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SUMMARY - When the concept of sustainable development has to be fully considered, then water management has to include new perspectives relative to resource conservation, environmental friendliness, technological appropriateness, economic viability, social acceptability and human oriented development. This is entirely justified since pressure on water resources utilization increases as a consequence of population growth, increased food demand and growing urbanization. Consequently, irrigation and agricultural water use has to expand but following new orientations in order to support increased food production, to face competition of other uses, and to provide for sustainable water utilization. Innovative issues are therefore required under the perspectives of environment and health, technological development, policy and institutional building, planning, and social and economic aspects.

Key words: sustainable development, water resources, irrigation, innovation, water management.

RESUME *- Si on considère le concept de développement durable d'une façon complète, il faut que la gestion de l'eau prenne en compte toutes ses implications, à savoir la conservation de la ressource, la compatibilité avec l'environnement, l'adéquation des technologies, la viabilité économique, l'acceptabilité sociale et l'orientation du développement vers l'homme. Ceci se justifie entièrement vu que la pression sur les ressources en eau grandit toujours en conséquence de la croissance de la population, des besoins alimentaires et de l'augmentation des populations urbaines. Par conséquent, l'irrigation et l'utilisation de l'eau en agriculture doivent connaître une expansion mais, en même temps, de nouvelles orientations telles qu'il soit possible d'aboutir à une augmentation de la production alimentaire, de faire face à la compétition croissante des autres usages de l'eau et de contribuer à une utilisation durable de l'eau. Il faut donc considérer de nouvelles orientations sous les perspectives de l'environnement et de la santé, du développement technologique, du renforcement des politiques et des institutions, de la planification et des questions économiques et sociales.*

Mots-clés: *Développement durable, ressources en eau, irrigation, innovation, gestion de l'eau.*

INTRODUCTION

The increased pressure on the natural resources, water and soil in particular, the population growth, the wide changes in agricultural policies and practices, the improved recognition of environmental problems, the globalization of the economy, the need for fair social and socio-economic balances, impose to rethink the issues of development (see Serageldin and Steer, 1994; The World Bank, 1994).

The challenging but widely accepted concept of sustainable development calls for new approaches on development and, therefore, on water management. The water resources are becoming more scarce, not only in quantity but because of the degrading quality, while competition for its use is increasing. The land resource, which is not renewable for the next generation, is also threaten by degradation and loss of soil productivity, particularly in areas where population growth is intense. New perspectives are required to manage both the soil and water. This is not only a question of allocating and controlling the water and land use, but of combining the knowledge of pressures influencing the resource itself, the relations between users and human and social objectives, the technologies available to improve and enhance the land and water use, the maintenance of biodiversity and natural and environmental balance. Despite the enormous progress on technological and managerial tools which are becoming available to improve management, we still have many gaps in knowledge and in transferring scientific and technological knowledge into practice.

This paper[1] focus on the need for considering the implications of sustainable development when looking for enhancing water management. However, the scope is limited but may contribute to fruitful discussions in this Seminar.

SUSTAINABLE DEVELOPMENT

The concept of sustainable development is supported by a large number of definitions. The WCED (1987) introduced the concept as the "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". Going further on the implication of this fundamental concept, the WCED (1987) proposed a more specific definition: "sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations".

The concept of sustainability relates therefore to the human legacy that present generations received from the past ones and should not destroy but enhance for the future. This has strong components under the perspectives of resource use, conservation and preservation, of economical nature, of technological and scientific progress, of social and institutional arrangements, of environmental equilibrium and of human development.

The FAO (1990) revised concepts proposed by many authors and formulated its own definition focusing on agriculture, forestry and fisheries: "sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable".

This definition fully agrees with that of WCED (1987), uses the same conceptual components and introduces the biodiversity implications.

The NRC (1991), analysing definitions of sustainable agriculture, states that "virtually all of which incorporate the following characteristics: long-term maintenance of natural resources and agricultural productivity, minimal adverse environmental impacts, adequate economic return to farmers, optimal crop production with minimized chemical inputs, satisfaction of human needs for food and income, and provision for the social needs of farm families and communities".

