, milk derivatives and meat products together with increasing consumer demand for better food quality. As the market and market prices begin to offer attractive incentives, farmers will be looking at more intensive production systems that in turn will demand more feeds, technology, a well organized provision of animals to be raised intensively, probably a still range-based semi-extensive production of stock to supply these animals, the application of rigorous epidemiological measures and better linkages of farmers to markets. To some extent, these trends are already being observed in the region. Cairo for instance, a metropolis that agglomerates nearly 15 million people with a vibrant demanding market, attracts and absorbs a considerable portion of the produce of peri-urban intensive livestock production systems as well as market-targeted production of more remote rural areas.

With the reduced contribution of rangelands to the diet of ruminants, there is a need for better grazing and range management, along with more efficient utilization of crop residues and by-products. Where the degradation of rangelands has reached severe levels, as is the case in WANA, a combination of governmental and research efforts will be needed to reverse these processes and to restore rangelands on a sustainable basis. Places where the processes are still not as acute, such as in Central Asian countries, the restoration of seasonal grazing will be required through research, information, community action, and governmental policies.

Increased livestock production and improved human welfare will be achieved through the enhancement of the feed base, efficient integration of conventional and non-conventional agricultural by-products and crop residues into feeding systems, increasing animal productivity, transformation of products into value-added derivatives, and judicious use and management of biodiversity.

It is argued that globalization will increase the benefits to all nations through expanded trade. But lack of communication and absence of appropriate institutions may lead to exclusion of the poor from international capital markets, leading to increased poverty in developing countries. This is particularly critical for farmers and herders in the rural areas where 75% of the world's poor live. Without participating in the process of globalization, farmers and herders in the WANA region will face enormous difficulties in sustaining livelihoods, which could lead to mass migration to urban centers and abroad. Waves of desperate migrants drowning in the sea have recently been reported in the popular media. These could be prevented if there are political and institutional changes both at national and international levels in supporting agricultural and rural development programs that improve rural livelihoods. According to a recent study by the Economic Research Service of the US Department of Agriculture (ERS-USDA), besides food insecurity, nutritional deficits will also intensify in vulnerable and lower income countries including those in the WANA region.

These challenges cannot be met if the agricultural sector's growth does not achieve substantial improvements relatively quickly. The agricultural sector cannot perform well without the positive performance of the whole rural sector. This requires development programs for the rural sector in agro-industries and in non-farm economies. These will absorb labor from the agriculture sector, enhance rural income, and increase the demand for agricultural goods. Growth of the agricultural sector can be achieved through increased uptake of agricultural technologies in relation to crop and livestock production, more effective organization of producers to reduce transaction costs, greater involvement of producers in identifying opportunities and incorporating their knowledge and experience into the research and development process, investment in infrastructure in the rural areas that reduce the cost of transportation, development of high value crops and identification of specific markets, reduction of post-harvest losses, improved marketing services, and better economic incentives through proper policy measures. These issues require substantial development in the capacity of national research and extension systems and education of farmers, which in turn require increased investments in agricultural research and extension. In addition, it is important that the rate of adoption of currently available technologies increases, and at the same time more relevant technologies and opportunities are identified and exploited. There is also a need to monitor and document the level of rural poverty and to better target the poor. Close monitoring of impact is critical to the success of different programs.

Session 5

Tools for Adapting to Global Change

Potential for Biological Adaptation in Climate Change, Crop Improvement/Systems Development and Possible Role of GMOs

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The success of breeding to increase yield and yield stability in stressful environments has been limited due to the high variability in frequency, intensity, timing and duration of a number of climatic stresses. The most important abiotic stresses affecting rainfed crops, such as barley in the West Asia region, are low temperatures in winter, terminal drought and terminal heat in spring. Additionally, a number of biotic stresses (root and leaf diseases, insects, and viruses) limit yields. Therefore, breeding for higher yields in stress environments must combine tolerance with both abiotic and biotic stresses.

ICARDA is close to the area where a number of crops, such as wheat, barley, lentil, and chickpea were domesticated, and where wild relatives and landraces are still widespread and co-evolving. Both wild relatives and landraces are the backbone of the breeding programs and both conventional and biotechnological approaches are capitalizing on the adapted gene complexes that were inherited from millennia of natural and human selection. The conventional approach involves two main methodologies: direct selection for performance, mainly yield, in the target environments, and indirect selection using morphological, physiological, and other traits related to improved yield performance under dry conditions.

