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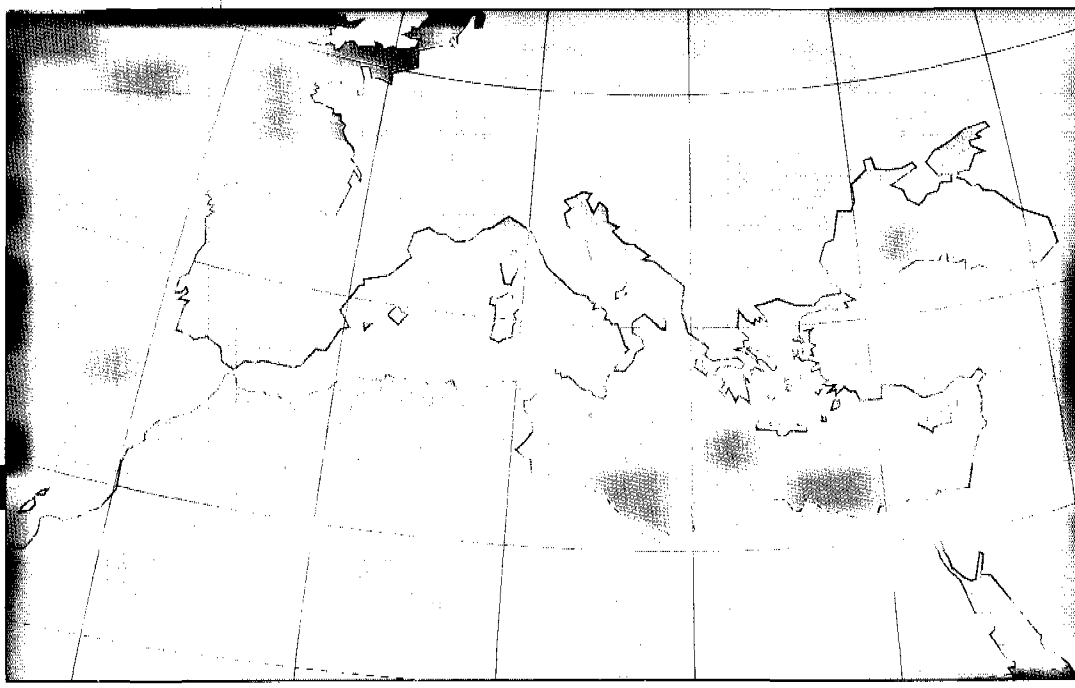

Cahiers OPTIONS méditerranéennes

Volume 1

Etat de l'Agriculture en Méditerranée

The Situation of Agriculture in Mediterranean Countries

N° 1. Ressources en eau : développement et gestion dans les pays méditerranéens

Water Resources: Development and Management in Mediterranean Countries

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Adana 3-9/IX/1992

Organisé en collaboration avec la Faculté d'Agriculture de l'Université de Çukurova, Adana, Türkiye
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n° 4. Les politiques agricoles et alimentaires (IAM.Montpellier)
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n° 2. Soils in the Mediterranean Region: Use, Management and Future Trends (IAM.Zaragoza)
n° 3. Management of Mediterranean Forest Lands: Environmental Aspects (IAM.Chania)
n° 4. Food and Agricultural Policies (IAM.Montpellier)
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FOREWORD

FOREWORD

Towards the preparation of the CIHEAM conference on Agricultural Policies in Mediterranean Countries, on the occasion of the 30th anniversary of the establishment of CIHEAM, Bari Institue has sponsored to organise a workshop on "water resources development and management in the Mediterranean countries" in Adana - Turkey - University of Cukurova Faculty of Agriculture.

The objectives of the workshop are:

- To present a general overview on water resources, irrigation and water management in the Mediterranean countries;

- To identify potentialities, constraints in water resources and management;

- To explore possibilities of cooperation, exchange and transfer of experience towards solving priority problems;

- To set a research and human resource development agenda for CIHEAM;

- To explore means and ways of establishing an information network among Mediterranean countries.

Conventional and unconventional water resources, water resources planning and management, water resources and irrigation practices and demands, water resources use and water resources economic, institutional and legislation aspects are the major technical issues treated by the workshop.

It is my great pleasure to express my acknowledgements to the Director of Bari Institue and the Director of research for their great effort in organizing the workshop.

Deep thanks and gratitude are also extended to the Cukurova University Authorities and the Dean of the Faculty of Agriculture for hosting the workshop and organizing the scientific tour.

On behalf of CIHEAM organization, I would like to express my deep thanks and gratitude to the EEC organization for its continuous technical and financial assistance in the training and research programmes developed by CIHEAM Institues and for its financing support to this meeting.

Finally, on behalf of the organizing committee, I would like to express my sincere appreciation for the participation of the representatives of the International Organizations: World Bank, FAO and UNEP and to the scientists and specialists from the majority of the Mediterranean countries. Without their scientific and technical contribution, this important publication printed by Bari Institue would have not been possible.

It is hoped that this workshop will provide useful information to water planners and managers, irrigation engineers and scientists on the main aspects to be taken into account in the development and management of water resources in the Mediterranean region. It is also hoped that the session discussions and recommendations will help to identify the areas where further research and development efforts are needed for a better use and management for our water resources.

I would like to assure that the CIHEAM and its four operating Institues will greatly benefit from this workshop and will use its outcomes as guidelines for the orientation, policy and programmes contributing to cope with the foreseable demands of a further developing Mediterranean region.

M. LASRAM

Secretary General of CIHEAM

II

INTRODUCTION

INTRODUCTION

Throughout human history, water has always been considered to be an important requirement for human welfare and economic development. The importance of water for life is of course nothing new. It has been well known since civilization started: "we made from water every living thing" (The Koran).

There is no doubt that for the Mediterranean Countries, particularly those with erratic rainfall patterns, efficient control and management of water have to be essential requirement for their continued development. The way in which water resources are being managed has increasingly severe environmental implications, including the accelerated soil and water degradation, the degradation of natural ecosystems and fresh water pollution. Without proper water management, self sufficiency in food and energy will continue to be mirage for most of these countries.

In the Mediterranean region, especially the arid and semi-arid countries, water resources have to be managed in an integrated manner, considering all components of water cycle and all uses, agriculture, urban, rural and industrial, including the maintenance of the aquatic environment.

Efforts should be directed to overcome the present constraints regarding integrated water management approach and in particular, the institutional weakness, inadequate networks, incompatible techniques for field laboratory and office work. Deficiency of staff and their capability and the lack of coordinated relevant research have constrained efforts further.

Challenges and opportunities for water resources development and management in the Mediterranean Countries call for improvement in the knowledge, capacity building and internal cooperation on national, regional and global level. Those are the tasks, Bari Institute is focusing its major activities on.

Cosimo Lacirignola
Director of Bari Institute

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1

AN OVERVIEW OF WATER RESOURCES IN THE MEDITERRANEAN COUNTRIES

A. HAMDY - C. LACIRIGNOLA

CIHEAM
IAM - B

AN OVERVIEW OF WATER RESOURCES IN THE MEDITERRANEAN COUNTRIES

A. HAMDY (*) and C. LACIRIGNOLA (*)

ABSTRACT

The knowledge we have of available water, though inadequate in many ways, has proved useful so far. However, the knowledge about availability, variability, reliability and quality has to become more precise.

In the face of population growth and the increasing demand for water, water quality deterioration, increasing environmental degradation and impeding climate change, more effort is required to assess water resources for rational planning and management to sustain development.

Those efforts should be directed to overcome the present constraints regarding water resources assessment and in particular the institutional weakness, inadequate networks, incompatible technologies for field, laboratory and office work.

Deficiency of staff and their capability and the lack of coordinated, relevant research have constrained efforts further.

Challenges and opportunities for water resources development in the Mediterranean Countries call for institutional reforms, improvements in the knowledge of hydrological processes and increase in funding, capacity building and international cooperation on national, sub-regional, regional and global levels.

INTRODUCTION

Water is a prerequisite for the survival of man and for his development. Current and projected problems with fresh water resources arise from the pressure to meet the food, agricultural, human settlement and industrial needs of a fast-growing population.

(*) Istituto Agronomico Mediterraneo, Bari - ITALY

There is no doubt that for developing countries of the Mediterranean region, with erratic rainfall patterns, efficient control and management of water use has to be an essential requirement for this continued development. Without proper water management, self sufficiency in food and energy will continue to be a mirage for most of these countries. Scarcity of water and reliability of its supply are major constraint for agricultural development in those countries. In the majority of these countries, many of all available sources of water which can be economically used have already been developed or are currently in the process of development. In some countries, such as Egypt or Jordan, no new major sources of water that can be further developed.

Water scarcity is taking a terrible toll on people everywhere, especially in developing countries. Globally, at least 1.7 billion people do not have adequate drinking water supplies and at least 3 billions lack access to proper sanitation. In the next 24 hours, while we are meeting, 25.000 people worldwide will die from waterborne diseases.

In the developing countries of the Mediterranean, the major challenge facing water planners and managers in the 1990s is that while physical availability of water is fixed, its demand will continue to increase steadily in the foreseeable future. Accordingly, the problem is how to balance demand and supply of water under those difficult conditions. In addition, the issue of potential climatic change due to global warming and what its impacts could be on natural resources including water, are basically unknown factors at present. This is part of a broader challenge to water planners and managers: to anticipate impacts of climate on the full range of water management and strategies.

MEDITERRANEAN CLIMATE

The mediterranean climate is characterized by a hot and dry season in summer and by mild temperatures associated to annual rainfall in winter. In the Mediterranean basin this climate is the result of interactions between the desert area in the South and the Atlantic Ocean in the North, namely some influences external to the Mediterranean sea.

Average yearly rainfall in the Mediterranean basin (Fig. 1) and the rainfall distribution (Fig. 2), indicate clearly that the rainfall is irregular during the year and over

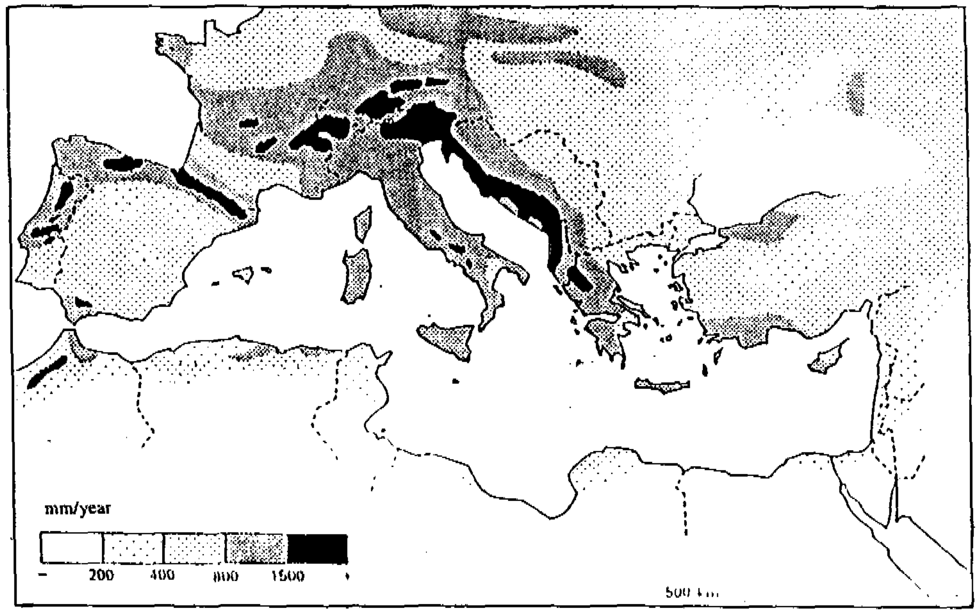


Fig.1 Average yearly rainfall in the Mediterranean Basin

Source: UNESCO-OMM European Climatic Atlas, 1970 & UNESCO World Water Balance

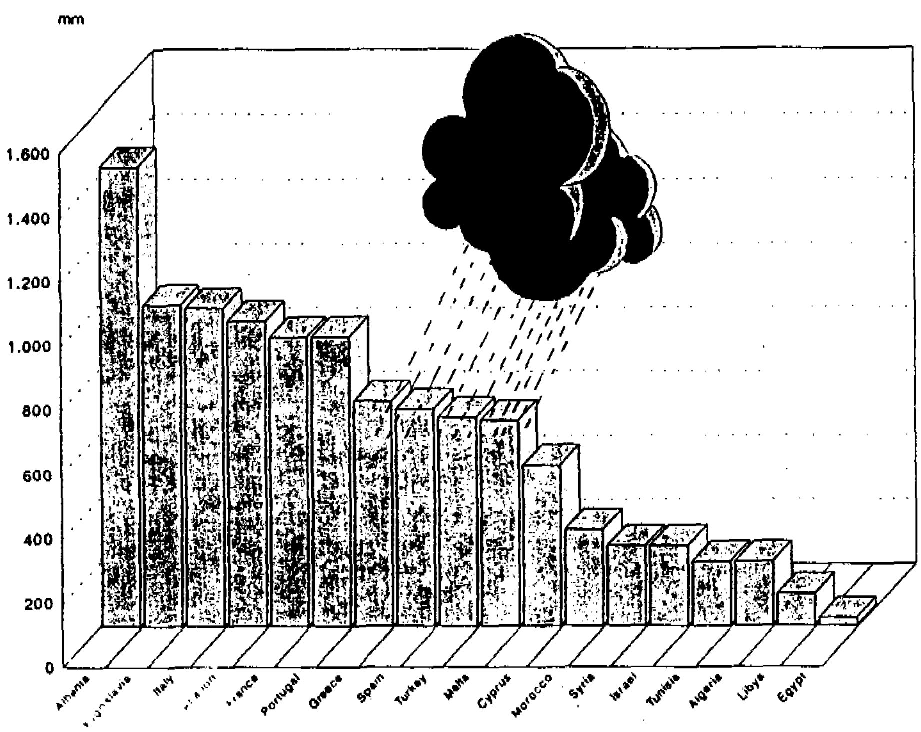


Fig.2 Rainfall Distribution in the Mediterranean Countries

the years above all in the South where the harvest of rainfed crops is never ensured. Furthermore, rain can be heavy and disastrous and it often provoks soil erosion.

Despite the apparent uniformity of Mediterranean climate a more detailed analysis shows great differences. The dry season duration (Fig. 3) clearly illustrates that, while the South is characterized by a long dry season averaging for more than seven months without any precipitation, in the Northern part the dry season is relatively limited and doesn't exceed 2-3 months.

In addition, the rainfall and temperature diagrams (Fig.4) show great differences between the North (autum rainfall) and the South (winter rainfall) of the basin. In summer, the simultaneous occurrence of high temperatures and small precipitation causes high evapotranspiration.

CLIMATIC CHANGES AND WATER RESOURCES

The possible global warming due to the greenhouse effect is now firmly on the world's scientific and political agenda.

The second World Climate Conference (SWCC) in its statement on the specific issues of climatic change impact stated that "among the most important impacts of climate change will be its effect on the hydrologic cycle and water management systems".

There is no question that if the existing rainfall and temperature patterns changes during the forthcoming decades, there could be important implications for agriculture production and water management, at global as well as regional and national levels, depending on the rates, magnitude and spactial distribution of such changes.

The most important implications of climatic fluctuations as they relate to water management are in terms of water availability form both surface and ground water sources; drought and flood management (including efficient operation and safety reservoirs); choice of proper cropping patterns to ensure crop-water requirements are met reliably; maintenance of water quality of rivers lekes canal systems and aquifers; and management of vulnerable, lowlying areas, especially in the deltaic and coastal regions.