[1] This paper is largely based on two previous ones (Pereira, 1994; Pereira *et al.*, 1994

Management has to be understood in a manner capable of responding to the requirements above: it has to be based on the knowledge of processes which can lead to resource degradation or to the maintenance of natural resources; allocation to uses has to consider not only production objectives and environmental impacts, but also the technologies which control resource degradation and enhance productivity; non-productive uses of the land and water should be given a value, as well as to environmentally friendly and improved uses of land and water which help degradation processes to be reversed; institutional solutions for land and water management have to combine the capabilities for enforcing policies and rules with the social acceptability of decisions and measures; the objectives for management should not be the natural resources by themselves or the economics of returns but also the human needs and aspirations.

CHALLENGES TO WATER RESOURCES DEVELOPMENT

Water availability: quantity and quality

The pressure on using the water resources makes their availability to be reduced and quality to be deteriorated (Engelmann and LeRoy, 1993). Many authors dealt with these problems, some focusing on the Mediterranean region (Grenon and Batisse, 1988; Hamdy and Lacirignola, 1993; 1994).

A global perspective of the water resources availability is presented in Table 1. It can be observed that in most of the regions the annual withdrawal represents a relatively small part (less than 20%) of the total annual internal renewable water resources. The exception is the Middle East and North Africa region, which share is estimated to be in average 73% of total water resources.

Data in Table 1 may do not give the appropriate size to the problems. In fact, in Middle East and North Africa 53% of the per capita annual withdrawals are below 1000 m^3/ca, and 18% between 1000 and 2000 m^3/ca. This indicates severe problems of water scarcity and drought. The question of water scarcity is particularly relevant since estimates of average annual growth of population indicate very high rates: 2.9% for 1990-2000 and 2.3% for 2000-2035 for Middle East and North Africa (Table 2). Forecasts for next 30 years show that water scarcity or water stress may affect a very large number of countries (Engelmann and LeRoy, 1993).

Agriculture has the highest share of water resources in low-and middle-income countries, while industry is the most important user in OECD countries (Table 1). Agriculture withdraws 89% of water in the average of Middle East and North Africa countries. A very high agricultural share of total water withdrawals also occurs in European Mediterranean countries. Consequently, this asks for appropriate and innovative management solutions.

The water quality is an expanding problem. Surface waters become more polluted - low dissolved oxygen and increased fecal coliforms - in developing countries. However, this trend is being reversed in high income countries (The World Bank, 1992). Agriculture is also a cause for pollution, particularly groundwater pollution (Logan, 1990; Bogárdi and Kuzelka, 1991).

Health problems are particularly acute. Considering that 900 millions of people are affected by diarrhoea each year, the World Bank (1992) estimates that water supply and sanitation improvements would decrease mortality from diarrhoea by 16% due to water quality, 25% due to availability of water, 37% regarding both improvements and 22% in relation to disposal of excreta. Several other diseases are related to water like malaria, filarasis, bilharziazia, schistosomiasis (Birley 1989; Tiffen, 1989; Hespanhol, 1994). This brings to the first line of identified problems those of availability of safe water and sanitation. These areas became prioritary for funding agencies (Petit, 1994).

[2] See discussions on this matter in Serageldin and Steer (1994a and b).

Table 1 *- Water availability (source: The World Bank, 1992)*

Country Group	Total annual internal renewable water resources (cubic kilo-meters)	Total annual water with-drawal (cubic kilometers)	Annual withdrawal as a share of total water esources (percent)	Per capita annual internal renewable water resources, 1990 (cubic meters)	Sectoral withdrawal as a share of total water resources (percent)		
					Agricultural	Domestic	Industry
Low and middle income	28,002	1,749	6	6,732	85	7	8
Sub-Saharan Africa	3,713	55	1	7,488	88	8	3
East-Asia and Pacific	7,915	631	8	5,009	86	6	8
South Asia	4,895	569	12	4,236	94	2	3
Europe	574	110	19	2,865	45	14	42
Middle East and North Africa	276	202	73	1,071	89	6	5
Latin America and the Caribbean	10,579	173	2	24,390	72	16	11
High income	8,368	893	11	10,528	39	14	47
OECD members	8,365	889	11	10,781	39	14	47
Other	4	4	119	186	67	22	12
World	40,856	3,017	7	7,744	69	9	22