Two biotechnological approaches are being tested to improve abiotic stress tolerance in crop plants. The first is the use of quantitative trait loci (QTL) analysis to identify breeding material with superior water-use efficiency and adaptation to arid conditions. Through genetic-linkage mapping, the analysis reveals the location of loci associated with performance under drought conditions. QTLs are then exploited through marker-assisted selection using DNA markers flanking the identified QTLs. The second approach relies on genetic transformation of crop plants using genes known to be involved in expression of drought tolerance. To identify such genes, methods are employed correlating metabolic responses with gene expression in the breeding material under stress. The genes thus identified will be incorporated into breeding lines with other improved agronomic traits. Examples of achievements of conventional and molecular breeding are presented, and new approaches to stress tolerance breeding are discussed.

Conserving and Accommodating Our Natural Heritage and Biodiversity

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Drylands are usually considered poor in biodiversity, but this is not the case in Central and West Asia and North Africa (CWANA). The Mediterranean region alone has some 25,000 plant species, many of which are endemic. Russian botanist N.I. Vavilov identified three of his eight centers of crop origin and diversity in the CWANA region and, later, J. Hawkes placed one of the three nuclear centers of agricultural origin in the semi-arid lands of the Near East arc. This plant and animal domestication center also later became a cradle of the great civilizations of the Near East. It was the domestication of wild cereals and pulses that started a rapid social development in the first settlements in Mesopotamia and Jordan Valley. Barley, cultivated einkorn, emmer wheat and lentil, were, together with domesticated sheep and goats, the first components of an agricultural package, which started one of the decisive events in human technological, cultural and social development, sometimes called the Neolithic Revolution. In fact, it was an evolutionary process, in which a number of additional plant species and animals of CWANA origin were gradually added to the first domesticates that spread in all directions from the original nuclear center.

The most important part of plant diversity is that which provides human food. At present, crops of the Near East origin satisfy 38% of caloric needs of the human population, and wheat alone provides one third of human food. The long crop evolution in the CWANA region, shaped both by the harsh environment and the farmer, resulted in a variety of landraces, which are still an essential component of rainfed agriculture, particularly in marginal, stressful areas and highlands. The landraces have also been a valuable source of genes for regional crop improvement and plant breeding globally.

However, the richest part of the crop gene pool, still mostly untapped, is in wild crop ancestors and other wild relatives. Their history is much longer and, consequently, the long coexistence with various abiotic stresses, pests and diseases resulted in rich diversity of stress-tolerance genes and adaptive gene complexes. This genetic diversity has only recently been explored in targeted breeding for low-input farming systems in CWANA rainfed areas. With advances in molecular biology and gene technology, the wild crop gene pool diversity is now becoming more accessible to research and breeding.

Biodiversity of other CWANA ecosystems may not be as significant globally as the field crop gene pool, but it is crucial for sustaining rural community livelihoods. Most of the CWANA territory is rangelands that accommodate diversity of plant species, many of them essential to nomadic herders and their animals. The rangelands may be surprisingly rich in plant biodiversity; for example, North Africa rangelands include more than 5,000 plant species. In addition to field crops, the CWANA region is a center of origin and diversity of a number of fruit trees. Almond, pistachio, pomegranate, olive, fig, pear and other fruit-tree landraces and wild relatives are not only a valuable component of the local diet, but also represent a rich gene pool for fruit tree improvement.

For millennia, the people of CWANA lived in harmony with the environment and explored the natural plant heritage in a sustainable way. However, the exponential human population growth in the last century drastically affected plant biodiversity in general, and diversity of plants important to agriculture, i.e. agrobiodiversity, in particular. With the current rural population growth rate over 3% in many CWANA countries, the demand for agricultural land is increasing. Consequently, marginal land and rangelands are increasingly brought into cultivation and this process leads to habitat loss of crop wild relatives. Moreover, the shrinking rangeland area together with unsustainable rangeland management results in rapid erosion of plant diversity and rangeland productivity. On-farm plant biodiversity is decreasing with modifications or abandonment of traditional farming systems, since the number of species grown is reduced and landraces are gradually replaced with improved germplasm. In addition to the current causes of biodiversity erosion, new threats such as climate change and incautious introduction of alien invasive species and genetically modified crops, are emerging. In the latter case, the risk of gene flow between a genetically modified crop and its close wild relatives of the primary and secondary gene pool may be high, depending on the geographical distribution and reproduction biology of the wild relatives.