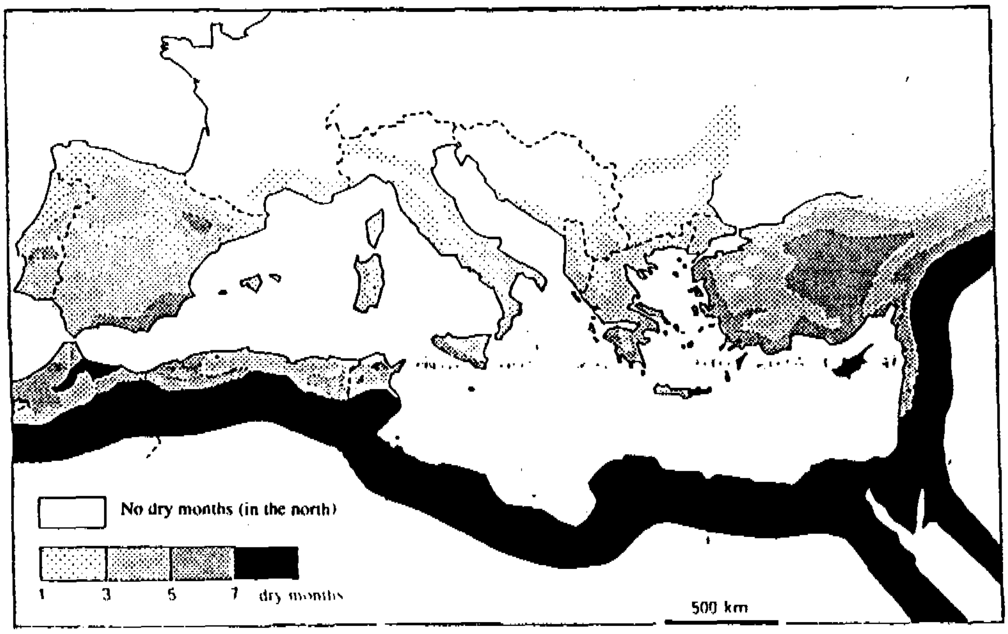


Fig.3 Dry Season Duration in the Mediterranean Basin

Source: P. Birot & J. Dresch, 1953 modified

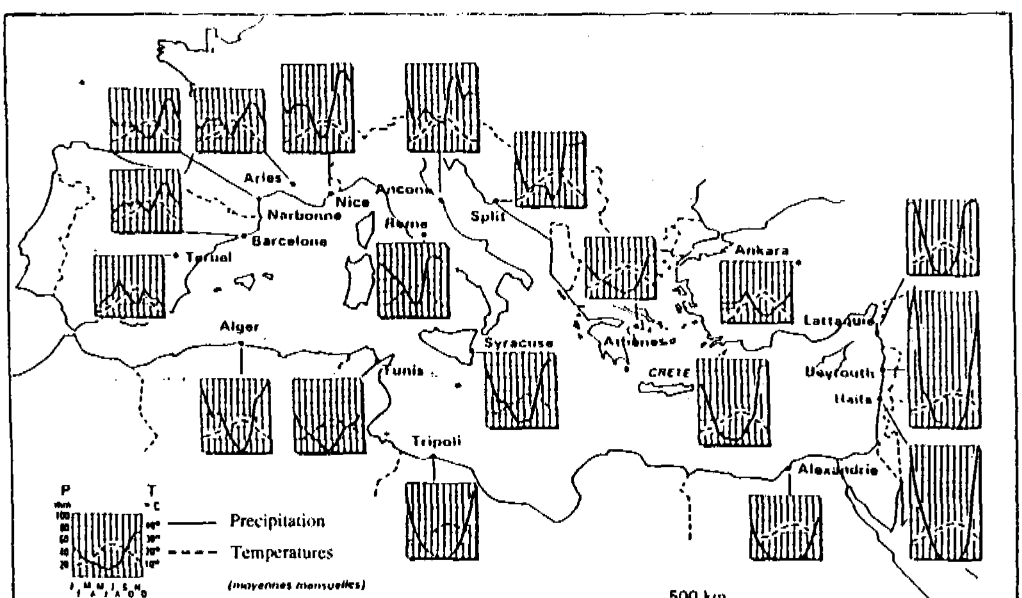


Fig.4 Rainfall & Temperatures diagrams of the Mediterranean Basin

Source: Plan Bleu

It is generally estimated that the global mean temperature might increase by 0.5 °C to 2 °C within the year 2030, reaching 3.5 °C within the year 2050, which is a considerable modification compared to the past. Moreover, it should be underlined that although all emissions of carbon dioxide and CFC would stop today, an increase in the world temperature would result all the same by inertia because of the amounts already in the atmosphere.

This global evolution will certainly have notable repercussions on the mediterranean climate, which might occur quite rapidly over the next decades, although their nature is not exactly known at present. It is estimated that due to a mean rise in the temperature by 1.5°C within the year 2025, the cyclonic systems which affect the central and western parts of the region in winter, will move towards the North. In the centre and West, rainfall will still depend to a large extent on the relief and will increase in the North, whereas the Southern regions where rainfall is uncertain might extend and evapotranspiration would generally increase. Such a change would have serious consequences, especially for agriculture and for the hydrologic regime. The modifications in the thermal structure of water masses resulting from this process could equally cause changes in sea currents which would affect, in return, the aerial currents of the region.

It is, however, estimated that the expected increase in temperature will cause a general raising of the sea level. Historically, the Mediterranean shores have not remained fixed lines due to slow variations of the sea level or to local tectonic movements and it has been possible to redraw the submersions and emersions which have occurred over the last millennia. The general trend since the end of glacial time has been a raising of the sea. The latter has reached about 1.3 mm per year through the last century and it is presently estimated that as a result of the greenhouse effect, which will cause a *swelling of the world ocean*, a 15 to 40 cm rise in the mean level of the Mediterranean sea is to be expected within the year 2025.

Although these will cause climatic variations, such as droughts or permanent changes, their evolution is still unpredictable for them to be actually integrated within scenarios directly. Nevertheless, they will be considered as "risks".

A UNEP-commissioned report released several months ago suggests that Egypt is one the countries most at risk. Other countries include the Netherlands, Bangladesh and Maldives (Tolba 1992).

In Egypt, the coastal areas of the Nile Delta are most vulnerable, and they account for 15% of Egypt total national product and 60% of its fisheries, and house nearly one- quarter of the nation's population. The lower Delta contains large tracts of land below one metre in elevation. Some areas - including coastal lagoons - are below sea level. A small sea-level rise could have profound impacts. It would overwhelm the brackish lakes of the northern Delta, which comprise one-third of the nation's fish catch. Rising sea levels would salinate lakes and aquifers in the lower Nile Delta, thus affecting as much as 20% of Egypt's 35000 square kilometres of arable land. The lakes of Maryut, Idku, Burrullos and Mawalah would also be engulfed by the sea. Rising sea levels could complicate sewage drainage systems, causing back-up of sewage flows, thereby increasing the risk of infectious diseases in overcrowded cities.

Within another framework, the climatic data might be modified, in limited areas, by the occurrence of microclimates. Urban climates are then modified by gazeous emissions (domestic heating, motor transports, industries) which cause a local warm-up of the climate associated to a modification of raifall distribution in the space and over time.

Preliminary assessments have been made by the IPCC on impacts on water resources in five regions of the world: North America, Western Europe, the Sahel in Africa, India and Australia. These were based on various scenarios of the increase in concentration of CO_2 and other "greenhouse" gases in the atmosphere. The IPCC's findings from these preliminary assessments indicated that "relatively small climate changes can cause large water resource problems in many areas especially arid and semiarid areas where demand or pollution has led to water scarcity. Little is known about regional details of greenhouse induced hydrometeorological change. It appears that many areas will have increased precipitation, soil moisture and water storage thus altering patterns of agriculture, ecosystem and other water uses. Water availability will decrease in other areas, a most important factor for already marginal situations such as the Sahel zone of West Africa".

The IPCC report goes on to state that "change drought risk represents potentially the most serious impact of climate change on agriculture at both regional and global levels". (IPCC 1990)

CLIMATIC CHANGES AND IRRIGATION REQUIREMENTS

The interrelationship between climatic change, water supply, and demand and resource availability are summarized in Fig. (5).

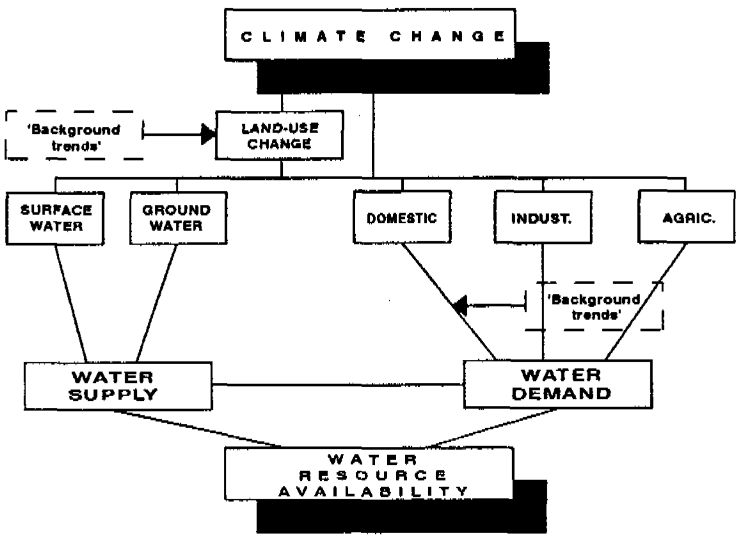


Fig.5 The interrelationships between climatic change, water supply, demand and resource availability. 'Background trends' represent changes due to evolving economic policies (ARNEL. 1992)

Climatic changes have a very significant impact on irrigation requirements. Recently in the Lesotho case study in southern Africa, Klohn and Arnell (1992) declared that the mean annual irrigation demand was found to be most sensitive to changes in evaporation.

A change in precipitation of 10% gave a change of approximately 5% in irrigation demand, while an increase in evaporation of 10% (corresponding to an increase of around 2C) increased irrigation demand by 18%.

Irrigation demands, in arid countries of the Mediterranean, comprise more than 75% of the total water demand, any increase in air temperature or change in other meteorological parameters will affect the irrigation water demands, growth and yield of the cultivated crops, as well as land use-pattern including cropping patterns. Assessing the increase in irrigation water demands resulting from a modification of the weather is important for developing future water supply alternatives and water management schemes.

Here, we outlined some of the challenges facing the water planners and the designers of water management strategies under climatic fluctuations and changes.

For the Mediterranean countries we need comprehensive, credible and cooperative water management policies that anticipate global warming and consequent climatic change. There is an urgent need to establish and/or expand reliable and cost-effective data-collection systems for hydrometeorological data, especially for rainfall, runoff, evapotranspiration and temperature covering all the Mediterranean countries. A reliable long-term data base is essential not only for efficient planning, managment and operation of water resources system but also to determine the future extent of climatic changes (if any) and how to deal with them effectively.

POPULATION IN THE MEDITERRANEAN COUNTRIES

The population evolution (1950-1990) and the expected average population (2000-2025) are given in Table (1) and illustrated in Figs (6 & 7).

Table 1. Population in the Mediterranean (millions)

	1950	1960	1970	1975	1980	1985	1990	1995	2000	2020	2025
World	2504	3013	3683	4079	4450	4854	5248	5679	6127	7806	8177
Medit.	232	270	318	346	375	407	442	477	514	651	685
North. Medit.	170	189	213	225	235	244	253	263	271	297	305
South. Medit.	62.7	81.1	106	121	141	163	189	215	243	354	381
Medit./ World %	9.3	9	8.6	8.4	8.4	8.4	8.4	8.4	8.4	8.3	8.4

Source: Mode d'acroissement de la population urbaine et rurale, ONU, 1981

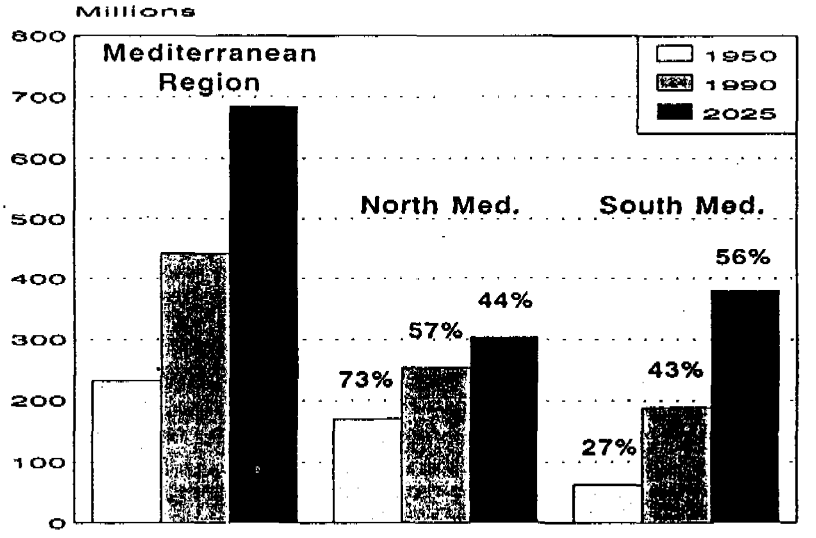


Fig.6 Population in the Mediterranean

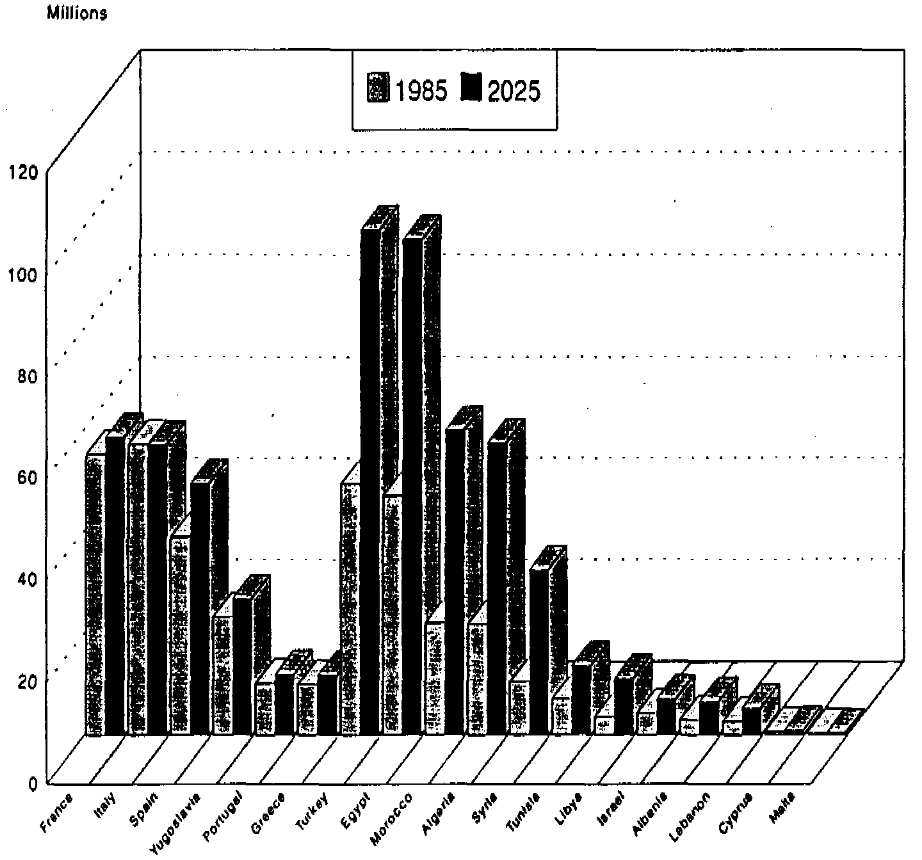


Fig.7 Population in the Mediterranean Countries (1987 - 2025)

The total population of the Mediterranean region has reachead now 443 millions representing 8.4 % of the world's population. Over 40 years (1950-1990), the total population of the southern mediterranean countries has triplicated, whereas, that of the north was only one and half times greater.

Taking the year 1985 as a reference, it is expected that the population of the Northen countries will be increased by only 25% in the year 2025, whereas the one of the South will increase by 133% giving a total increase of 77% for all the the Mediterranean countries. In the southern Mediterranean countries, the population growth rate is very high averaging 3.3% as compared with the northern countries and having an annual increase of only 0.63%. In the year 2025, the southern zone will have more than 55% of the Mediterranean population compared with only 27% in 1950.

From the analysis of the demographic characteristics of the 18 Mediterranean countries, the following three demographic groupings could be identified :

Region A: Spain, France, Greece, Italy, Portugal, Yougoslavia;

Region B: Algeria, Egypt, Libya, Morocco, Syria, Tunisia, Turkey;

Region C: Albania, Cyprus, Israel, Lebanon, Malta.

The population of these three groupings are provided in Table (2).

As a whole, the Mediterranean population experienced a 67% increase over 35 years from 1950 to 1985, at a mean annual rate of 1.5%, lower than 1.9% observed for the whole world population. The actual rate reached a maximum towards the end of the 60's.

Then, it has slowly decreased but remained still high, in the order of 1.4% between 1986 and 2000 and 1% between 2000 and 2025 (Fig.8).

This evolution is different in the three regions. The countries of region A experience growth rate sharply lower than those of the countries of regions B and C: 0.8% against 2.3% respectively between 1950 and 1985. In 2025 region A only accounts for 38% of the total Mediterranean population against 68% in 1950 and 54% in 1985. Conversely, region B grouped about 60% of the whole Mediterranean population, in absolute terms two times as high as its actual value, and about 5 times higher than in 1950.

Table 2. Evolution of the total population of the Mediterranean countries

Zones		Population (millions) 1950	1970	1985	1990	2000	2025	Multipliers with respect to 1985: 1985	1990	2000	2025
Medit. countries	Total	218.9	295.2	364.7	391.6	444.1	559.1	1.00	1.07	1.22	1.53
	Zone A	148.2	176.4	193.4	197.4	204.5	211.2	1.00	1.02	1.06	1.09
	Zone B	66.2	110.5	161	182.3	225.4	328	1.00	1.13	1.40	2.04
	Zone C	4.5	8.3	10.3	11.9	14.2	19.9	1.00	1.15	1.38	1.93

Source: Mode d'acroissement de la population urbaine et rurale, ONU, 1981

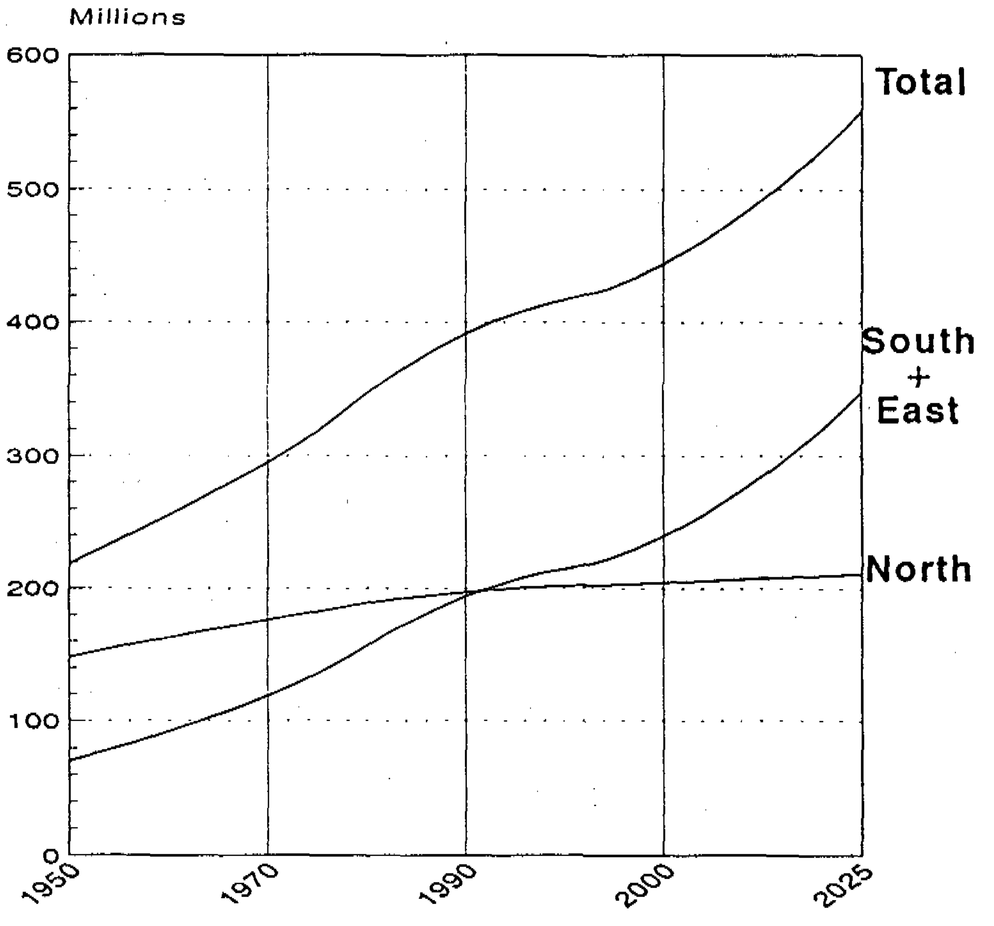


Fig.8 Evolution of the Total Population of the Mediterranean Countries

The growth in population will be accompanied by increasing urbanization. In 1990 the urban population as percentage of the total was of the values 62, 67 and 55% with respect to 52, 57 and 42% for the year 1970 for the whole, North and south of the Mediterranean region respectively (Fig 9).