POPULATION GROWTH, POVERTY, FOOD REQUIREMENTS AND URBANIZATION

The analysis of the growth of the world population (Table 2) shows that population would more than double in the next 40 years if present annual growth rates would be maintained. However, this rate has already decreased in Asia, Pacific, Latin America and Caribbean, with the lower growth rates in Europe and OECD countries. The highest rates of population growth occur in Sub-Saharan Africa and Middle East and North Africa, where population is expected to more than double by 2030. Most of population growth will occur in developing countries, reducing to only 10% the population of OECD countries by 2030. Such growth of the population will put more pressure on land and water resources in these regions, which happen to be those facing major problems of water scarcity (and, unfortunately, also degradation of land resources).

It is known that a large part of the world population has not enough food. Famine is not only originated by war, droughts or floods. It is also a consequence of living in fragile environments, cultivating unsuitable areas and crowding the neighbourhoods of large cities with poor access to work in industry and services. In general, famine and malnutrition are correlated with poverty.

About one fourth of the human population is below the poverty line, with associated problems of food shortage (Table 3). This represents near one third of population in developing countries and half of Sub-Saharan Africa. Mankind has to provide food for more 3.6 billions persons by 2030 but also to overcome food shortages of one fourth of the population. Estimates indicate that world's food production has to double in the next 40 years, however more than double in areas of large population growth.

During the last 30 years increases in cereal production in developing countries amount for 118%. 92% is attributable to increase in average yields. However, the Middle East and North Africa regions had only an increase in production of 76%, and the proportion attributable to increased average yields was 77%. It happens that already available technologies allow for much higher average yields than those currently available: an optimized combination of seeds, farming practices, fertilizing, and irrigation could provide for a maximum average yield of maize of 21 t/ha (Waggoner, 1994). Considering that current average cereal yields in developed countries is now over 4 ton/ha, while in developing countries are 2.3 t/ha, with only 1.4 t/ha in the Middle East and North-Africa region, one can conclude like Waggoner (1994) that not only it is possible to rise yields but to spare land for nature.

However, to improve the food supply to feed the growing population will require new land and water resources management. Uncertainties associated with global climate changes have also to be overcome (see Rosenzweig and Parry, 1993).

Urbanization is another aspect of particular importance because growth of population is associated with urbanization. Trends in Table 4 indicate that half of world population is now living in cities when 25 years ago near two thirds was rural population. The trend also shows that by 2030 near three-quarters of the world population will be urban. The large differences between developed and developing countries by 1965 are attenuating rapidly. This rises several questions: the increase of poverty in crowded neighbourhoods of large cities, the use of agricultural land to extend these neighbourhoods, the increase in the water demand for domestic and industrial uses, the growing need for safe water and sanitation, the increased demand for energy, the decrease of manpower for the traditional cropping systems, the growing distance between human environments and nature.

Table 2 *- Population and average annual growth (source: The World Bank, 1992)*

Country Group	Population (millions)					Average annual growth (percent)				
	1973	1980	1990	2000	2030	1965-73	1973-80	1980-90	1990-2000	2000-30
Low and middle income	2,923	3,383	4,146	4,981	7,441	2.5	2.1	2.0	1.9	1.4
Sub-Saharan Africa	302	366	495	668	1,346	2.7	2.8	3.1	3.0	2.4
East-Asia and Pacific	1,195	1,347	1,577	1,818	2,378	2.6	1.7	1.6	1.4	0.9
South Asia	781	919	1,148	1,377	1,978	2.4	2.4	2.2	1.8	1.1
Europe	167	182	200	217	258	1.1	1.2	1.0	0.8	0.6
Middle East and North Africa	154	189	256	341	674	2.7	3.0	3.1	2.9	2.3
Latin America and the Caribbean	299	352	433	516	731	2.6	2.4	2.1	1.8	1.2
High income	726	766	816	859	919	1.0	0.8	0.6	0.5	0.2
OECD members	698	733	777	814	863	0.9	0.7	0.6	0.5	0.2
World	3,924	4,443	5,284	6,185	8,869	2.1	1.8	1.7	1.6	1.2