Considering the above threats and trends, conservation and sustainable utilization of the remaining plant biodiversity and agrobiodiversity, in particular, is the major challenge to NARS in the CWANA region and the international community has to provide necessary assistance to this effort. To save at least a part of the rich natural plant heritage before it is lost, ICARDA has conducted, jointly with national programs, more than 130 collection missions to 20 countries in the CWANA region, in which 22,000 natural populations of crops, wild relatives, forage, pasture and rangeland wild species and crop landraces were sampled from the original habitat and stored ex situ at ICARDA and, whenever possible, also in NARS genebanks. Moreover, ICARDA acquired from other genebanks and donors an additional 63,000 accessions originally collected in the CWANA region. Currently, ICARDA's genebank holdings of CWANA origin include 25,000 wild species and 60,000 accessions of landraces or selections from them. The Center is holding this germplasm in trust for the international community under the auspices of FAO, but this status will change soon, when ICARDA joins the International Treaty for Plant Genetic Resources for Food and Agriculture. However, ICARDA's genebank accessions will remain a readily accessible source of genetic diversity for breeding and research at ICARDA, NARS, and elsewhere.

Nevertheless, ex situ genebank collections represent only fractions of the rich genetic diversity that has accumulated for millennia in the natural populations and farmers' fields and orchards. Therefore, the ex situ effort has to be complemented by conserving agrobiodiversity in the original habitat in participation with those who manage and utilize it, i.e. farmers, herders and their communities. There are several on-going projects in the CWANA region, in which the in situ/on-farm approaches are tested. The current GEF/UNDP project, coordinated by ICARDA in collaboration with IPGRI and ACSAD, on agrobiodiversity conservation through sustainable utilization in Jordan, Lebanon, the Palestinian Authority and Syria, is probably the most comprehensive one, being focused on globally important cereal and pulse indigenous gene pool, forage and pasture legume wild species and several fruit tree genera. The main task of the project is to identify and test, together with local communities and other stakeholders, sustainable options for in situ conservation of the target germplasm. These alternatives are ultimately aimed at improving community livelihoods through sustainable utilization of the indigenous agrobiodiversity inherited from generations of their ancestors.

Conservation of CWANA rangeland diversity is vitally important to sustain livelihoods of many poor people, who depend on rangelands. ICARDA is, therefore, assisting NARS in developing project proposals on rangeland biodiversity conservation of both plants and livestock, again in close participation of the rural communities. The current project concepts include countries of Central and West Asia, the Arabian Peninsula and North Africa.

Prospects for Water-Use Efficiency in the WANA Region

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Improvements in agricultural water-use efficiency in the WANA region must be sought in both irrigated and rainfed agriculture. There is no reason to isolate rainfed from irrigated agriculture, since in many agricultural systems a continuum exists from rainfed, with or without water harvesting, to supplementary irrigation, to full irrigation.

Improving the efficiency of water use in agriculture via increased water productivity

Large amounts of water evaporate through crops, normally several hundred kg of water per kg of biomass produced. In some rainfed systems, only 5% of the rainfall or less is consumed as transpiration (T). In irrigated systems, some 30% of the water input is considered normal as transpirational losses. There are, therefore, substantial opportunities to increase the proportion of rainfall and irrigation water that is used consumptively in agricultural systems, thus improving the efficiency of water-use. Given the large variation in natural resource endowment, such opportunities are very diverse and occur at multiple scales, from plot to farm to watershed and region and at the biological, environmental, and management levels.

Not all water used in agriculture is lost to the system. It can be recovered, at least in part, and reused. Thus, efforts to improve the efficiency of water use may or may not lead to net water savings, depending on whether the water saved is part of the recoverable or the unrecoverable losses. It is therefore important to make such a distinction, for which two general ratios are useful in expressing the efficiency of water use for biological production:

Water Use Efficiency (WUE) = Water consumptively used in ET/Water input
Water Productivity (WP) = Yield/Water consumptively used in ET

Improving WUE by reducing the water input into the plot or the farm may or may not result in an overall improvement for the reasons stated above. Also, some of the influencing factors are related to the physical infrastructure of water delivery and management, coupled with a very strong institutional and social component.