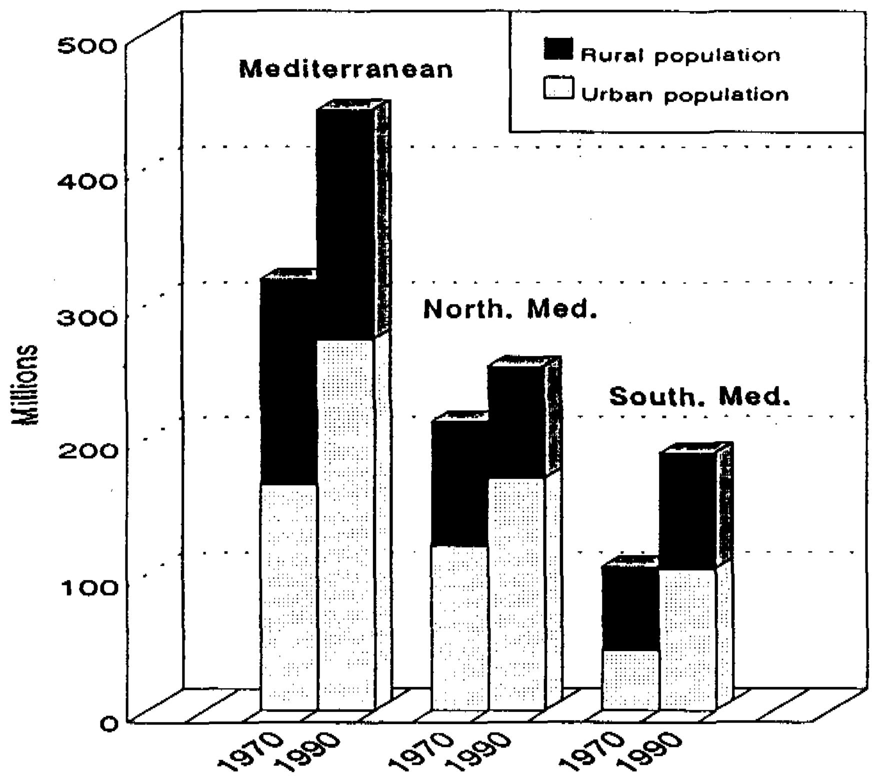


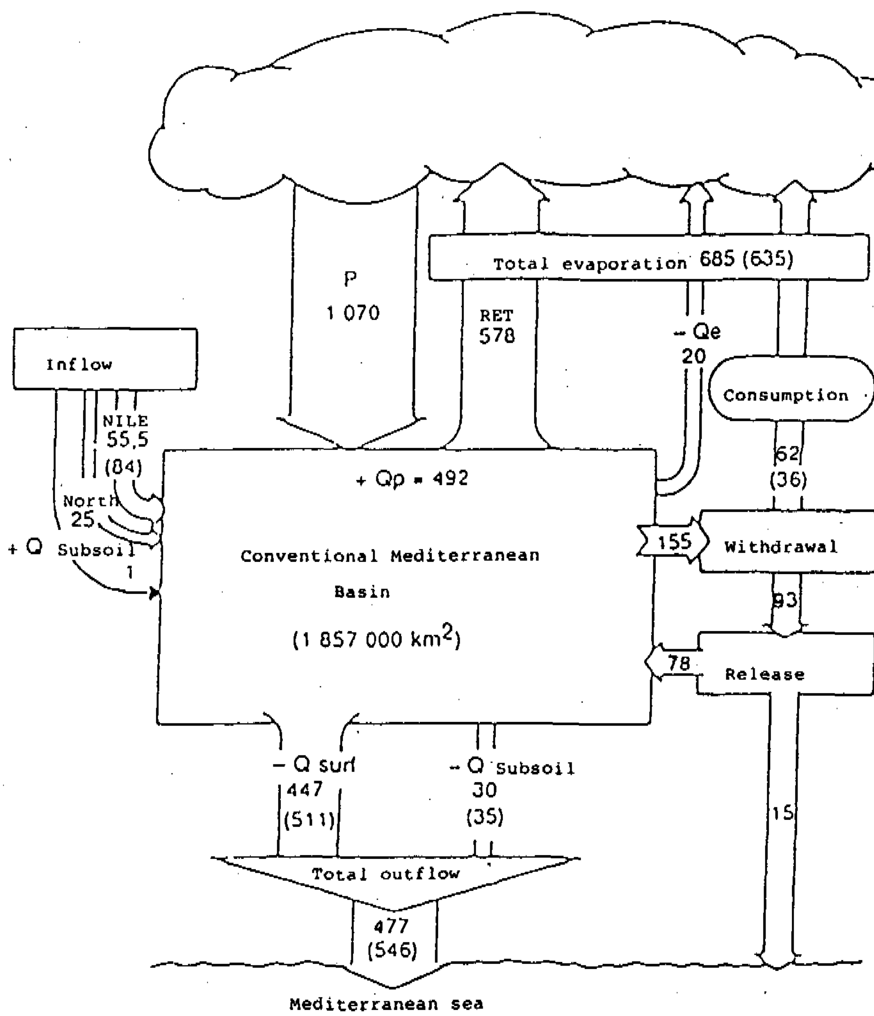
Fig.9 Urban • Rural Population in the Mediterranean.

Generally, the annual growth rate of urbanization is high in the Mediterranean region, but it is much higher in the South, 4.5% with respect to the North 2.8%.

This population increase will impose serious stress on the fresh water resources particularly with consumptive uses in the developing countries of the Mediterranean region.

WATER RESOURCES IN THE MEDITERRANEAN REGION

Figure 10 summarizes the global water balance of the Mediterranean region. On a regional scale, water is a poor and irregularly distributed resource.



Units: billion m^3 / year (Gm^3 / year)
P= Precipitation
RET= Effective evotranspiration
+ Qp= Potential flow (=effective rainfall)
- Qe= Water losses by evaporation
+ Q subsoil= Subsoil inflow
- Q surface= Surface outflow --> sea
- Q subsoil= Subsoil outflow --> sea

Fig.10 Present global water balance of the Mediterranean Basin

Source: Plan Bleu (J. Margat, 1990).

The multiple uses and functions suggest conflicts, both among different human uses (including those between farms and in-situ uses) and between them and the natural functions.

Table 3 summarizes the balance in the mid-80s in terms of water supply and demand related to uses in the Mediterranean area.

Table 3. Water supply and demand in the Mediterranean catchment area

Catchement area		Resources		Demand		Ratio Supply	Ratio Demand
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
	Estimated population in millions	Total water resources bill. m^3/year	Stable or stabilized water resources bill. m^3/year	Water withdrawals bill. m^3/year	Net consumption bill. m^3/year	Exploitation ratio referred to (b): d/b	Exploitation ratio referred to (c): d/c
Spain	≈16	31.1	7.5	13.8	11.7	38	184
France	12.4	74	35.2	15.75	≈2.37	21	45
Italy	57.2	187	30.5	46.35	≈15	25	152
Malta	0.33	≈0.03	0.023	0.023	0.02	≈77	100
Yugosl.	≈2.4	77.5	11.5	1.5	0.28	2	13
Albania	2.2	21.3	6.5	≈0.2	0.036	1	3
Greece	9.44	58.6	7.7	7	3.65	12	91
Turkey	11.9	≈67	15.6	6.7	≈3.27	10	43
Cyprus	0.66	0.9	0.27	0.54	0.40	60	200
Syria	≈1.7	4	2.3	0.88	0.51	22	38
Lebanon	3.16	≈4	≈2.8	0.6	0.38	15	21
Israel	4.34	≈1.3	0.28	≈1.5	0.95	115	536
Egypt	46.7	57.3	55.8	55.9	≈39	98	100
Libya	≈2.3	≈0.7	≈0.2	1.6	1.25	229	800
Tunisia	5.5	3.1	≈1.5	≈2	1.45	65	133
Algeria	15	10.9	2.5	1.7	≈1	16	68
Morocco	2.2	3.8	0.9	1.1	0.57	29	122
Total	193	602	...	157	82	...	...

Source: Plan Bleu (after J. Margat, 1988)

The water physical resources are included in columns *b* & *c*. These physical resources are the available ones, i.e they do not include rainfall resources but include spontaneous runoff from nearby countries. These resources are renewable: they do not include the resources provided by the exploitation of reserves, such as fossile water, which are significant for most North African countries, nor other unconventional resources such as the production of fresh water by sea water desalination, etc.. (the amount excludes the double counts due to the spontaneous exchanges between neighbouring countries in the region, in the order of 28 billion m^3/year). All these resources are not necessarily accessible. The most accessible fraction is the natural runoff of waterstreams and ground water, or the flood runoff trained by existing infrastructres (reservoirs) (column *c*, for which some uncertainties about infrastructures make a summation impossible). Gross withdrawals, for all grouped uses, making use of both regular or regularized water and irregular water, equal the allocated amounts (column *d*). A fraction of this withdrawn water is not returned to continental water of the natural medium. Calculated by general coefficients, such a fraction represents the net amounts of consumed water (column *e*).

Two ratios allow demands to be compared to supplies:

- the ratio of withdrawals to total resources (*d* over *b*, column *f*);

- the ratio of withdrawals to the regular fraction (*d* over *c*, column *g*).

It is worthwhile noticing that for the Mediterranean region:

- storage reservoir infrastructures increased by at least 55% natural regular resources (20% of which due to the Nile infrastructures only);

- out of the 154 billion m^3/year withdrawn, about 72% (110 billion m^3) are used for irrigated farming, 10% for the production of drinking water supplied to built-up areas (mostly domestic uses) and 16% for unjoined industries, including thermal power stations;

- a large portion of the waters flowing into the Mediterranean Sea (theoretical resources minus the net amounts consumed, column *b* minus column *e*, say about 486 billion m^3/year) carries some residues of wastewater, resulting in a considerable depreciation of its value, in terms of quality.

The high rates of utilization in most countries lead us to expect low rates of future supply (20% for Egypt for example), or no supply in extreme cases (Israel, Libya, Malta, for instance where the rate is already above 100%).

The volume of polluted water discharged into the sea, on the one hand, and the risks of conflicts related to the rise in demand to meet the needs of agriculture and urbanization (drinking water) intensification, on the other, led to choose water as the second "environmental component".

AVAILABLE TOTAL WATER AND WATER WITHDRAWAL

Clearly, water availability alone is just a first indicator as to whether abundance or scarcity is more likely. Not all water made available by nature can be used and the actual withdrawals depend upon upstream - downstream relations as well as upon water needs emerging from the socio-economic development.

Total available water, withdrawal and the withdrawal per capita are shown in Table (4). Concerning the total available water, it is quite clear that they greatly vary from one country to the other of the Mediterranean region. Generally, the northern countries are relatively rich in their available water resources with maximum values of 244 billion m^3 in Yugoslavia and minimum 62 billion m^3 in Greece. The other northern countries are of values in between with an average of around 144 billion m^3. Contrasts exist in the southern and eastern part of the Mediterranean region, where total available waters are of values much lower than in the north. The poorest among those countries is Malta with only 0.03 billion m^3, followed by Libya 0.60 billion m^3, then Cyprus 1 billion m^3 and Israel 1.65 billion m^3.

Regarding the water withdrawal as percentage of total water available (Fig 11), it is quite clear that in the countries of very poor water resources; the withdrawal water had exceeded the total available one (Libya 245% and Israel 104%). With the rich countries (Yugoslavia and Albania) their water withdrawal did not exceed 4% of the total.

On the other hand, the southern countries with high population intensity, water withdrawal is relatively intensive, around 30% of the total which is nearly two times superior to that withdrawn by the northern countries.

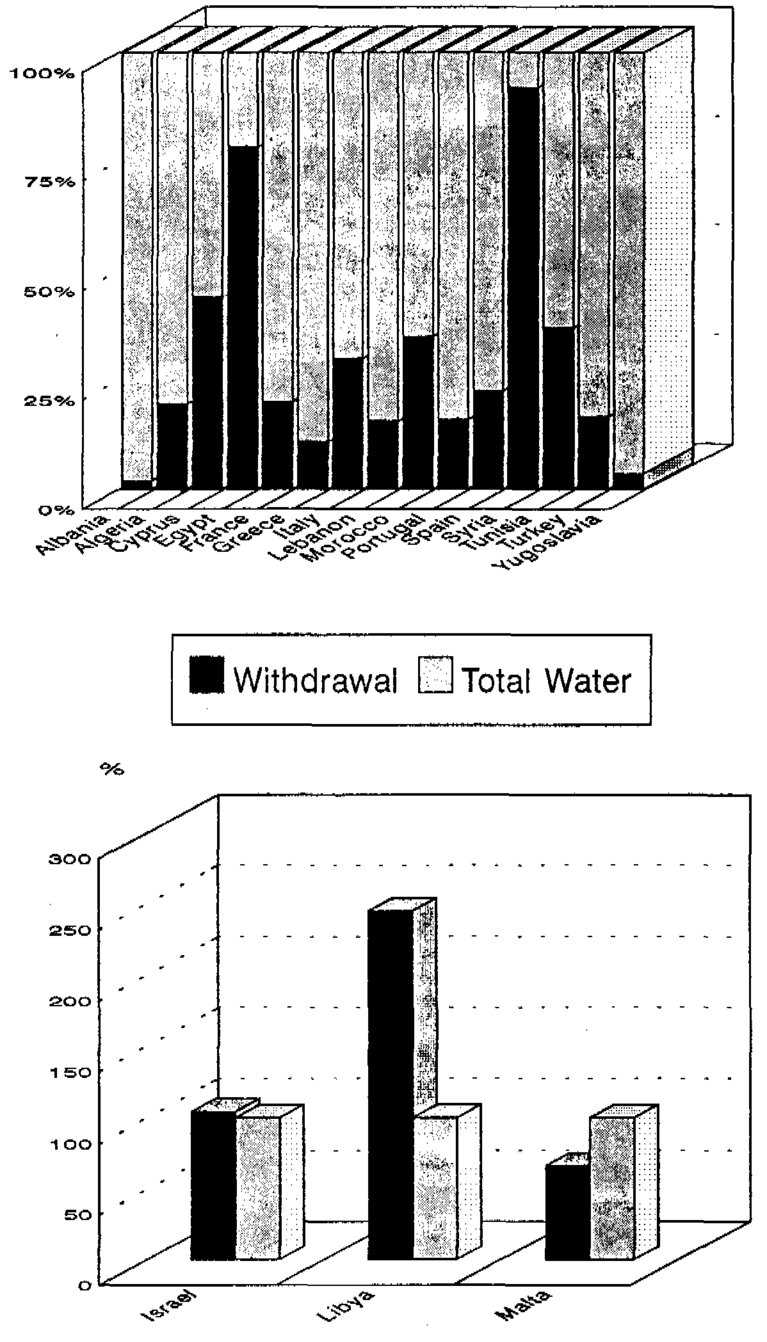


Fig.11 Water Withdrawal in the Mediterranean Countries 1987

In some countries (Egypt and Syria), the already withdrawn water is very excessive, amounting to nearly 90% of the total available water resource.

The water withdrawal per capita (Fig. 12) greatly varies not only between the regions of the Mediterranean area but also among the countries. Among the Mediterranean countries, the highest withdrawal per capita is found to be in Portugal with over 1000 m^3/year, whereas the lowest refers to Malta with only 51.5 m^3/year. The withdrawal per capita in Egypt is nearly equal to that of Italy but is twice greater than that in Morocco, and nearly six times greater than Tunisia and Algeria.