***Table 3** - Poverty (source: The World Bank, 1992)*

Region	Percentage of population below the poverty line		
	1985	1990	2000
All developing countries	30.5	29.7	24.1
South Asia	51.8	49.0	36.9
East Asia	13.2	11.3	4.2
Sub-Saharan Africa	47.6	47.8	49.7
Middle East and North Africa	30.6	33.1	30.6
Eastern Europe (excluding former USSR)	7.1	7.1	5.8
Latin America and the Caribbean	22.4	25.5	24.9

***Table 4** - Urbanization (source: The World Bank,1992)*

Country groups	Urban population in percentage of *total population*		Average annual growth rate (%) *of urban population*	
	1965	1990	1965-80	1980-90
Low and Middle incomes	24	44	3.7	6.6
Sub-Saharan Africa	14	29	5.8	5.9
East Asia and Pacific	19	50	3.0	12.0
South Asia	18	26	3.9	3.9
Europe	40	60	2.7	2.6
Middle East and North Africa	35	51	4.6	4.4
Latin America and the Caribbean	53	71	3.9	3.0
High income economies	72	77	1.3	0.8
OECD	72	77	1.2	0.8
World	36	50	2.6	4.5

Irrigation

Worldwide, water is the major factor limiting crop yields and food production. Irrigation has been critical to increasing crop yields and production by eliminating or reducing plant water stress. However, irrigation development has introduced major changes in the environmental and socio-economic conditions of an area (Jensen, 1993). In the process, existing equilibria are disturbed and over time, new ones are established. The underlying premise is that the new conditions established under irrigated agriculture satisfy humankind's objectives better than those practised before.

While only one-sixth of the world's cropped land is irrigated, this area produces approximately one-third of the world's food supply (Wagooner, 1994). Over one-half of the increase in food production over the last 25 years has come from irrigated land (Rangeley, 1990) and further irrigation will undoubtedly continue to play a critically important role in assuring the food security of the world's expanding population. Irrigation also contributes significantly to poverty alleviation and general improvement in the quality of rural life. Further, it enhances the productive capacity in otherwise harsh environments and reduces the need for horizontal expansion of rain-fed agriculture onto marginal lands.

Irrigation development, while contributing to the economic well-being of many countries, also has potential negative effects, mainly waterlogging and salt affected soils (Jensen, 1993). Arid and semi-arid water stressed areas are particularly sensitive to those detrimental effects (Agnew and Anderson, 1992). While many of these can be minimized or avoided altogether by better planning, or mitigated by appropriate measures, questions have arisen as to whether irrigation is capable of continuing the high levels of agricultural production in the long run without undue damage to the environment. Interest in sustainable development has arisen as a consequence.

To feed the rapidly growing population, food production must be increased by enlarging the area served by irrigation, or by intensifying agricultural production on the existing irrigated and rain-fed lands. Irrigated agriculture has expanded, horizontally into areas where conditions for production are less favorable, and vertically, by increasing production per unit area of land through intensification. Much of the additional agricultural production has been achieved through the development of new irrigation projects and products, and the use of high-yielding varieties, which require optimum management of land and water. Unfortunately, growth in grain production has slowed during the past few years.

These trends point to the danger of a decline in per capita agricultural production, which will become even more dramatic with the increasing world population. Hence, the world food and water problems may worsen with time. The growth in demand exceeds that of production in the developing countries, and further, this spread may increase when accounting for the increased expectations of future generations.

During the past four decades, development of irrigated agriculture provided a major part of the increase in production necessary to meet population demands. On a global basis, the average rate of irrigation expansion was about 1 percent per year in the early 1960s and reached a maximum of 2.3 percent per year from 1972 to 1975 (Waggoner, 1994). The rate of expansion began to decrease in the mid-1970s and is now about 1 percent per year (Jensen, 1993).