The improvement of WP by increasing yield and/or reducing ET, always results in a reduction of agricultural water requirements. Indeed, all the yield improvement research carried out by the CGIAR has made an important contribution to the global increase in agricultural WP experienced over the last decades. In contrast, very little progress has been made in reducing ET, the denominator in the WP ratio.

WUE in the WANA region approaches, in many cases, 50%, which is higher than in other regions. However, rainfed and irrigated WPs are relatively low, e.g., rainfed and irrigated yields of wheat, 1.29 and 3.18 t/ha respectively; barley, 1.30 and 2.07 t/ha; maize, 2.14 and 4.85 t/ha. Although the arid environments have inherently lower WPs than the more humid areas, there is substantial potential for improving rainfed and irrigation WPs, and thus improve water-use efficiencies.

The challenges and opportunities for future research in improving WP can be discussed around three system components: the biological (crop), the environmental, and the management component. However, it is through synergies among such components that progress in increasing WP has been and will be made.

In the biological area, genetic improvement of WP has already been achieved as part of the yield gains effort, particularly in the irrigated systems, and more will be possible as effective demand for biological products continue to improve, allowing farmers to increase yields. Specific breeding programmes aimed at improving WP, in rainfed systems, have not been nearly as successful except in the relatively favourable rainfed production systems. Primary reasons in the unfavourable rainfed systems have been the multiplicity of crop responses to drought and the large variability of drought-prone environments. Notwithstanding such difficulties that make short-term progress in drought adaptation a very uncertain proposition, biotechnology offers new possibilities that, combined with the expertise that several CGIAR Centers now have in crop adaptation and performance in adverse environments, should open an important avenue to enable "xeric genes" to be concentrated in agronomic plant types. As an example, one important goal would be to produce cultivars that would avoid the catastrophic impact of severe droughts but continue to provide high or bumper yields in average and good rainfall years. Another important long-term research objective could be the development of C4-type wheat and barley to significantly increase the WP of these major rainfed and irrigated crops.

The major reason why it has been so difficult to reduce ET is that it is primarily dependent on the evaporative demand of the environment. That characteristic cannot be changed easily, but there are opportunities for WP improvement if crops could be raised when the evaporative demand is lowest; i.e., in winter. However, the primary way to reduce total ET is by growing a crop that has lower total water requirements because of its shorter growth cycle. Here, crop choice, environment and management (by selecting optimal planting dates) interact and new research could produce excellent results if modeling is combined with experiments to offer the best strategies that maximize WP and income. As it is the T portion of ET, which determines biological performance, increasing T through rapid or continuous ground cover can lead to higher WP.

The major opportunities that exist in improving WP and that demand priority research efforts reside within the management component. There are also challenges in the biophysical area related to maximizing WP under limited or deficit irrigation. It is likely that many irrigated areas in the region will be forced to use limited supplies in an optimal fashion. New tools of spatial analysis and simulation modeling have much to add to the development of effective tools for advising irrigators in optimal scheduling methods. One other major challenge in rainfed but also, irrigated systems, is the need to maximize the potential for stored soil water in the crop root zone. Until now the major advances in the improvement of WP have been achieved by yield increases through improved crop husbandry. A primary issue in this regard is the study of the interactions between soil fertility, plant nutrition and water management, from the plant, plot and system levels up to the basin level. Because of little or no involvement of social scientists in the research and extension efforts, a major gap exists in most agricultural systems between what is known to increase WP and what is actually applied. Herein lies an important opportunity to link several actors and disciplines in agricultural water-management research in the major water-limited agricultural systems.

Traditionally, water productivity concepts have been applied mainly to crop production but they can also be defined for livestock or aquaculture. In addition, further consideration needs to be given to different uses of water within the basin, and integrating food production from aquatic ecosystems. Also, water harvesting offers opportunities to improve WUE and WP. Elsewhere, the use of waste and marginal waters may offer opportunities to improve WUE.

Policy, institutional and social aspects of water management

Water shortage in several countries in the WANA region is the greatest constraint on agriculture and rural development. Yet, wherever irrigation water is available, it is apparently used liberally. In the absence of any real economic or political pressure to recognize the scarcity value of water, irrigation water-use efficiencies and water productivities will remain relatively low. There is thus an urgent need for renewed research on water policy, institutions, and social aspects of water management.