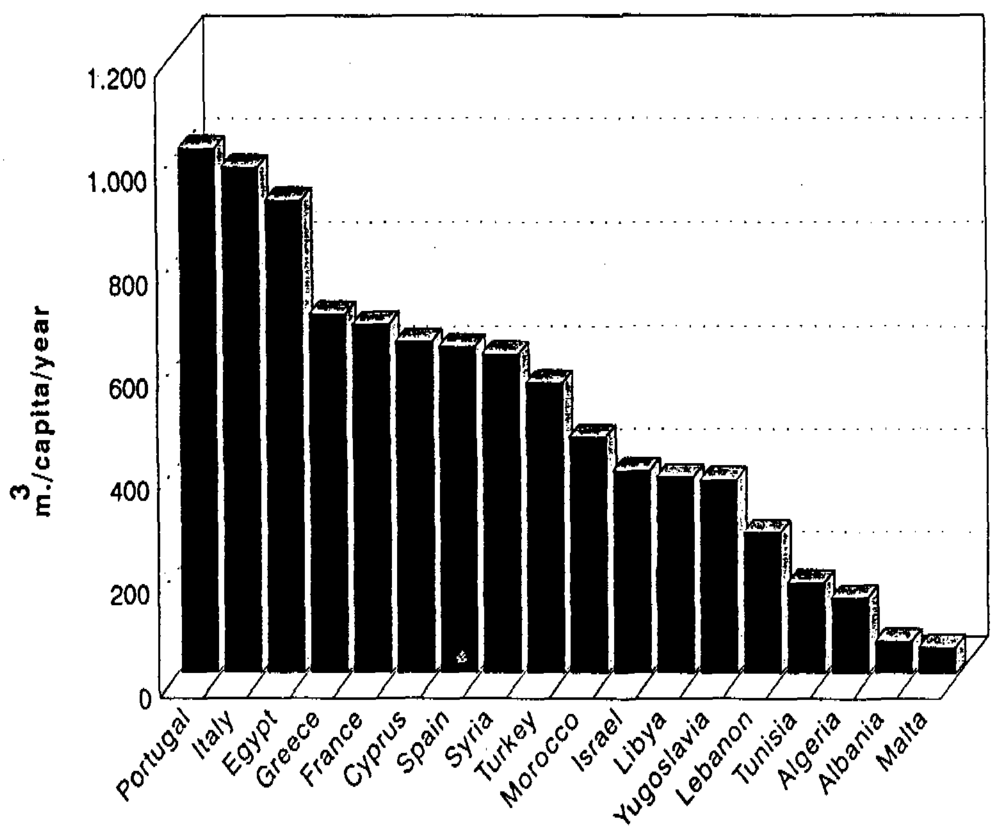


Fig.12 Withdrawal per Capita in the Mediterranean Countries (1987)

The previous data characterize the situation in the year 1987. Assuming that we need to keep the water withdrawal per capita, by the year 2025, at a value around that of 1987, the prospects for the year 2025 are really complicated and announces difficulties and severe problems, particularly for the countries with shortage in water resources and a relevant population growth rate. In Egypt, the water to be withdrawan will be doubled and nearly twice the actual total available resources.

Table 5. Water resources: total, withdrawal and withdrawal per capita

Country	Total water available	Total water per capita		* Category	
		1987	2025	1987	2025
Albania	10.00	3.144	1.530	Medium	Low
Algeria	17.20	0.743	0.300	Very Low	Very Low
Cyprus	1.00	1.462	1.117	Low	Low
Egypt	57.50	1.170	0.590	Low	Very Low
France	185.00	3.366	3.161	Low	Low
Greece	62.90	6.316	5.351	Medium	Medium
Israel	1.65	0.375	0.235	Very Low	Very Low
Italy	187.00	3.259	3.284	Low	Low
Lebanon	4.80	1.738	0.919	Low	Low
Libya	0.60	0.155	0.054	Very Low	Very Low
Malta	0.03	0.077	0.065	Very Low	Very Low
Morocco	30.00	1.304	0.501	Low	Very Low
Portugal	65.60	6.344	5.505	Low	Low
Spain	109.80	2.815	2.230	Low	Low
Syria	7.60	0.672	0.236	Low	Low
Tunisia	3.50	0.473	0.257	Very Low	Very Low
Turkey	172.90	3.364	1.741	Low	Low
Yugoslavia	244.00	10.400	9.164	High	Medium

Water availability per capita (World resources Institute, 1986):

* Category	Per capita availability m^3/year
Very Low	1000 or less
Low	1000 - 5000
Medium	5000 - 10000
High	10000 and more

Units:

Total water available in billions m^3

Total water available per capita in 1000 m^3

This will be also the case with the majority of the southern mediterrnean countries (Tunisia, Morocco, Algeria), hence for the realization of this assumption more than 90% of

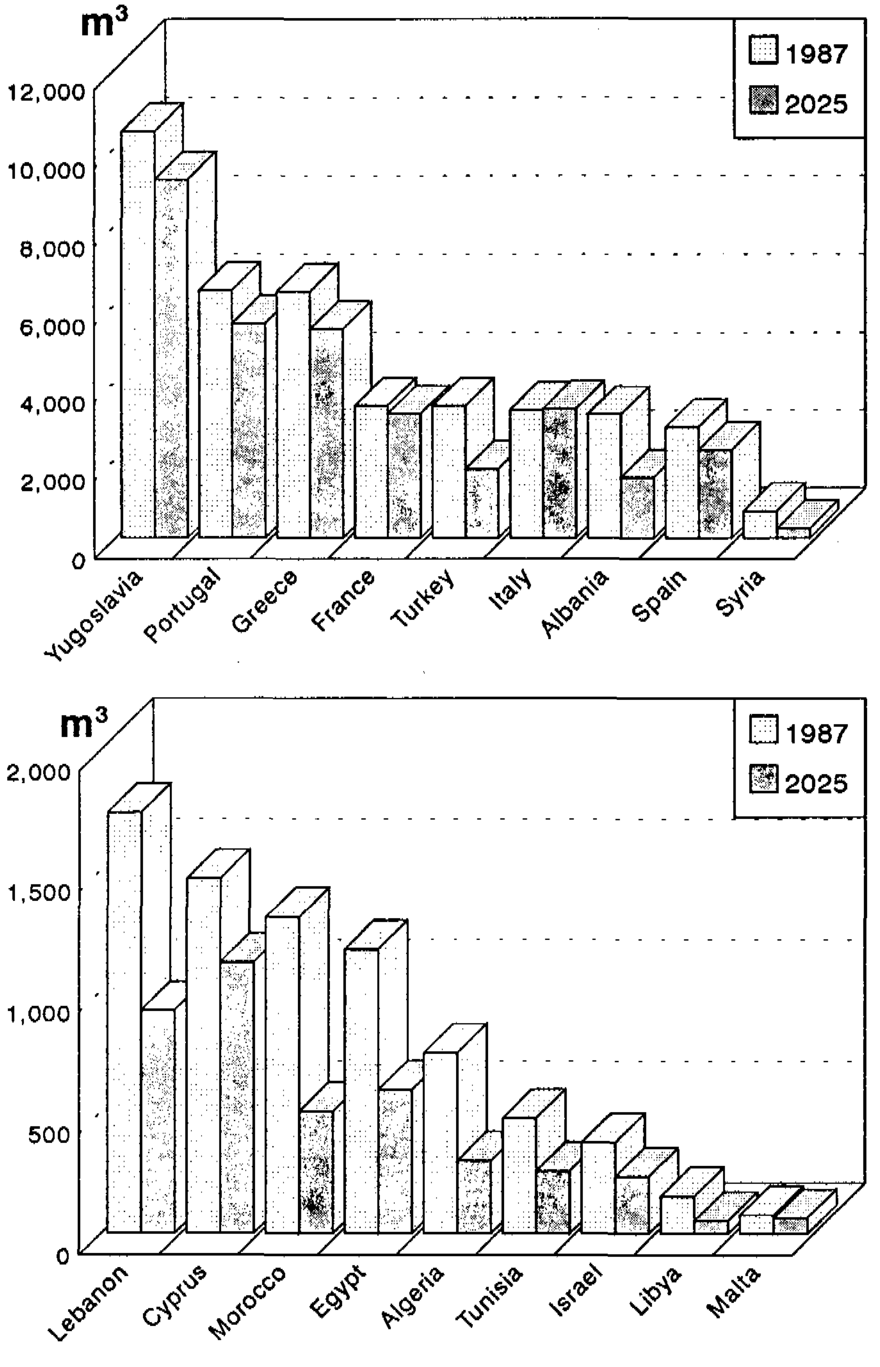


Fig.13 Water Availability per Capita in the Mediterranean Countries (1987 - 2025)

the total available water resources have to be withdrawn, this being practically impossible. In other countries (Libya, and Syria) to satisfy the water needs for the year 2025 the situation will be much worse.

This is clearer by considering the water availability per capita (Fig. 13 and Table 5). In terms of per capita water availability there are wide variations between countries. For example, France and Italy provides about three times more water per person than Egypt and Morocco, seven times more than Tunisia and nearly ten times more than Algeria.

The picture for the year 2025 shows that much less water will be available per capita in the Southern and Eastern part of the Mediterranean than the Northern one.

In the year 2025, it is expected that water availability per capita in the Southern countries will drastically drop (50 to 70%) with respect to the year 1987, with an average around 60%, but availability will be reasonably stable in the northern countries with very slight differences not exceeding 10%.

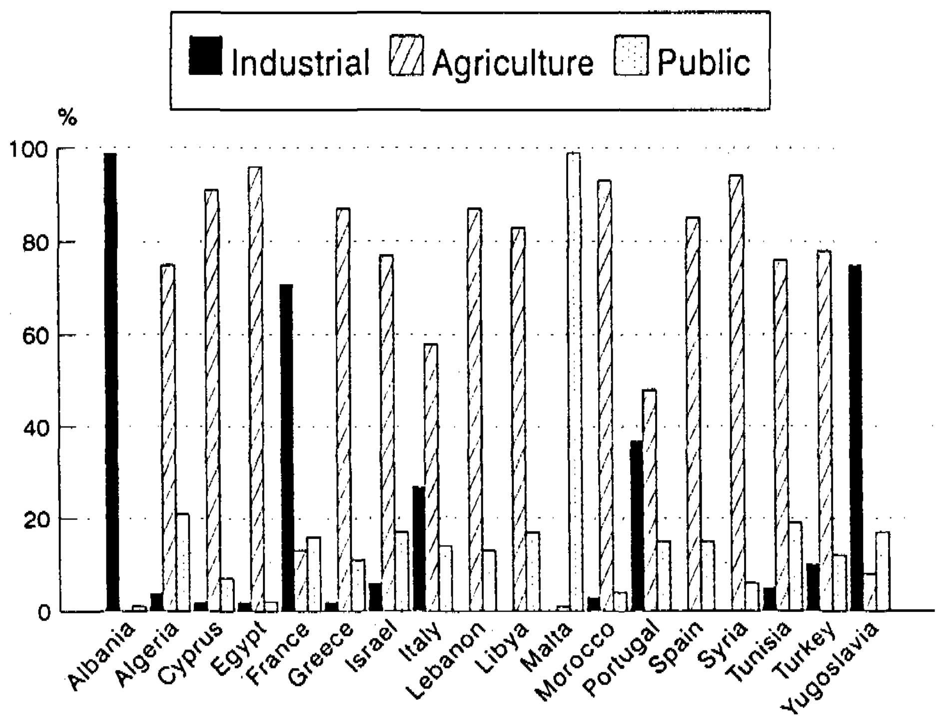


Fig.14 Sectorial Water Use in the Mediterranean Countries

This will normally be reflected on the sectorial water distribution and its use (Fig 14). Under such conditions, countries will experience difficulties in ensuring self sufficiency in meeting agricultural, domestic and industrial water needs. In the developing Mediterranean countries, because of the critical priority for drinking water, it is expected that the balance of water distribution between domestic, municipial, industrial and agricultural sectors will change in the favour of the first of these sectors.

LAND AND WATER RESOURCES

Land use and repartition of agricultural surfaces are illustrated in Figs (15 & 16).

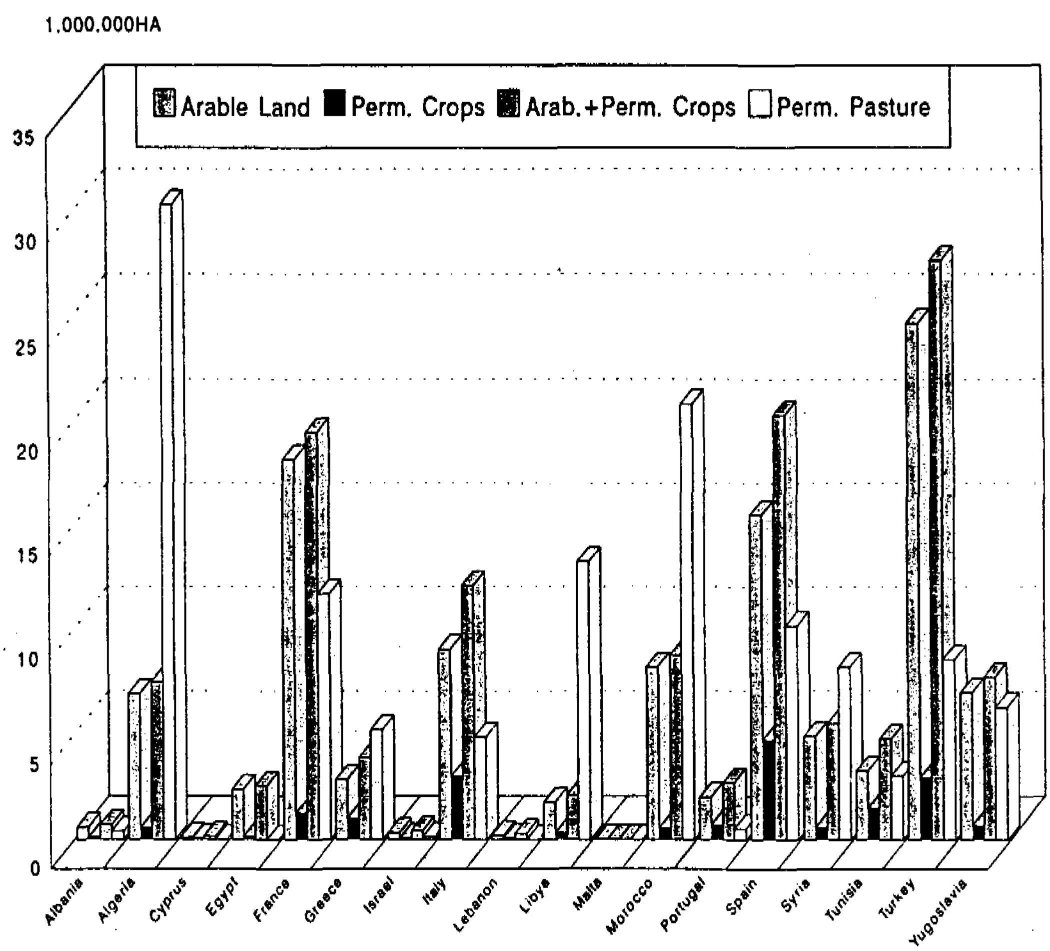


Fig.15 Land Distribution In Mediterranean Countries

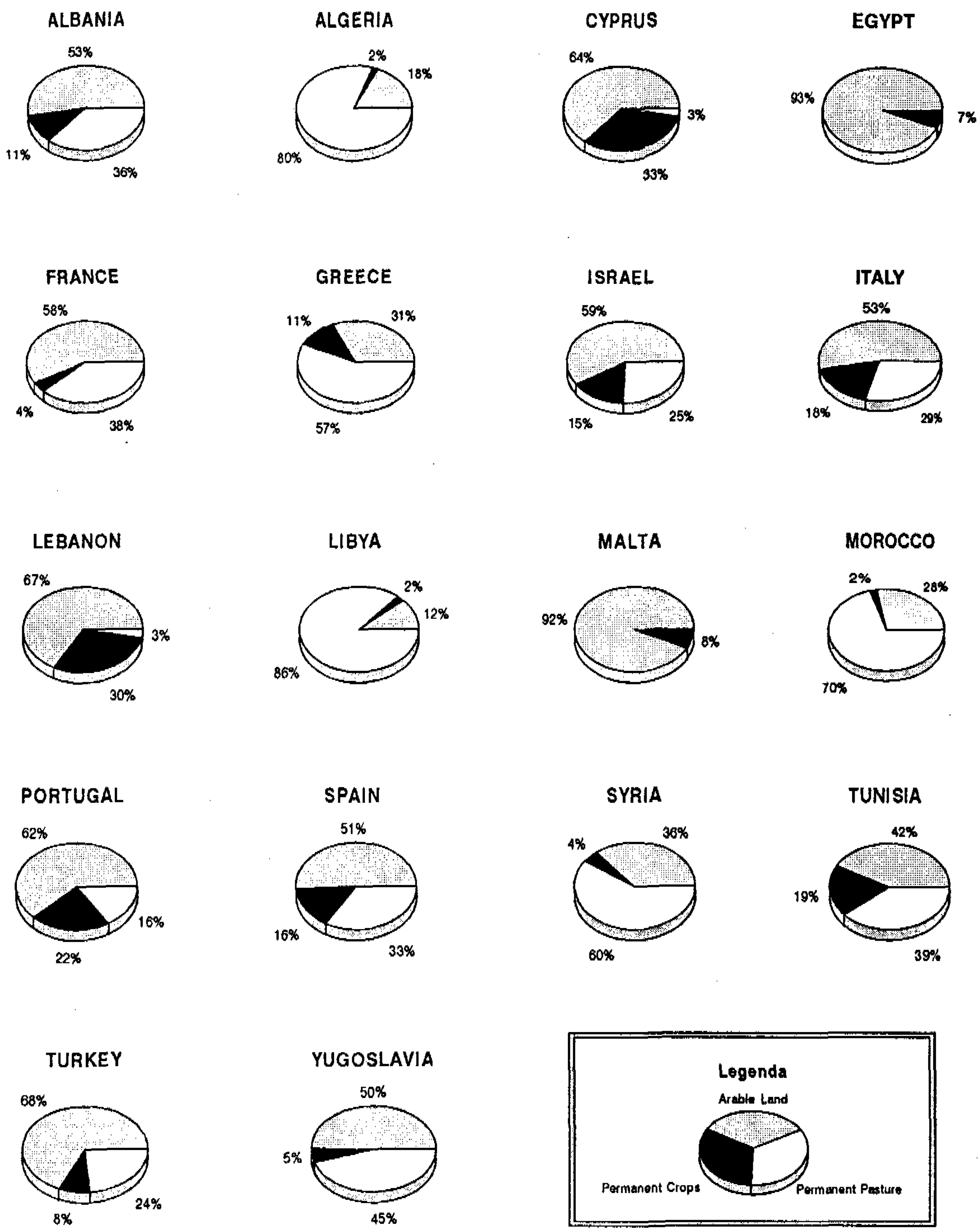


Fig.16 Repartition of Agricultural Surfaces

The figures show that the extent of soils grown with respect to the total area of countries is always below 50% in the Mediterranean countries and even below 10% in few cases (Algeria, Libya, Egypt) where the total land area mostly consists of deserts.