The reasons for this decrease in expansion are many. Two of the most commonly cited causes are the high cost of irrigation development, and the decline of the world price for major cereals. Further, and perhaps most importantly, as much of the land suitable for irrigation development and available water supplies have already been developed, progressively more expensive, economically less favorable and environmentally more sensitive areas are left for further expansion. However, authors like Crosson (1993) admit that irrigated areas may be increased by 50%.

Scarcity of water is a major constraint for further irrigation development in arid and semi-arid countries, In many countries, all available water sources which can be economically used have already been developed or are in the process of development. As the competitive demands for water continue to increase it is imperative that this limited resource be used efficiently for agricultural and other uses (Hennessy, 1993). In some scarce areas, more water will be diverted from agriculture to meet expanding needs for domestic and urban uses because of population growth. The use of unconventional water resources in agriculture will also expand.

Water resources play a major role in feeding the world's population and these finite water supplies face an ever expanding demand from many competing water users. Existing irrigation methods and practice are being placed under increased scrutiny from many fronts. Irrigation research must now focus on other alternatives such as increasing crop production per unit of irrigated land and per unit of water consumed by evaporation. Yet, the fact remains that new irrigation development and improved management of existing water systems, particularly in developing countries, must be capable of providing needed food and fibber production while at the same time addressing key environmental and social issues.

NEED FOR INNOVATIVE ISSUES

Problems identified above call for new innovative issues in water management in such a way that development not only sustains the fast growing and urbanized population, but be sustainable, i.e., resource preserving, environmentally non-degrading, technically appropriate, economically viable, socially acceptable and human oriented.

Assuming the challenges above, a Research Agenda on sustainability of water resources utilization in agriculture evolved from group discussions in a NATO Advanced Research Workshop held at Vimeiro, Portugal, March 1994 (Pereira *et al.*, 1994). The resulting primary issues and priorities are listed below:

Priority Issues

1 - **Environmental and health impacts**
- **Water quality management**

2 - **Rehabilitation and modernization of irrigation systems**

3 - **Technology and rules for use of waste and saline water**
- **Policy issues**
- **User participation for planning and managing irrigation and drainage systems**

4 - **Basin wide integrated water resources planning**
- **Human resources development**

5 - **Irrigation and drainage system performance**
- **Water savings methodologies**

6 - **Rainfed agricultural water management and water harvesting**
- **Economics of development of both irrigated and rainfed agricultural schemes**

7 - **Land and water institutional issues**

8 - **Availability of land and water resources**

These issues concern the different components and implications of sustainability such as: resource conservation; technical appropriateness; environmental concerns; economic viability; and social and institutional adequacy. They also relate to: management techniques; innovative technologies; evaluation, assessment and monitoring methodologies; and measures, rules, guidelines and training tools. They cover broad areas of concern, of interest both to the developed and developing countries.

The development of the priority topics listed above is presented in the following subheadings and is based on the referred Research Agenda (Pereira *et al.*, 1994).

Environmental, health and water quality

These aspects have been considered with first priority.

The *environmental and health* impacts include:

a) evaluating the potential of irrigation as a means for environmentally sustainable land use and food production, as well as the potential adverse environmental impacts resulting from neglecting or abandoning irrigation systems;

b) the development of appropriate tools for assessing and controlling the impacts of using low quality water in irrigated agriculture, and appropriate techniques for the maintenance of waste water systems;

c) the control of water-related diseases, including monitoring health hazards environmental management for vector control, and expand the epidemiological studies of agrochemical waste water and drainage water reuse;

d) improve land evaluation criteria and methodologies for irrigation planning to include the assessment of the impacts on the environment.

Water quality management concerns:

a) water quality monitoring, including the development of reduced cost methods of assessment and standards for chemical, physical and biological loads, and the aspects relative to pollution from agrochemicals;

b) economic and effective mechanisms for disposal or reuse of drainage water, salts and agricultural wastes in arid and semiarid lands;

c) appropriate methods for waste water treatment for agriculture reuse;

d) best management practices to minimize water quality degradation in irrigated agriculture and improve the productivity of irrigated agriculture with the efficient delivery of water.