ICARDA, other CGIAR Centres and their NARS partners have the potential to make significant contributions in this area for two reasons; they can freely exchange information and compare features of institutions in the various areas, and they can act as a more objective advisor when policy and management research is carried out on institutional development and change. New knowledge on the different user-organized water institutions must be developed to remove a critical constraint in many areas where innovative water institutions could make the most important contribution to improved water management. There are multiple aspects of integrating biophysical and socioeconomic issues that could be covered in this area of research and, given the limited resources, priority should be given to in-depth ex-ante assessments of the benefits of the research prior to launching the projects. For rainfed systems, research must go beyond "how much can one get per unit of water" and explain how farming communities have adapted their agricultural systems to variations in weather and climate to optimize WUE and WP. Given that many important social science research issues have not been investigated sufficiently, work in this area could explore broad areas of water economics, law, anthropology and other social sciences.

There is clearly no single solution to improving WUE and WP in the WANA region, given the large variation in resource endowment, levels of social and economic development, competence of governments, economic development and trade policies, institutional capabilities, social capital base of farming communities, and access to new technologies.

Energy-Use Efficiency

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The world is facing a serious challenge of maintaining energy supplies in the developed world, and extending its availability to underdeveloped countries. A sizeable number of people (about two billion) lack access to adequate energy supplies. Global warming and greenhouse effects further burden energy resources by increasing the temperature and reducing water availability. Such conditions would make the WANA region warmer and drier, leading to a tremendous increase in its energy and water requirements. Therefore, efforts should be made to control rising temperatures and increase the availability of energy. To achieve this, a 50% reduction in global CO_2 level is required, and energy has to be made available to half a billion more people by 2050.

The UN Climate Convention and the Kyoto Protocol have outlined a time-bound action plan. A six percent reduction in emission of greenhouse gases is proposed during 2008-2012, followed by up to 50% after that. Compensation is to be provided to fossil-fuel-dependent countries through extending technical assistance for diversification of economies. The so-called clean development mechanism is to be introduced as an instrument to provide carbon credits to the North, and availability of capital and clean technology to the South. However, the withdrawal of the US from the Kyoto Protocol, which left 24% of world emissions uncovered, was a serious blow to these global efforts. And so far, Russia has not ratified, and unless it does so, the protocol will not enter into force. As a later development, the US developed a national climate plan emphasizing the following:

- Stabilization not reduction of CO_2
- Consideration of CO_2 intensity per GDP
- Technology transfer to developing countries, and support for capacity building
- A new budget of 4 million USD/year for the climate plan.

Energy is a high priority issue in EU states, and in countries like the US and Japan. In contrast, most of the developing countries have yet to recognize energy as a priority sector and to formulate their energy policies. Reduction in greenhouse gas emissions is achievable through large investments in technology, introduction of carbon trading schemes, development of clean fossil fuel energy, and introduction of carbon sequestration in forestry and agriculture.

Despite the above realization, the following serious misunderstandings block the way for proper initiatives:

- Natural gas resources will be exhausted soon
- Climate change can be ignored as long as scientific evidence is incomplete
- The hydrogen age is something for the very long term
- Solutions for the climate change problem will greatly change our society.

A review of data on proven resources of oil and gas (BP Statistical Review) reveals that there are larger than ever reserves of fossil fuel energy. The CO_2 storage capacity is large, and the possibility of producing climate-neutral electricity at affordable prices, and using hydrogen as clean energy, is significantly high. Recent research on the use of CO_2 free natural gas for electricity generation has demonstrated a 90% reduction in CO_2 emissions. Daimler Chrysler Corporation has developed and tested no-emission cars that work on liquid hydrogen.

These advances indicate that clean development has already started and needs to be further strengthened by acting on the following:

- Stimulation of new capital flow (public and FDI)
- Reduction in local air pollution as well as global GHG emissions
- Transfer of clean technology in energy sector (replacement of diesel or coal based electricity plants by natural gas plants)
- Counting of carbon sequestration in forestry activities.