For a total area of about 850 million hectares, 125 millions are arable land and land under permanent crops. Pastures represent several hundred million hectares, suitable for extensive animal breeding with great possibility of a relatively high animal production through a proper and better management.

Arable land refers to land under temporary crops, meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow or lying idle.

The land under permanent crops refers to land cultivated with crops that occupy the soil for long periods and need not to be replanted after each harvest; it includes land under shrubs, fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber.

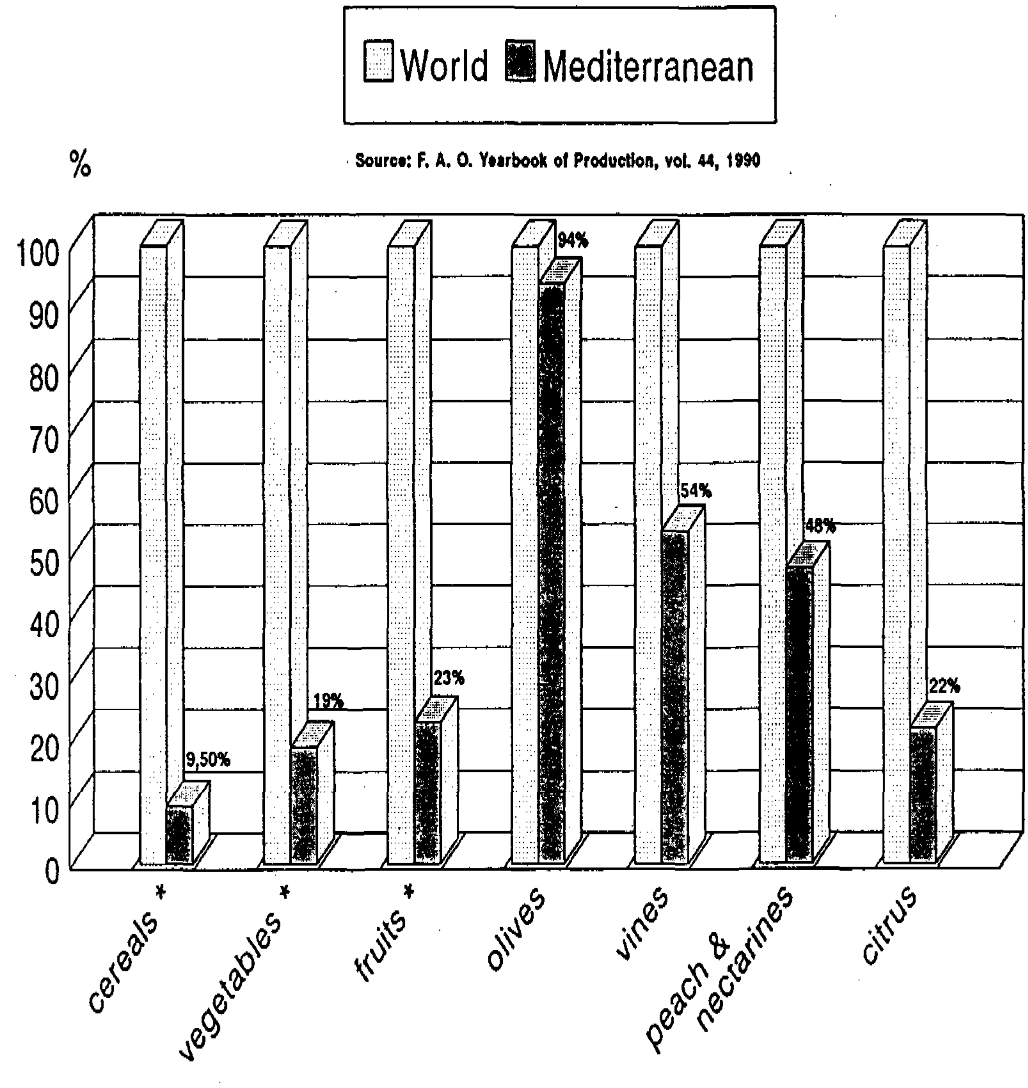
The permanent meadows and pastures refer to land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

There are great differences in the land use between one country and an other in the Mediterranean region Fig. (16), and this also holds true among the Southern, Northern and Eastern Mediterranean regions Table (6).

Table 6. Land use as percentage of cultivated area

Regions	Cultivated area		
	Annual crops %	Permanent crops %	Permanent pastures %
North	57.55	10.90	30.89
South	38.60	6.40	55.00
East	56.50	2.50	22.75
Average	50.88	12.60	36.21

The production of some of the main crops in the Mediterranean region versus the world production is given in Fig (17).



* average of production 1986/89

Fig.17 Main Crops in the Mediterranean

The data evidently declare that, the production of certain Mediterranean crops is very high and amounts to a relatively high portion of the world out put [olives 94%, vines 45%, peach and nectarines 48%, citrus and fruits 24%].

IRRIGATION AND WATER RESOURCES

The irrigated land in the Mediterranean countries, the evolution pattern and the percentage of surface irrigated to the total cultived is given in Figs. (18, 19 & 20) respectively.

Only four countries do irrigate more than one quarter of their cultivated land (Albania, Cyprus, Israel, Lebanon). The case of Egypt, where agriculture is completely irrigated, is a particular one.

In the northern Mediterranean countries (Italy, Greece, Portugal, Spain), the irrigated surface ranges between 10 to 20% of the total cultivated one with the exception of France with only 4%. In the rest of the Mediterranean countries, the irrigated land corresponds to less than 10% of the cultivated one (Algeria, Libya, Malta, Morocco, Syria, Tunisia, Turkey, Yugoslavia).

At present, the irrigated areas account for more than 16 million hectares; in 15 years, these areas has increased by 3 million hectares and the growth rate seems to stabilize around 200,000 hectares per year. This implies the use of a supplementary capacity in the order of 2 billion m^3 of water per year only for agriculture. This will certainly cause some difficulties for the partioning of water resources between agriculture and urbanization. It is likely that the use and recycling of both urban and irrigation wastewater will become necessary in a given number of countries, particularly those of the arid region of the Mediterranean area.

Irrigation is extremely water intensive. It takes about 1000 tons of water to grow one ton of grain and 2000 tons to grow one ton of rice. In the Mediterranean area irrigation represents 72% of the total water withdrawals.

Despite the high periority and massive resources invested in the water resources development, the performance of large public irrigation systems has fallen short of expectation in developing and developed countries of the Mediterranean area. Crop yield and efficency in water use are typically less than originally projected and less than reasonably achieved. In addition, the mismanaged irrigation project schemes lead to the "sterilization" of some of the best and most productive soils. Salinity now seriously

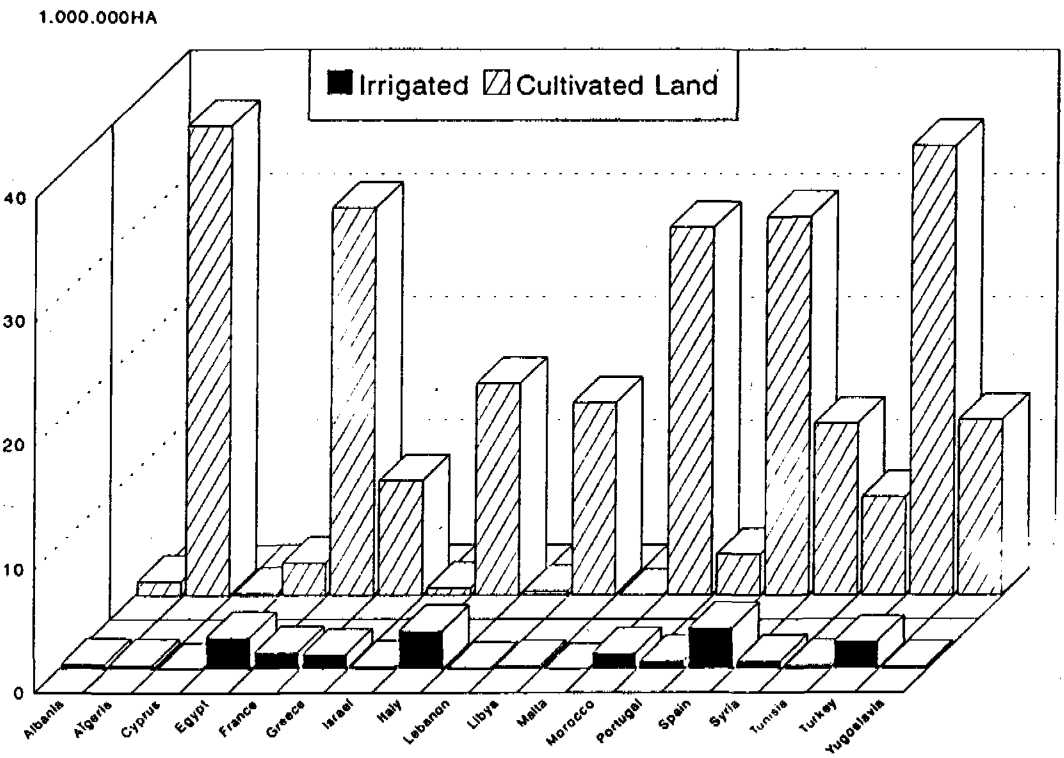


Fig.18 Irrigated Lands in Mediterranean Countries

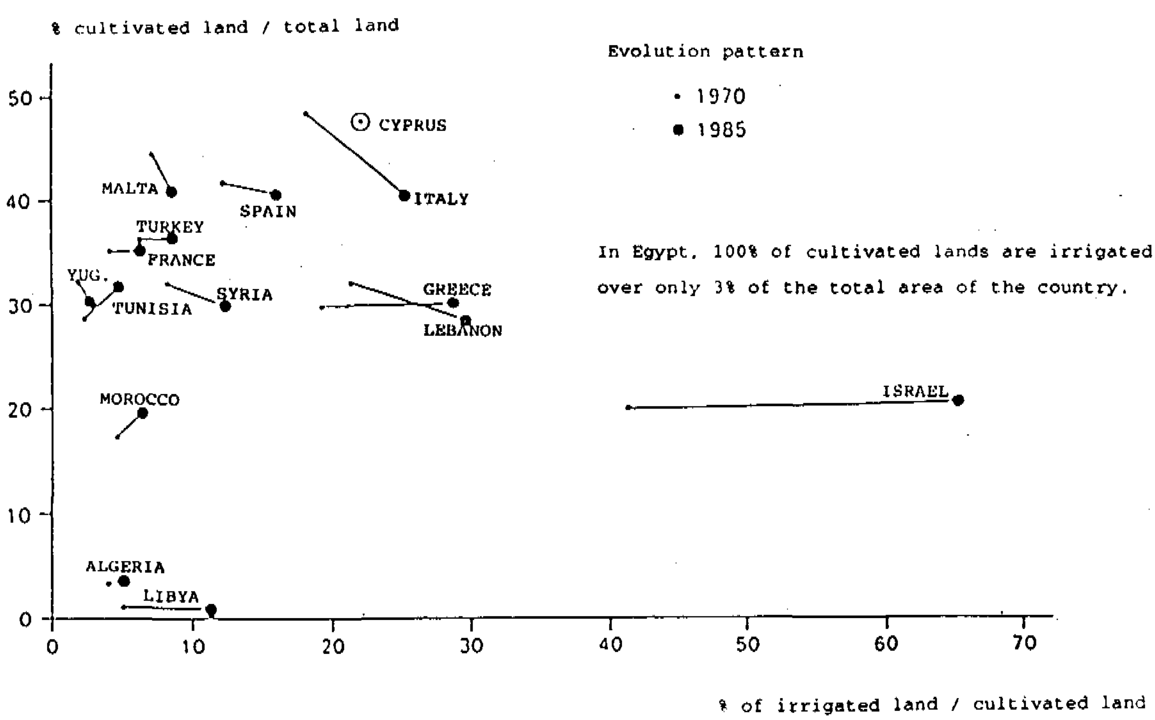


Fig.19 Total Cultivated and Irrigated Areas

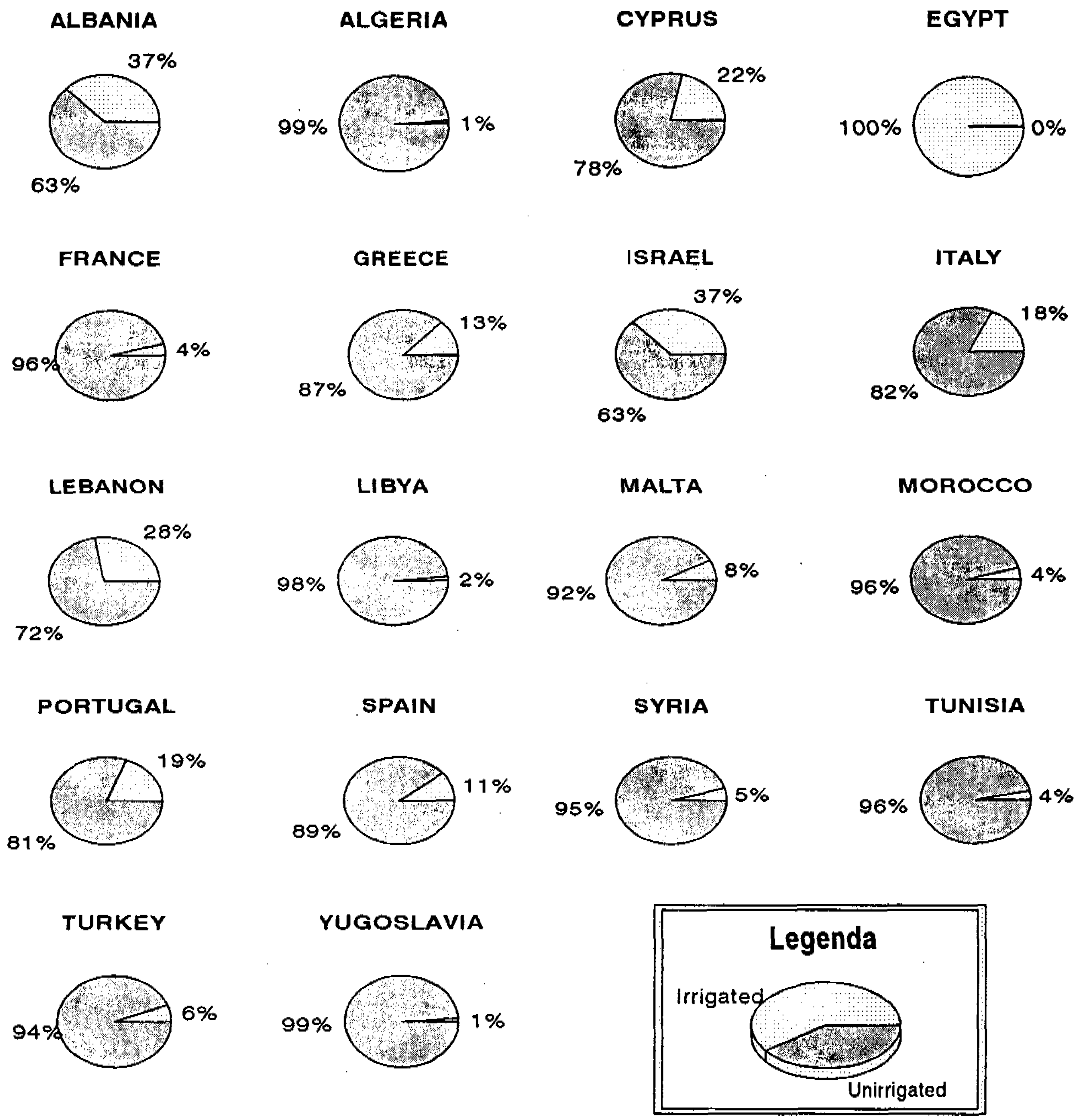


Fig.20 Irrigated Land in the Mediterranean Countries (%)

affects productivity in the majority of the southern Mediterranean countries as well as in the costal zone.

Despite the many social, political, cultural and economical differences between the Mediterranean countries in arid and semi arid environments, many similarities actually exist. The following rank first:

(1) Poor management practices, inefficient water use, and failure to place a high economic value on water result in resource degradation by water logging, soil and water salinization and pollution of acquifers.

(2) Incentives for water conservation in agriculture are few and disincentives are numerous.

(3) Irrigation is developing faster than the water source mobilization. The rapid population growth and the increasing demand for water for other uses are leading to rapid mining of acquifers, water shortages, and to competitions and conflicts.

(4) The outlook for developing new water supplies to meet increasing demands is questionable, given limited financial resources, escalating construction costs, and rising environemental oppositions.

POSSIBLE WATER SAVINGS

Significant water savings are possible in the Mediterranean regions through :

- Better management of water conveyance

The modernization of conveyance works and networks could result in saving 20 to 30%, and in a better irrigation management.

The investments and running costs for these improvements, indeed high, should be compared to the ones resulting from the mobilization of new resources. Concrete cases in South-Eastern France show that they can be far lower.

- Increasing irrigation efficiency

Many opportunities exist for improving irrigation efficiency, which would release water for other sectors, reduce conflicts, and improve agricultural productivity.