Technical issues

High priorities should be given to the technical aspects oriented to modernize irrigation and drainage systems and to provide for appropriate use of saline and unconventional water.

Concerning rehabilitation and modernization of irrigation systems, main aspects relate to:

a) procedures for integrated planning and management of irrigation and drainage systems;

b) development of locally-adapted water-efficient on-farm irrigation technologies, i.e., the improvement of on-farm irrigation performances;

c) integrated irrigation and fertilizer management including fertigation, chemigation and irrigation scheduling;

d) low cost technologies for canal construction and improvement, and appropriate techniques for improved water regulation and control;

e) strategies for sustained increases in output per unit input of water and land;

f) control sediment in irrigation and drainage systems;

g) enhanced methods for field evaluation of on-farm and off-farm system performances and system monitoring, including water supply, water quality, salinization and environmental, economic and social impacts.

The appropriate *use of saline and waste water* requires:

a) improved knowledge on salinity and solute processes under irrigated agriculture;

b) methods, techniques and guidelines for use, control and management of low quality water for irrigation;

c) expanded research on adaptation of crops and cropping systems to use low quality and saline water;

d) criteria and guidelines for the use of saline water and for saline water table management.

Institutional and policy issues

Innovative issues are required to make water management effective. They concern the mechanisms to improve user's participation and to strengthen the institutions involved in water resources planning and management, as well as the laws and regulations relative to water policies.

Issues to enhance *user's participation* in management of irrigation and drainage systems include:

a) the improvement of programs aiming at the transfer of responsibility from government to users relative to the operation, maintenance, and management of irrigation and drainage systems;

b) guidelines for user organizations to administer water for different uses;

c) the recognition of indigenous knowledge, human reluctance to change, and traditional social arrangements;

d) mechanisms which can improve the coordination and division of responsibility between government, public and water user institutions and the irrigation industry.

The *policy issues for water management* relate to:

a) appropriate procedures for allocation of surface and ground water for different purposes and uses;

b) water laws and rights which provide for equity in water distribution and allocation;

c) legal instruments and procedures for implementing water conservation and efficient management practices.

The *institutional building* issues mainly concern human resource development:

a) training, at all levels, of personnel involved in planning, construction, operation, maintenance and management of agricultural, irrigation systems;

b) technology transfer at all levels of irrigation and drainage management, including farmers;

c) improved mechanisms to promote and assure dialogue among water users, water user associations and water authorities;

d) research and training on modernizing surface irrigation systems, both on- and off-farm;

e) institutional arrangements which enable appropriate training and technology transfer on water management;

f) enhanced financial, institutional and other infrastructure which provides support services to farmers.

Planning and socio-economic issues

These aspects are focused in this seminar. Innovations in these areas are required not only concerning the methodologies to be utilized but under the conceptual approaches derived from the sustainability requirements relative to economic viability, social acceptability and human oriented development.

In which concerns planning, main issues relate to *basin-wide integrated water resources planning:*

a) political economy of water resources development for agriculture and rural areas;

b) criteria, policies and procedures for transboundary basin planning and management;

c) development of basin-wide integrated water resources planning and management including soil and water conservation;

d) strategies for water harvesting on arid and semi-arid lands;

e) drought mitigation methodologies;

f) monitoring and controlling surface and ground water salinity;

g) technologies for water reuse in developing countries.

New issues related to the *economic and social aspects* of water management refer to:

a) evaluating the role of irrigation in meeting global food requirements;

b) determining the social and economic aspects of increasing water use efficiency in agriculture;

c) impacts of water pricing on water demand and consumption;

d) economic and macroeconomic criteria for irrigation investment including public *versus* private investment;

e) criteria to ensure the economical viability of existing irrigation schemes, including water pricing and financial responsibility of users, as well as mechanisms to ensure financing of maintenance and rehabilitation of irrigation systems;

f) analysis of the subsidies system for irrigated agriculture and the financial vulnerability of irrigated agriculture to external changes such as prices of agricultural products and natural disasters;

g) innovative methodologies for assessing benefits of soil and water conservation and water harvesting.

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