The WANA region has an extremely fragile ecosystem where about 45% of land is degraded. Severe population pressure and excessive use of domestic fuel-wood further aggravates the environmental degradation. Understanding the socioeconomic reasons for excess use of fuel-wood is a pre-requisite to addressing the problem. The region suffers from acute poverty and therefore households cannot afford to buy cooking gas. Even for people with economic capability, lack of marketing infrastructure, and poor availability of gas is prohibitive. In some cases, strong preferences for taste markedly affect fuel consumption. Imports of wood and charcoal for special cooking practices by many Gulf countries is an outcome of such preferences. Therefore, it is important to formulate vigorous and eco-friendly energy policies. Availability of energy in a country or region is also affected by natural calamities and changing political scenarios. Armenia, which used to be an electricity exporter till 1990, became an energy-starved nation just within three years. Factors, such as the collapse of USSR and a major earthquake, leading to the closure of nuclear power plants, forced Armenians to use more fuel wood for their energy requirements. As a result, a 20% reduction was recorded in the total forest cover.

To bail out the CWANA region from the energy crisis, and save the overdegraded environment, immediate actions are required at both local and national levels. Stronger energy policies, increase in import of natural gas, and developing a working partnership with organizations like ICARDA, are the immediate steps required on the part of governments. Ratification and enforcement of the Kyoto Protocol, using its clean development mechanism (CDM), lobbying for inclusion of agriculture in CDM and attempts to diversify the economy in fossil-fuel-dependent countries, would be further steps to adapt to the global changes. At a local level, more agroforestry plantations with woody species, increased use of renewable energy (solar energy), and use of fuel-effective stoves will tremendously boost the effectiveness of government efforts.

Poverty in the Age of Science: Challenges for the International Community

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Poverty is a condition of deprivation, not just absence of income. It can be overcome through an overall development of individuals and communities. Very often, development is misunderstood to mean economic upliftment of the poor, instead of expanding the scope of freedom for every individual. The poor, hungry, and destitute do not have the opportunity to choose, so they cannot enjoy the power of equality, an essential part of any viable development program. Effective development leading to poverty alleviation requires favorable policies, free flow of scientific knowledge and reduction in economic inequities in society and among nations.

Economic growth, one of the components of poverty reduction, is achievable through an improved macro economy, and increased investment in the development of infrastructure and human resources. But such growth does not necessarily ensure poverty reduction. Wrong government policies always jeopardize gains of development, and the poor benefit last and least. Therefore, poor countries are required to shift their social and economic policies. A comparison of spending by developed and developing countries on their social welfare systems fully substantiates this. While their defense budgets are almost equal, (4-5% of GNP), developing countries allocate only 3% of their GNP to public welfare programs, in contrast with 17% in the developed world. Thus, government policies have a major role to play in promoting sound economic growth and poverty reduction.

After witnessing the industrial and agricultural revolutions, the world is now embracing the 'scientific knowledge-based revolution'. Science now permeates the cultural outlook of more people than ever before. More and more scientific discoveries are being employed to serve humanity; new information and communication technologies are revolutionizing every aspect of human life; economic globalization is expanding at a faster rate than ever, and modern scientific gadgets are providing more personal freedom to individuals. While the developed world is already reaping rich harvests from the knowledge-based economy, only the surface has been scratched in a few developing countries. It is extremely frustrating that benefits are restricted to a minor percentage of the world's population. Whereas the 20% of blessed ones have access to all existing modern amenities and abundance of food, which leads to problems like obesity, a vast majority of the population of the world (women and children) depend on scavenging garbage heaps for their survival. Cases of starvation, deaths, and extreme malnutrition are *still common* in many parts of the globe. Problems of hunger and poverty are more compounded by ever-increasing civil wars, acts of terrorism, and man-made disasters leading to an astronomical increase in numbers of refugees. Abraham Lincoln once said that a nation cannot be half free and half slave and, therefore, slavery must be abolished. Similarly, it can be argued that a partly rich and mostly poor humanity cannot survive. The menace of poverty has to be tackled through scientific endeavors, and the global scientific community is invited to emerge as abolitionists of hunger.