In the southern part of the Mediterranean region, for example, improving irrigation efficiency by just 10% would double the amount of water for urban residences and business.

The case of Egypt, with the very critical available water resources to cope with the future development, a 10 percent increase in water efficency (which average less than 40%) would release enough water to increase the irrigated area by nearly 10% or to be used for other purposes, thus reducing the pressure for future development of water supplies.

- Water demand regulation by water price

The general thesis behind water pricing is that if right water prices could be charged on the users, they would then become rational optimizers. If the farmers had to pay an economic price for this resource, great water saving could be achieved through the significant reduction in the excessive water use . In addition, the revenues thus generated through water pricing will enable the irrigation institutions to operate and maintain their irrigation systems more efficiently.

Despite the fact that during the eigthies water pricing was seriously considered as a tool for water saving and a better water use efficency, unfortunately so far in the mojority of the developing Mediterranean countries, it has not been applied.

Water pricing is a very effective way of reaching water management objectives in the region. A pricing policy must be found which assures balanced economic development.

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2

WATER RESOURCES IN SOME SOUTHERN MEDITERRANEAN COUNTRIES

A. HAMDY - C. LACIRIGNOLA

CIHEAM
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WATER RESOURCES IN SOME SOUTHERN MEDITERRANEAN COUNTRIES

A. HAMDY (*) and C. LACIRIGNOLA (*)

ABSTRACT

In the majority of southern Mediterranean countries, the structural imbalance between the constantly increasing demand for water to meet needs and the natural available water resources will be apparent around the year 2000. In this situation, economics in the use of water in the sector of agriculture, industry and built-up areas is vital in the arid and semi-arid countries over the next few decades. Any action aimed at economy in the use of water will have an important impact in preventing the destruction of the basic structures of development.

In such countries, the sustainability of the development system can only be the adoption of a long-term strategy which brings together the physical, economic and social factors.

This strategy must be based on a dynamic evaluation of the underground and surface water resources by analysing their regime and behaviour. This evaluation must take account of the occurrence of exceptional droughts. National water policy should be prepared to guide the harnessing and use of water by comparing short and long term resources, adopting several hypotheses and putting forward several alternatives.

The recycling of used water could lead to a great deal of progress, but is still limited by the lack of research in this field. This approch appears to have a great future and will enable the impact of scarcity to be minimized in times to come.

INTRODUCTION

The southern Mediterranean Countries cover an area typical of the arid and semirarid countries. They are characterized by the scarcity of water resources and by a marked variablity of climate over time and in space.

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The Mediterranean Countries comprise 86% desert and 7% arid land with a rainfall between 400 and 600 mm.

The population growth rate is very high, averaging 3%, and the exodus from the countryside is leading to disorganized creation of areas on the outskrits of towns where living conditions are poor.

Food requirements of these countries are met by a level of imports which generally exceeds 50%; the rate of increase in food requirements is currently exceeding the rate growth in agricultural proportion.

The rapid growth in population and its needs is thus leading to a huge increase in the demand of drinking and irrigation water.

The water supply in these countries is sensitive and fragile, industrial development is leading to severe overexploitation of water resources and the pressure of urbanization, the lack of understanding of the detrimental effects of various forms of development and technology adopted have had complex and degrading effects on environment.

Over the last few decades several major and varied actions have been taken in the field of water resources in the arid and semi-arid Mediterranean countries.

The outcome of these actions and the analysis of what has been achieved will largely contribute towards perfecting the future strategy to be adopted in order to manage, exploit and protect water resources better.

The role of CIHEAM, through training and the exchange of experience between the different countries, will enable to draw a greater profit from this fund of knowledge.

WATER RESOURCES IN EGYPT

The major challange facing Egypt is the absolute need to better develop and manage very limited natural sources: water, land and energy to meet the needs of a population growing at a rate of 2,5%.

The population in Egypt was 36 millions in 1960 and 56 millions in the 1990 and it is expected to go up to 70 millions by the year 2000.

Table 1 summarizes the available and expected future water resources for Egypt for the years 1990, 2000. Table 2 gives the present and future water demands. A schematic representation is also given in Figs (1 & 2).

Table 1. Egypt Water Resources

Source	Quantity in billions m3/year	
	Present 1990	Year 2000
River Nile Water	55.5	* 57.5
Groundwater (Nile Valley & Delta)	2.6	4.9
Agricultrure Dreinage water	4.7	7.0
Treated Municipial Sewage water	0.2	1.1
Saving Flow water Management Programs	-	1.0
Deep Groundwater (deserts)	0.5	2.5
TOTAL	63.5	74

* First stage of Jonglei Completed

Source: Abu-Zeid and Rady (1991)

Table 2. Egypt Water Demands

USE	Quantity in billions m^3./year	
	1990	Year 2000
Irrigation	47.7	59.9
Municipial uses	3.1	3.1
Industrial	4.6	6.1
Navigation & regulation	1.8	0.3
TOTAL	59.2	69.4

1. Includes the irrigation requirements for an additional 1.6 million acres to be reclaimed by the year 2000.

2. Additional requirements for the year 2000 will be secured through reducing system losses from a present value of 50% to 20%.

Source: Abu-Zeid and Rady (1991)

As shown by table 2, the total annual water use in Egypt was estimated at 59.2 billion m^3, of which agricultural use accounted for 84%. This amount does not include an annual estimated loss of 2 billion m^3 due to evaporation from the irrigation system. Annual evapotranspiration losses are estimated at 34.8 billion m^3.

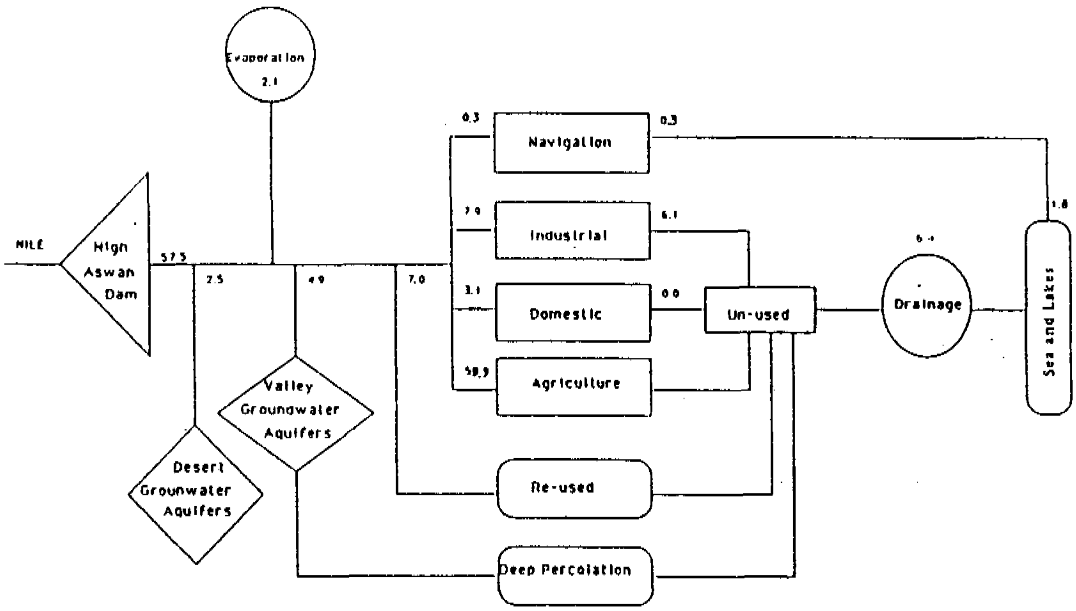

Fig.1 Water Availability and Use in Egypt, 1990

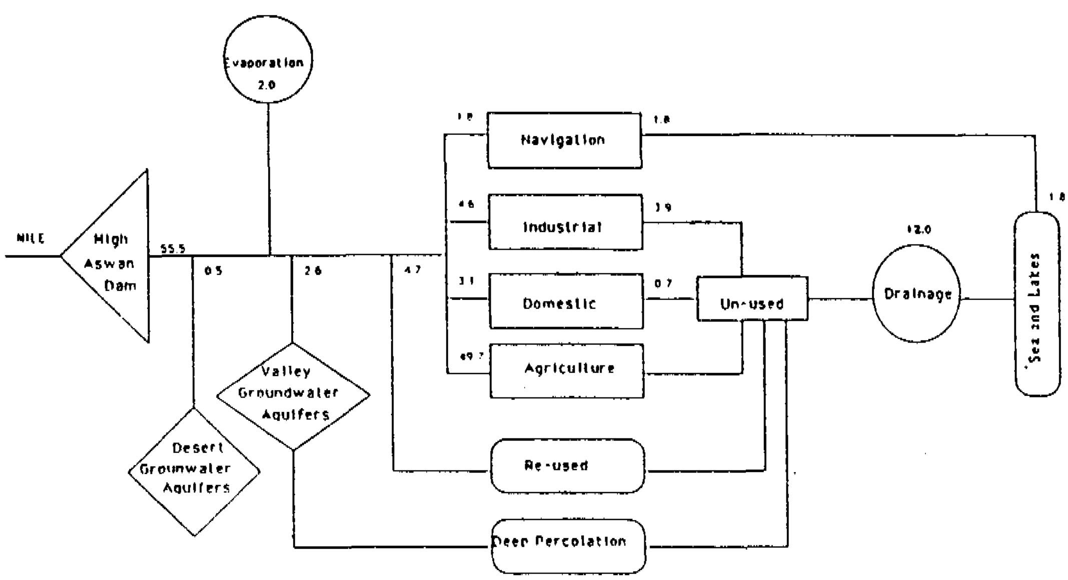

Fig.2 Water Availability and Use in Egypt, 2000

Table 3. Per capita Quota for Water Resources.

Year	Population (millions)	Total renewable resource	Total per capita quota per year	Uses other than agriculture	Water available for agricolture	Per capita quota for agriculture per year
		10^9 m^3	10^3 m^3	10^9 m^3	109 m^3	103 m^3
1990	55	56.9	1035	6.2	50.7	922
2000	70	56.9	813	10.2	46.7	667
2010	84	58.9	701	12.3	46.6	555
2020	100	58.9	589	14.6	44.3	443
2025	110	58.9	536	21.9	37.0	337

Source: Abu - Zeid and Rady (1991).

Considering the increase in demand, the per capita quota of fresh water has been continuously decreasing (Table 3).

In the agricultural sector, the per capita quota is decreasing severely from 922 m^3 in 1990 to 337 m^3 in 2025. This also holds true for the total per capita quota per year which is estimated to be around 536 m^3 in 2025 which represents 65% of that in the year 1990.

Industrial, municipal and navigational use accounted for 8%, 5% and 3% repectively. Current estimates indicate that the total percentage of water use by agricultural and municipal sectors will remain almost similar to 1990, but the share of industry will increase by 50%, and navigation will decline very substantially (Table 3).

Strategies and plans for water reuse

By the year 2000, the agricultural development will require an additional 10.2 billion m^3 of water with respect to that estimated for the year 1990.

Development beyond 2000 will require new resources, which should be met through intensifying the reuse of water and using non-conventional water resources, as well as providing efficient family planning measures to reduce the population growth rate at 1.8 instead of 2.5 percent.

The main plans for using marginal quality water in order to alleviate water shortage problems are: (a) reuse of up to 7 billion m^3 of agricultural drainage water; (b) reuse of about 4.4 billion m^3 from ground water in the Delta and Nile Valley; and (c) reuse of about 1 billion m^3 of treated sewage water.

Reuse of agricultural drainage water

The total amount of drainage water discharged annually varies from 14 billion m^3 in 1984 to 12 billion m^3 in 1989 (Table 4).

Table 4. Nile Water Flow Downstream HAD and Drainage Water Flowing to the Sea

Year	Nile water D. S. HAD billion m^3	Drainage water Quantity (billion m3)	Drainage water Salinity ds/m
1984 - 85	56.40	14.30	3.71
1985 - 86	55.52	14.07	3.72
1986 - 87	55.19	13.59	3.59
1987 - 88	52.86	12.27	4.12
1988 - 89	53.24	12.03	4.26

Source: Abu - Zeid and Rady (1991).

The salinity of this water ranges between 1000 and 5000 ppm, about 70% of this water has salinity of less that 3000 ppm.

The amount of drainage water presently used in irrigation is 4.7 billion m3 annually, which is expected to be increased gradually and reach 7.0 billion m3 by the year 2000. It should be noted that the potential saving from improved water management and increasing water reuse are not naturally exclusive. There is a real danger that salinity could increase steadily over the years.

Reuse of treated waste water

To fullfill the shortage gap in the available fresh water sources, the reuse of treated wasted water is a new source of additional irrigation water. The contribution of this source for the agricultural development in the year 2000 is estimated to be 1.1 billion m^3 which is five times greater than that used in the year 1990.

The potentiality of using this water source in irrigation is relatively high as it is estimated that the total amount of waste water that would be available from greater Cairo, will increase from 0.9 billion m^3 in 1990 to 1,7 billion m^3 in 2000 and 1.93 billion m^3 annually by 2010.

Future water availability for Egypt

There are two major risks and uncertainties in term of future water availability for Egypt that need adequate attention. These are the reliability of the flow regime of the Nile on the basis of which the High Dam was designed, and the International character of the Nile. There is no guarantee that the River regime in the future would flow similar past patterns. In addition, the issue of potential climatic change due to global warming and what its impacts could be on the Egyptian agriculture and the Nile are basically unknown factors at present.

For agricultural uses, and up to the year 2000, the new sources of water for Egypt are likely to be reuse of treated wastewater and drainage water. Both these resources have health and environmental implications, and hence, a functional monitoring system is absolutely essential if these sources are to be extensively and properly utilized.

ALGERIA WATER RESOURCES

Algeria, is a semi arid country; rainfall varies from 2000 mm/year on the high lying areas along the sea to 100 mm/year north of Sahara; great differences do exist between East and West. Precipitation shows a quite great variation over time and an uneven distribution in space in the North.

Water resources in Algeria are limited in quantities (Table 5). Their fluctation over time and their uneven distribution over the country necessitates the set up of a strict planning and a proper water policy to run such limited resource in an optimal way.

As shown by Table 5, the surface water contributes to nearly 65% of the total available water and the rest (35%) is exploited from the underground water. The total estimated mobilized water represents nearly 42% of the total available water; nearly 2/3 of it (71%) is surface water and 29% as underground water.

Table 5. Total water resource (billions m^3)

Water source	Evaluated	Mobilized (estimated)	Ratio of Mobilization
Surface water	12.40	5.7	50%
Underground water North of Algeria	1.80	1.62	90%
Underground water South of Algeria	5.00	0.7	14%
TOTAL	19.20	8.02	41.77%

Source: Hadji (1991).

ACTUAL MOBILIZED WATER AND ITS USE

Over a potential of 12.4 billion m^3 the volume which is mobilized at present is only 4.38 billions. The use of the present mobilized water is illustrated in Table 6.

Table 6. Mobilized water use.

Source	Mobilized	Potable water	Irrigation	Energy	Total
Dams & diversions works	1.80	0.42	0.70	0.20	1.32
Northern underground water	1.60	0.81	0.79	-	1.60
Southern underground water	0.70	0.25	0.45	-	0.70
Springs and streams	0.28	0.12	0.16	-	0.28
TOTAL	4.38	1.60 (41%)	2.10 (54%)	0.20 (5%)	3.90 (100%)

Source: Hadji (1991).

PERSPECTIVES OF MOBILIZATION OF WATER RESOURCES

The water resources that could be mobilized are outlined as follows :

- 1.8 billion m^3 (underground water-North)
- 2 to 4.9 billion m^3 (underground water-South)
- 5.7 billion m^3 (surface water)

This gives a total of 9.6 to 12.4 billion m^3 showing an increase with a minimum of 20% and a maximum of 55% of the estimated mobilized water resources (Table 5).

In addition, such mobilized water could be increased through the artificial replinishment of groundwater storage by either the surface waters not mobilized by dams or by the re-use of recycled wastewater or by both.

WATER DEMAND

A - Drinking and industrial water demand

The urgent supply of drinking water for the whole population was one of the priority objectives of Algeria in the course of its different development plans. This option is also sanctioned by the law on water. In 1990, the rate of connection to a public network is 86% in towns and 71% in rural environment. The rate is 85% for built-up areas, either rural or urban.

The forecasts of the drinking water and industrial demand made on the basis of the trends observed show that water requirements would be equal to:

- 2.9 billion m^3 by the year 2010 for a population of 42.7 million inhabitants, 28 millions of which in urban areas.

- 4.1 billion m^3 by the year 2025 for a total population of 57 million inhabitants, 70% of which are concentrated in urban areas. This demand represents 55% of the resources which can be mobilized in the North of the country where almost the whole population is concentrated.

B- Water demand for irrigation

Major conflicts are always present between the two great consumers of the resource: domestic use on one hand, and the development of irrigation on the other.

If one considers that drinking water requirements are a priority because of their important impacts on the health of population, the volumes which can be used for irrigation will be the ones made available after satisfying the drinking water requirements.

Water resources available for irrigation by the year 2010 are given in Table 7 in billion m^3.

Table 7. Water resources available for irrigation (year 2010).

Regions	Available	Drinking water needs		Volume available for irrigation	
		2010	2025	2010	2025
Total north	7.418	2.568	3.674	4.852	3.628
Total south	5.014	0.301	0.441	4.71	4.573
Total Algeria	12.432	2.869	4.115	9.565	8.201

Source: Hadji (1991).

For the north of the country, the volume available for irrigation, which is about five billions m^3, can be increased by the amounts of recycled water from the built-up areas which are estimated on the basis of recovering 50% of the volumes consumed.

This is the global available volume and the comparison "requirements-resources" per region shows unbalances which cannot always be compensated by transfers.

In the south of the country, water resource is not a limitig factor at least in terms of quantity.