The knowledge-based economy has given a tremendous boost to industrial and agricultural developments, and novel opportunities have come up through web-based businesses. But the poor are totally marginalized, and their very existence is endangered due to practices like product patenting. Economic disparity between developed and underdeveloped countries greatly hampers human resource development, which is a prerequisite for any knowledge-based economy. Human resource development increases the power of human capital of a country. But owing to a lack of infrastructure and facilities, poor countries are seldom able to improve their human resource. While countries like Japan, United States, EU member states, and China have 78, 69, 40 and 6 researchers and engineers for every 10,000 workers, respectively, the average for developing countries is only 0.5.

Other than human capital, poor countries have little access to essential tools of a knowledge-based economy (education, computers, and internet). A 1980 survey conducted in low-, middle- and high-income countries revealed a gross tertiary enrollment of 4, 11, and 34 %, respectively. After 16 years, 1% increase was recorded in low-income countries in contrast with that of 16% in high-income groups. A consideration of the number of people having access to computers is also very discouraging. Out of every 10,000 persons in developed countries, 1,800 own personal computers. But in the middle- and low-income countries, this figure is restricted to only 230 and 1, respectively. Similarly, 88% of the population of developed countries has access to the Internet as compared to 12% in the developing world. The scenario is not too different at the primary education level. While the schools of rich countries have access to ultra-modern amenities, their counterparts in developing countries do not have even blackboards and facilities that can be called school buildings.

Farmers in the underdeveloped world are also untouched by the agricultural revolution. It is appalling that most of them are still using the same old muscle power (human labor and domesticated animals) that their ancestors used about 2000 years ago. Undoubtedly, such conditions are the outcome of a scientific apartheid against the poor, which blocks their access to knowledge. Scientists of the world have to fight back this emerging menace to check the ever-growing gap between the poor and rich.

Globalization is viewed as a tool to spread the benefits of development. It is supposed to be achieved through free flow of capital, goods and services but not labor. However, a gap in demand and supply of labor in developed countries always triggers migration of labor, including highly skilled workers from the developing world. Given proper opportunities in their homelands, majority of immigrants would prefer to stay at home and contribute to the knowledge-based economy. Developing countries also lose power of human capital through mass recruitment of professionals by the rich nations. For instance, owing to a broad skill gap for networking specialists, Germany is negotiating to import computer professionals from poor nations. Millions of professionals from developing countries are already working in North America. Such a flight of human capital further blocks the way for the development of a knowledge-based economy in developing or under-developed countries.

Any improvement in the lives of people living below the poverty line is preconditioned by a reduction in inequality within society and countries, promotion of social capital, maintenance of wealth per person, and an increase in income. A shift in attitude is needed to understand and, eventually, alleviate poverty. The CWANA region suffers more because of poverty, vulnerability of agriculture to environment, and deprivation of access to modern knowledge and tools. To tackle this, special imaginative programs are needed for which science has to be mobilized. Ways and means have to be explored to increase the production of arid regions, reduce the vulnerability of rainfed agriculture, tackle the cause of inadequate water supply, nullify the adverse effects of climate change, and provide free access to tools of research and innovation.

Currently, the private sector contributes two-thirds of the total investment in research and development. However, to be sustainable, it heavily depends on intellectual property rights, that are serious deterrents to free flow of knowledge. In 1999, just one corporation (IBM) had 2,756 patents as compared with a total of 2,643 held by 144 countries collectively. Such trends are disturbing and they totally block free access to tools of knowledge-based economy.

A strong alliance of stakeholders like international agencies, research centers, national governments, NGOs, community groups, foundations and the private sector is urgently required to fight poverty and promote sustainable development. Implementing poor-friendly policies, institution building, developing human resources, providing appropriate finances, and forming an effective coalition between concerned agencies can root out the menace of poverty. However, special attention has to be paid to the overall development of individuals and communities, rather than just focusing on increasing their income. Sustainable results are attainable through increased development of capital, which should include the man-made assets, natural and human resources and social capitals. Economists have to focus more on largely ignored capitals (59% human + 20% natural) as compared to the 21% produced assets. Involvement, participation and good governance are the keys to increase the much-needed social capital. Therefore, it is the responsibility of the scientific community to involve the so far ignored 80% people in the process of knowledge generation and to participate in developing a knowledge-based global economy. Accordingly, the whole global system needs a thorough revision, and international centers like ICARDA have to act as catalysts to develop knowledge centers in less developed countries. We need to be imaginative and bold to think of a better future for the marginalized, women and children to whom we are responsible to give a better world.

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