FUTURE WATER AVAILABILITY IN ALGERIA

The availability of water per inhabitant will be increasingly reduced since it will pass from 540 m^3/year in 1987 to about 200 m^3/year/capita in 2025.

This increasing reduction of water availability per capita will not enable to face the socio-economic requirements of the country thus requiring the use of alternative resources such as brakhish and treated waste waters. A proper water management policy should be adopted: to reduce losses in the drinking water networks, to control wastes through appropriate tariffing, to recycle water in all the industrial units and especially the high water consumption industries, and to improve the irrigation efficiency and reduce the unit demand of irrigation water.

A great risk which Algeria could face in the future is a further reduction in its water resources. This could be the consequence, if some of its water resources will be made un-usable because of pollution by municipial or industrial waste waters or by the phytosanitary products and other fertilizers used in agriculture. Pollution then risks being the major cause of water scarcity in future, thus making the conservation of water resources a must.

WATER RESOURCES IN MOROCCO

Although an essentially semi-arid country, Morocco includes a rather large humid zone in the northern coastal Atlantic plains and especially the Atlas mountain massifs which constitue a real water reservoir draining in all directions.

Then, contrary to arid countries, Morocco has a notable potential of underground and surface waters. But, both are unevenly distributed over time and in space.

Average annual precipitations vary from 1000 mm to less than 100 mm:

- 1000 mm at some points of Atlas and Rif

- 300 to 600 mm on the northern Atlantic coastal plains

- less than 100 East of Atlas

Precipitations distributed over 5 to 6 months in wet years occur three to four times per year in dry periods.

Flow regime and the precipitation regime are characterized by great seasonal and annual variations. Estimated to 23 billion m^3/year as an average, surface flows become as low as 10 billion m^3 per year in a moderately dry year, and less than 5 billion m^3 in very dry years. Renewable underground water resources are estimated to be equal to 7 billion m^3/year.

The hydrological balance of Morocco is given by Table 8.

Table 8. Hydrological balance of Morocco (billions m^3)

Surface (km^2)	Rainfall / year	R: E. T. / year	Discharges / year
760900	155	130	23

Source: S. Mohamed (1991)

MOBILIZED WATER RESOURCES (1985)

Over a potential of surface waters of 23 billion m^3/year as an average, 6.3 billion m^3/year are regulated by huge hydraulic works with a storage capacity of 10 billion m^3 (Table 9).

Table 9. Average flow and regulated volume, millions m^3 (1985).

Average flow	Regulated volume %	Regulation rate %
23.0	6.3	27.0

Surface waters - volumes regulated by th3 large dams - subdivision per basin (Nouredin B., 1985)

The mobilization of surface waters is essentialy controlled by the state, whereas the mobilization of groudwaters is mainly a private initiative. As a rough estimate, the groundwater amounts to 3 billion m^3 withdrawn each year, of which 2.5 billion m^3 for irrigation and 0.5 billion m^3 for the supply of water for municipal and industrial use.

A recent study to evaluate the potential surface water by using simulation models (Sibhi, 1991), gave an estimation of surface water supply from 72 dams equal to 12 billion m^3/year.

In this study, the potential of underground water resources estimated to be equal to 3 billion of m^3/year covers the discharge usable in most of the extended ground water of Morocco, giving a potential total water resources of 15 billion m^3/year (Table 10).

Table 10. Water potential resources in Morocco.

Numbers of dams	Volume supplied billion m^3/year	Ground water discharge billion m^3/year	Total
72.0	11.73	3.23	15.0

From this study it was indicated that the potential underground and surface waters that can be mobilized at medium term are 15 billion m^3/year. Those can cover the water requirements for agricultural uses at the end of management, and for drinking and industrial uses by the year 2000 which are estimated to be equal to 12.5 billion m^3/year.

The potential of water resources that can be mobilized at medium term represents about 65% of the effective rainfall to be equal to 23 billion of m^3/year in the hydrological cycle.

WATER RESOURCES USE

Municipal and industrial sector:

The volumes of water withdrawn by this sector in the course of 1984 are estimated to 0.7 billion m^3/year of which: 0.5 billion m^3 for urban areas, 0.1 billion for rural areas and 0.1 billion for industry not connected to municipal network (Nouredin, 1985). Water supply of population is traditionally taken from underground waters. But, the latter being equally used for irrigation, they are becoming increasingly insufficient to supply the required discharge. Therefore, surface waters requiring high treatment and conveyance cost are increasingly demanded.

The progressive changing of the situation in favour of surface waters calls for the set up of urgent measures to preserve the water quality of rivers which still receive untreated municipal and industrial waters.

The irrigation sector:

Agricultural development through irrigation and flood spreading concerns (year 1985) about one million hectares subdivided as follows:

- 550,000 hectares dominated by large dams;
- 250,000 hectares irrigated by small dams;
- 200,000 hectares receiving flood spreading.

Water demand for irrigation in modern schemes varies depending on climatic conditions, the cropping pattern and the intensification coefficient. Since land exploitation has reached full regime only on a small number of schemes, it is difficult under these conditions to estabilish the real level of unit water demand per scheme.

Even when land exploitation has reached the expected level, the evaluation of real demand still remains problematic, in the absence of a strict control of conveyance network efficiency and of natural flows, on one hand, and because of the difficulties faced for the calibration of theorical models establishing the relationships between yield and water use on the other hand.

However, rough estimates indicate that nearly 90% of the available total water resources, 9.3 billion m^3/year, are used for irrigation of which 2.5 billion m^3, nearly 27%, is supplied from the groundwater and the rest, nearly 7 billion m^3 (73%), is supplied from dams.

Water requirements:

Water requirements of the different sectors by the year 2000 are summarized in Table 11.

Table 11. Agricultural, drinking, and industrial water requirements by the year 2000.

Surface irrigated x 1000 ha by large dams	Surface irrigated x 1000 ha by small dams	Agricultural needs billion m^3 / year	Domestic and industrial needs billion m^3 / year
867	403	9.7	2.6

Source: Sibhi, 1991.

Comparing the requirements of the various sectors in the year 2000 with the year 1985, it is clear, that, while the water needs for the agricultural sector will be increased only by 10%, the requirements in the domestic and industrial water use is nearly six times greater than in the year 1985.

The demand of municipal and industrial water, for long considered a non significant item of the budget, has increasingly become competitive with the demand of water for irrigation.

As underground waters got exhausted, the competition between municipal water demand and irrigation for such waters was substituted by an inverse competition between irrigation and municipial waters for surface waters.

This will necessitate giving much weight to the water quality aspects to avoid future health hazards and sanitation problems.

PERSPECTIVE REUSE OF WASTE WATER IN AGRICULTURE

The amount of waste water released by all towns is estimated to be equal to 370 million m^3 in 1996 and to more than one billion m^3 in the year 2025 (Bebchokroum and Bouchama, 1992).

In Morocco, and all the Southern countries of the Mediterranean area, the reuse of reclaimed waste water is going to be an increasingly important source for irrigation and agricultural development.

The problems aside from massive population growth rate, countinuing urbanization and the rapid development of the urban and rural water domestic supplies, water supply shortage and waste water disposal regulations by the aim of protecting environment and public health, 'all are pushing towards a realistic reuse of the enormous quantities of waste water which have not been effectively used so far.

WATER RESOURCES IN TUNISIA

The major features of Tunisian climate result in insufficient and uneven rainfall which makes irrigation a must.

RAINFALL

The general feature of the climate and the presence of the Ridge , which is the continuation of the Atlas relief of Algeria, lead to schematically divide the country into three regions from north to south:

- a sub-humid and humid region, to the far north, receiving an average annual rainfall exceeding 500 mm, with abundant rainy areas in Khroumirie and Mogods mountains (Tabarka, Ain-Draham and Sejnane of more than 1000 mm per year);

- an arid region receiving only 200 to 300 mm with great local differences in the centre of the country, and limited to the south by the line Sfax-Gafsa and including the northern part of Jerba island;

- the rest of the country has a sub-desertic and desertic climate where rainfall varies from 0 to 100 -150 mm.

These data can be expressed differently. Out of 16 million hectares of the country (of which 4 million hectares of arable land):

- 50% receive less than 200 mm of rainfall/year

- 40% receive less than 200 and 600, and

- 10% only receive more than 600 mm/year.

In general, Tunisia suffers from a great rainfall deficit. In Tunisia, climatic irregularities make it almost impossible to speak of average rainfall; extreme values and their frequency are at least as important to be known as the so-called average. So, a relatively dry year can be followed by an even drier year or a very rainy year with torrential precipitation which causes erosion, or sometimes catastrophic floods. The annual rainfall can double or even more than that, north of the Ridge, and it can become 5 times greater in the south.

MOBILIZED WATER RESOURCES

Mobilization of the water potential in 1972 and 1980 is summarized in Table 12.

Table 12. Mobilization of water resources.

Nature	1972		1980	
	Volume (Mm^3)	%	Volume (Mm^3)	%
Surface	240.2	45.8	370	34.6
Underground	284.5	54.2	700	65.4
Total	524.7	100	1070	100

Source: 1972: Postma, 1973 - 1980: Mansour,1980

The total water that can be mobilized is equal to 2.7 billion m^3. In 1980, the mobilized water amounted to nearly 40% of the total, which is nearly the double of that in 1972. The nature of mobilized water has undergone considerable changes, in 1980 the groundwater accounted for nearly 2/3 of the mobilized water.

POTENTIAL OF WATER MOBILIZATION

Tunisia, through its four water master plans - North, far-North, Centre and South - is intending to mobilize all its water resources by the end of the century.

The evolution of resources during the six years (1980-1985) are given in Table 13.

Table 13. Evolution of mobilization of water resources (millions m^3)

Resource	1980			1985		
	To mobilize	Mobilized	%	To mobilize	Mobilized	%
Surface	2292	1150	50	2292	1392	61
Free ground water	486	395	81	586	563	96
Deep ground water	1031	530	51	1139	669	59

For surface waters, whose potential has not changed, the works operating between 1980 and 1985 will enable to mobilize almost additional 250 Mm^3, that is 11% of the resource. As for surface and deep ground water, the mobilization degree has respectively increased by 15 and 9%. In total, mobilization of waters in 1985 reached 65% of the resource which will accelerate the extension of irrigable land (Table 14).

Table 14. Global evolution of irrigable lands. (ha). (1965 - 1985)

Regions	Irrigable lands (ha)		
	1965	1979	1985
North	54 200	120 030	139 480
Centre & South	24 600	91 660	104 050
TOTAL	78 800	211 690	243 530

During the period (1979-1985), the irrigated surface had been increased by nearly 15% giving a total irrigated land nearly 3 times greater with respect to the year 1965.

Table 15. Total water resources and its use billion m^3

Water sources			Water use		
Total water available	Total mobilized water	Total withdrawal water	Drinking water	Industry	Irrigation
5.017	2.624	2.300	0.2	ε	2.1

Source: Margat, J. (1991)

As shown by Table 15, the total water withdrawal represents 52.3 of the total water available and accounts for nearly 90% of the total mobilized water. Regarding the water use, it is quite clear that the majority of the withdrawn water (91%) is allocated to the irrigation sector and only 9% is for the domestic use. The rising in population at a relatively high growth rate (3%) and the continuing urbanization will necessitate that greater portion from the withdrawn water must be directed to satisfy the rise in the drinking water demands. In the year 2025, it is expected that nearly 30% of the withdrawn water will be allocated to satisfy the perspective demands of drinking water.

In Tunisia, with its limited water resources, to satisfy the development in the irrigated area according to the country plan, on one hand, and the required water supply for domestic use on the other one, the reuse of treated waste waters in agricultural becomes a must.

TREATED WASTE WATER USE PERSPECTIVES

Irrigation for agriculture development will face increasing problems of water quantity and quality. These problems are even more severe if one considers that all conventional water resources are limited for future requirements.

In the last ten years, agricultural exploitation of treated waste waters has been an important element in national plans.

The volume of waste waters was equal to 81.5 million m^3 in 1989, and is expected to reach 147 million m^3 by increasing the number of running treatement stations from 24 to 65 (Bahri, 1991). Advantages that could result from the use of this new source in irrigation is not only the saving of the valuable fresh water sources but also minimizing pollution of water-courses and the atmosphere.

PERSPECTIVE OF WATER RESOURCES IN THE SOUTHERN MEDITERRANEAN COUNTRIES

From the previous analysis of water resources in the southern Mediterranean countries, it follows that these countries are classified as very poor to poor with respect to their water availability/capita whereas, concerning the water withdrawals/capita, they are not of the same category (Table 16).

Table 16. Classification of Southern Mediterranean according to their water availability and water demand m^3 per capita (population 1985)

Water availability (resources) / Water demand (withdrawals)		Countries					
		Scarce < 500	Very poor 500 to 1000	Poor 1000 to 2000	Medium 2000 to 10000	Abundant 10000 to 100000	Over abundant > 100000
Very Low:	< 100						
Low:	100 to 200	Libya	Algeria				
Moderate:	200 to 500		Tunisia				
High:	500 to 1000			Morocco			
Very High:	> 1000			Egypt			

Source: Margat, J. (1991)

The limited water resources in these countries on one hand and the population growth with a relatively high rate on the other one will be the major constraint for further agricultural and socio-economic development. Water demands are fast approching the limit of resources and the majority of these countries could enter a period of chronic shortage during the nineties.

In the approaching year 2000 and beyond, these countries will be facing several similar problems, at the top of which, we will find:

Table 17. Renewable natural water resources per country, total and per capita for year 1985 and the year 2020.

Coutries	Global resources per country		Resources per capita (yearly average flow)	
	Total average annual flow billion m³ / year	significant inflow from neighbouring coutries included in the total billion m³ / year	1985 m³ / year	2020 m³ / year
Algeria	19.1	0.2	874	405
Egypt	58.3 *	56.5 *	1 238	680
Libya	0.7	0.0	194	70
Morocco (with Occ. Sahara)	30.0	0.0	1 369	780
Tunisia	4.35	0.6	609	356

* Potential resource including a part of the attributed Nile flow.

Source: Margat, J. *(1991)*

- Declining water resources per inhabitant both in terms of water availability and water withdrawals. It is expected that the available water/capita will be reduced by nearly 50% of the present one (Table 17).

- Exploitation of water at a relatively high rate with the risk of water quality deterioration.

- Excessive reduction in water withdrawals per capita, which will impose its significant effect on the water sectorial use, creating notable competition and conflict among users in the various sectors and of the irrigation and domestic sector in particular. Priorities will be given to satisfy the drinking water demands on the expenses of the available water allocated for the irrigation sector with the consequence of less irrigated surface and more land degradation.

- Progressive degradation in the quality of available water resources because of increasing waste load discharged into water bodies and atmosphere.

This clearly demonstrates the urgent need for setting a national water policy for each country encompassing all water resources and implementation of measures so that available water supplies will match future needs over time. National water policy will differ from one country to another according to the prevealing existing conditions in each of them and the foreseable future demands.

NATIONAL WATER POLICY

The management and use of fresh water has become a vital task for sustainable development in the southern developing countries of the Mediterranean area.

This task requieres a coherent set of water policies at national levels. It is time for an update of the national water policy to respond and to give reasonable resolutions to the main problem on how to balance demand and supply of water under those difficult conditions of limited water resources and continue increase in the water demand.

FRAMEWORK OF THE POLICY

The proposed policy framework should be based on the interrelationships of the following three systems:

- The natural water resources system (the supply side), consisting of the hydrologic cycle, including its surface water and groundwater components, and the close interactions of water with air, land and biota in the context of river basins, watersheds and coastal zones.

- The human activity system (the demand side), which affects and is affected by the natural water resources system in many ways, including floods, droughts and pollution.

- The water resources management system (the harmonizing of supply and demand), which governs both the demands (e.g. for water supplies and services) and adverse impacts (e.g. pollution) imposed by the human activity system on the water resources system, and the adverse impacts (e.g. extreme events - floods, droughts) imposed by the water resources system on human activities.

Based on these three dimensions, the important elements for policy can be developed on comprehensive and consistent bases.

The accelerated growth in demand, the sustained pressure on resources and the ease by which water can currently be harnessed by technical means necessitate the followings:

- Carrying out careful evaluation of the water resources assessment activities with a view to clarifying functions and coordinating activities;

- Monitoring of the different flows by establishing a measuring and metering system;

- Strenghtening and expansion of data collection networks for water resources assessment to provide a solid contribution to the monitoring effort;

- The administration of water by legislative tools taking into account the specific features for them to be applicable;

- Define broad national objectives that can be addressed, either in whole or in part, by management of the nation's water resources;

- Identify present and most likely broad future water needs to achieve the national objectives;

- Develop a comprehensive, flexible master program of regulations and projects to meet future long-range and near-term water needs;

- Define institutional responsibility for implementing the master program, modifying existing ministry responsibilities where appropriate and establishing new institutions where required. (Implementing a master water program includes acquiring basic data, establishing priority of needs, establishing criteria, developing regulations, planning, design, and construction of projects, operation, on-going evaluation of the master program, and modification of the program over time as predictions of future needs are revised);

- Establish a program for educating and training engineers, scientists and technicians in water and related resources so that the country can be fully responsible for its master water program;

- Establish a research capability coordinated with planning, design, construction and management aspects of the master water program to define and investigate research problems and solutions, including adaption of existing technologies from elsewhere to the country needs and conditions and developing new technology appropriate to the country.

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3

UNCONVENTIONAL WATER RESOURCE USE AND MANAGEMENT

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ITALY

UNCONVENTIONAL WATER RESOURCE USE AND MANAGEMENT

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ABSTRACT

In arid and semi-arid regions, as most of the Mediterranean countries, the use of unconventional water resources has been seen to play an ever more important role in satisfying the increasing water requirements. It is quite difficult to make a classification of the unconventional water resources. Water quality is the most important factor in managing unconventional water resources; quality is a complex factor since there are many water quality parameters which vary with continuity. Two major categories of unconventional water resources could be identified, the first including waters with high organic matter and microorganism content (such as municipal wastewater) and the second including waters with high saline concentration (such as sea and brackish water, some industrial and agricultural wastewaters, etc.). In many Mediterranean countries municipal wastewater reuse has been practised for a long time and actually represents the most relevant use of unconventional resources. In this paper a network is presented which highlights the main indirect effects of the agricultural use of municipal wastewater. The results of research and the analysis of case-studies lead us to the conclusion that the development of irrigation with wastewaters may have a certain importance in the Mediterranean countries. There are good reasons for updating specific and realistic regulations, which would be based on the recent WHO guidelines.

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RESUME

Dans les régions arides et demi-arides comme la plupart des pays de la Méditerranée, l'utilisation de ressources hydriques non conventionnelles résulte très important pour la satisfaction des croissante besoins hydriques. Il est très difficile faire une classification des ressources hydriques non conventionnelles. La qualité de l'eau est le plus important facteur dans la gestion des ressources hydriques non conventionnelle; la qualité est un facteur complexe parce que les paramétres de qualité de l'eau sont nombreux et ils varient avec continuité. On pourrait saisir deux grandes catégories de ressources hydriques non conventionnelles, la première incluant d'eaux avec d'élevées substances organiques et contenu de microorganisme (comme les eaux usées municipales) et la seconde incluant d'eaux avec une élevée concentration saline (comme l'eau de mer et saumatre, les eaux usées industrielles et agricoles, etc.). Dans beaucoup de pays méditerranéens le réutilisation des eaux usées municipales a été pratiqué pendant beaucoup de temps et maintenant il représente le système d'utilisation plus important des ressources hydriques non conventionnelles. Dans cette travail on presente un graphe qui met en évidence les principaux effets indirects dans l'utilisation en agriculture des eaux usée municipales. Les résultats de la recherche et l'analyse des cas étudiés nous permettent de conclure que le développement de l'irrigation par eaux uséess est d'importance pas négligeable dans les pays méditerranéens. Il y a des valides raisons pour la promulgation d'une normative spécifique et réaliste, en se fondant sur les directives WHO récentes.

1. PRELIMINARY CONSIDERATIONS

Each water resource and each use has specific spatial and temporal distributions of characteristics of water quantity and water quality variables (Yevjevich, 1978).

Man has usually modified the characteristics of natural resources in order to satisfy water demand; water quality has been modified by means of treatment plants, temporal water distribution by means of storage regulation, resource location by means of supply, conveyance and distribution works. Recently attempts have also been made to modify water quantity increasing rainfall by seeding clouds with silver iodide. Water resource management should integrate all these activities in a rational and economical way.

The main uses of water are: civil, industrial, agricultural, hydroelectric, aquatic life, recreation and navigation. Some of these uses are well-known and acknowledged while others, such as recreation or acquatic life conservation, have sometimes been classified under other headings. The removal of salts and waste elements (both with a natural or artificial origin) and the sediment transport in water courses for beach protection could also be considered as water uses.

Conventional water resources generally include surface and ground water. At the moment there is no general consensus on how "unconventional water resources" are to be defined. Generally speaking, resources other than "good quality surface or ground water" are termed "unconventional resources". Examples of such resources are wastewater, brackish water and sea water; other water resources include water which has precipitated from the atmosphere (rain, snow, ice, water vapour and condensation) and is used directly, and the increase in water resources due to the artificial increase in rainfall. These definitions of unconventional water resources include quite different types of water as regards spatial and temporal distributions of quantity and quality.

The main unconventional water resources are waste, brackish and sea waters. These differ from the "surface" and "ground" water resources, as far as quality is concerned. The fact that there are many water quality parameters which vary with continuity should be kept in mind. Moreover, some quality parameters assume different meanings according to the type of resource they are found in; for example, this is the case of the ratio between microbiological indicators and pathogenic microorganisms which is different in surface water versus wastewater. The definition of wastewater is imprecise too. In fact most water courses (especially rivers) and groundwaters receive wastewater discharges which influence quantitative and qualitative characteristics of water in downstream sections. Furthermore, the qualitative characteristics of wastewater are not uniform (depending on use and treatment) and are not specific (they can also be found in surface and groundwater).

2. WATER QUALITY AND UNCONVENTIONAL RESOURCES

2.1 The role of water quality

As previously stated water quality is the main factor in managing unconventional water resources. Here some considerations on water quality regarding unconventional water are reported.

Water quality is the most complex of the various factors (quantity, space, time) affecting water suitability for each use. There are many parameters which characterize water quality. Chemical quality of water depends on the type and entity of dispersed solids (dissolved or suspended); the physical characteristics and the presence of microorganisms can also affect the suitability of the water for each use.

Man can intentionally modify water quality by means of treatment plants; he can also unintentionally affect water quality (generally in an undesirable way) during use. All water quality parameters can be modified by means of suitable treatment each with quite different costs. In managing unconventional resources, treatment costs play a very important role; these costs can range from about 1/100 US dollar per m^3 (e.g. simple sand removal) to 1/10 US dollar per m^3 (e.g. partial removal of organic matter). With more advanced treatments (strong reduction of organic matter, suspended solids, microorganisms, nutrients, etc.) the cost increases; the cost for the desalination of sea water (strictly related to energy cost and plant type and size) are always over 1 US dollar per m^3.

As we can see, in some cases the required modification of water quality can be very expensive (also with respect to supply, conveyance and regulation costs); for this reason the guideline, given in 1958 by the Social Council of the O.N.U., according to which no water of superior quality, unless it is extremely abundant, should be used for a purpose for which a lower quality of water can be tolerated, is widely accepted.

Often, treatment of water before use has been considered apart from treatment after use (before discharge into water bodies). The difference between these kinds of treatment is of no importance if we accept that the only aim of treatment is to protect downstream uses (including in situ uses such as recreation and aquatic life).

Quality of discharges can be controlled not only by treatment but also by modifying water utilization processes. As a matter of fact in many industries and in irrigation, water "consumption" (modifications in quantity), water use and water "pollution" (modification in quality) are conditioned by utilization modalities. A further variable is given by the recycling of water within an industrial factory.

For example in sprinkler irrigation drained or deep percolated waters have a higher saline concentration in comparison with surface irrigation, as a consequence of reduced water volumes due to the higher hydraulic efficiency (water consumption is almost the same). Microirrigation seems to permit a slight increase in saline concentrations and hydraulic efficiency and a decrease in water consumption and total salt contribution.

2.2 Potential uses of unconventional water resources

As we have seen it is difficult to classify unconventional waters. However, we can select two main categories. In the first we can include waters which have a high content of dissolved solids. Sea water, wastewater from some industrial processes, drainage water from agricultural land, some surface and ground waters with a high level of salinity which occurs both naturally or because of discharge, may all be included in this category. The treatments for the removal of dissolved solids are usually extremely expensive; the salts are undesirable elements for almost all kinds of uses (excluding navigation, marine aquatic life and some forms of recreational use). Less remunerative utilizations such as irrigation can use brackish water only without expensive treatments; this occurs when the characteristics of soil and crops, the non-excessive saline concentration and the irrigation and drainage modalities limit the disadvantages linked to salinity (i.e. reduction in productivity) to acceptable levels. Unconventional water resources, particularly brackish water resources, play an important role in periods of drought, when they can supplement conventional waters for irrigation (Barbagallo et al., 1992; Hamdy, 1992).

The partial elimination of dissolved solids from brackish water for civil and industrial purposes may be opportune (by means of reverse osmosis or synthetic resins). The desalination of sea water is beneficial from an economic point of view only when water is an extremely valuable comodity (for example, in small islands or in very arid areas) or when there are plants which can keep the costs low by carrying out the double function of producing desalinated water and power (Micale, 1989).

The second category of unconventional resources should comprise all those waters which contain residues of animal and/or vegetable origin and whose quality is consequently characterized by a high content of organic substance, nutrients (azote, phosphorous, potassium) and microorganisms. Municipal wastewater, zootechnic wastewater and food industries effluents, not to mention some water courses which receive wastewater discharges, may all be included in this category. The substances in these water, with few exceptions (i.e. pathogenic microorganisms), do not pollute cultivated soils; consequently, in many countries of the Mediterranean the use of these waters for irrigation is ideal.

As our time and space is limited we will now pass directly on to the reuse of municipal wastewater which represents a very important resource, offers many agricultural and environmental advantages, and has characteristics which are uniform enough to permit us to make some generalisations.

2.3 Reuse of wastewater for irrigation and subsequent environmental effects

As previously observed, the reuse of wastewater in Mediterranean conditions is the most important and practical of all the possible forms of unconventional resource use. Generally speaking this reuse is most common in the inland areas which are located at a suitable height above sea level and which are near areas to be irrigated. In some cases it is also opportune to reuse the effluent of the rainy season by constructing suitable reservoirs (Shuval et al., 1986; Barbagallo et al., 1990).

There are many factors which interact in a complex way creating a series of processes which make the evaluation of the environmental effects of wastewater reuse extremely difficult (Indelicato et al., 1992).

The main actions related to the use of municipal wastewater concern the absence of a discharge in water bodies, the contribution to the soil of macroelements (nutrients, salts, etc.) microelements (boron, heavy metals, etc.) and water, and the contribution (to crops, soil, groundwater, etc.) of micro- organisms. Each of these actions produces effects of different order (primary, secondary, etc.), as shown in the cause- condition-effect network of fig. 1. The presence and the entity of the effects depend on a single condition or on a combination of conditions.

Some less important or less common effects (indicated in the network by a dotted line) are represented by the contribution to the soil of organic matter and by the diffusion in the atmosphere of volatile and/or gaseous substances.

Figure 1 shows the prevalence of indirect effects caused by irrigation with wastewater. For each link in the network it is necessary to develop a relationship which quantifies the effects on the basis of the values assumed by the parameters characterizing impact actions and conditions. In some cases this is quite straightforward as the results of basic investigations are available. This is the case of the effects of saline content of water on soil and crops; evaluation criteria have already been developed in order to determine the suitability of water. However, most of the cause-condition-effect relationships require further research in order to acquire a basic knowledge and/or to interpret and use the results obtained in the past. In some cases it is necessary to modify evaluation criteria already established.

Basic investigations, field surveys and experimental tests on the effects of municipal wastewater irrigation have been carried out in Sicily and have mainly concerned (Indelicato at al., 1988):

- the contribution of nutrient macroelements and the effects of their accumulation in the soil (particularly phosphorous and potassium) or their deep percolation (nitrogen);

- the contribution of boron to the soil and the related effects on crops;

- the contribution of micro-organisms and the related effects on groundwater and agricultural products (the effects depending also on irrigation methods);

- the water contribution to the soil with particular reference to the actual and potential volume of utilizable wastewater.

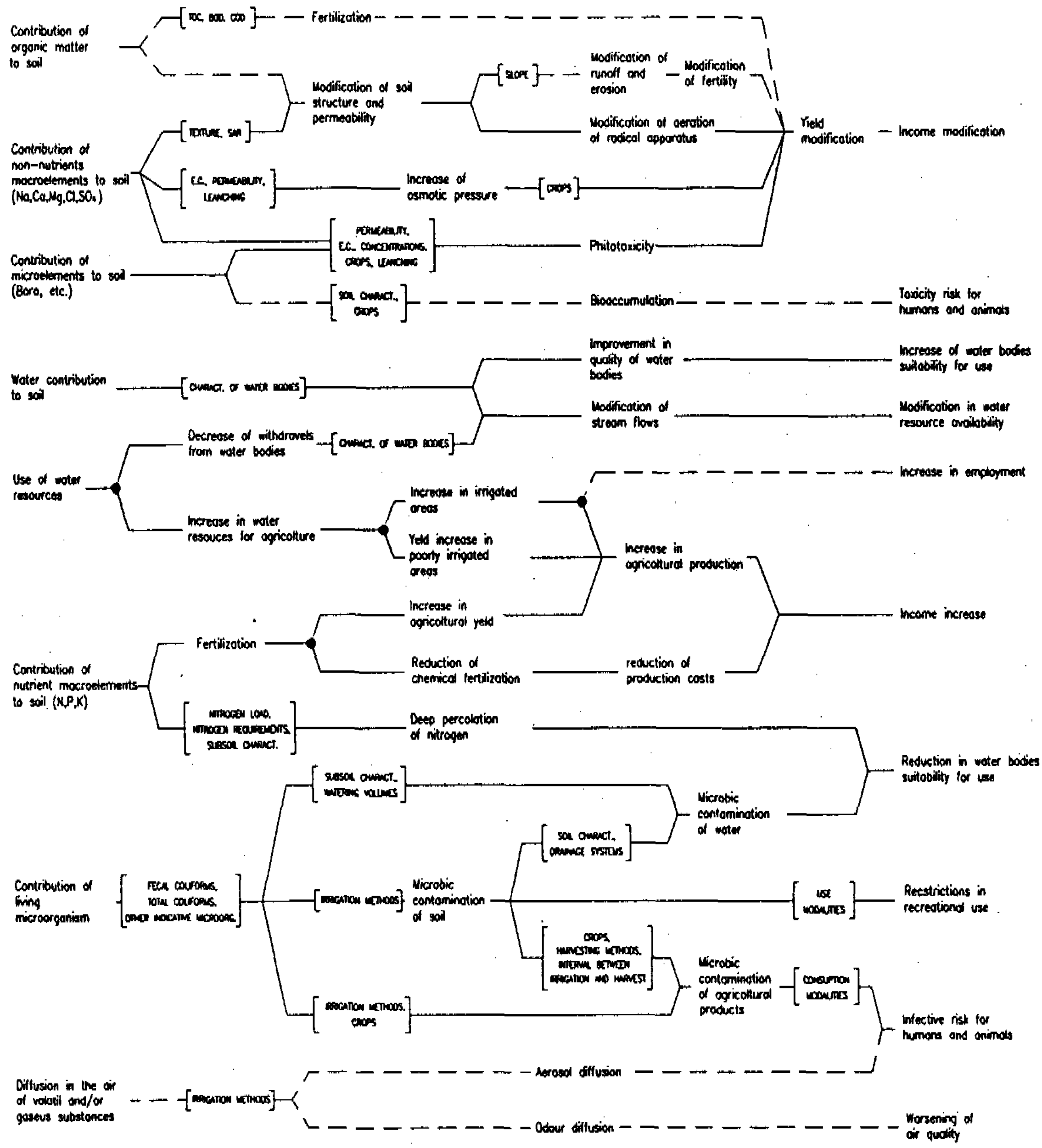

FIG. 1 - Environmental effects of wastewater reuse for irrigation

2.4 Localized wastewater irrigation in order to reduce sanitary risks

The main problem of wastewater reuse is constituted by sanitary risks. This problem can be solved both by suitable treatment or by acting on irrigation methods and modalities.

Health risks connected to wastewater agricultural use can be sufficiently reduced by employing localized irrigation methods. In fact in small reuse systems the realization of advanced depuration plants makes reuse rather expensive and unreliable because of operational difficulties. Thus, in these cases it is best to limit wastewater treatment (for example just to sedimentation or oxidation pond) and to irrigate with methods which avoid any contact of crops with wastewaters (Tamburino et al., 1989).

Localized irrigation methods, such as capillary sub-irrigation and drip irrigation, could reduce health risks, especially if they are employed in arboreous cultivations, but often occlusion of emitters is a problem.

Experimental investigations have been carried out in order to study the causes of occlusion of emitters. Different emitters have been tested with wastewaters treated at different levels. The best results have been obtained with microtubes with a diameter between 2 and 4 mm (Capra et al., 1985; Barbagallo et al., 1988). The delivered flows are generally superior to those of standard drippers; this produces some disadvantages such as the increase in pipe diameter and cost. Such disadvantages are partly reduced in irrigation of arboreous cultivations which have fewer emitters per unit area. It is usually possible to reduce delivered flows to acceptable values by using low pressures and microtubes of sufficient length. Good results have also been obtained with elastic fissured emitters (Tournon, 1972, 1979).

In order to minimize the risk of occlusion, filtration by metal cartridges with holes between 0.5 and 1.5 mm inferior to half of the orifices of employed emitters, is sufficient. Cleaning out operations are simplified with these filters (in comparison with filters of nylon fabric with smaller openings). Moreover, the cleaning out operation of these filters does not have to be repeated so often even if primary effluent has been employed.

Bacteriological investigations carried out on localized irrigation systems have shown a low or absent microbic contamination of crops (grapes). Even in those cases where contact of grapes with untreated wastewaters has been simulated, a rapid inactivation of infectious micro-organisms has been observed due to environmental factors (in particular solar radiation) hostile to micro-organism survival (Barbagallo et al., 1988).

3. SOME REMARKS ON WASTEWATER REUSE IN THE MEDITERRANEAN COUNTRIES

No complete or reliable sure information on wastewater reuse in the Mediterranean countries is available. Here some remarks, which cannot be termed exhaustive, on wastewater reuse are reported from various literature sources.

There are over 200*10^6 inhabitants in the Mediterranean countries of which 70% is concentrated on the coastal areas, which are approximately 46*10^3 Km long.

The water availability varies considerably from one country to another according to climatic conditions. The Northern countries (France, Italy) and some Eastern countries of the Mediterranean basin (Albania, Greece, Lebanon, Turkey, Yugoslavia) have greater availability of water resources, which however are not fully made use of. The more Western countries of the basin (Algeria, Morocco, Portugal, Spain) and the island of Cyprus have less water resources. In some of these countries (Algeria, Greece, Italy, Turkey) water resource availability varies from region to region; e. g. Sicily and Sardinia are a case apart from the rest of Italy as they have a more arid climate. In the South and the East of the basin there are countries with very few water resources (Egypt, Israel, Libya, Malta, Syria, Tunisia); in these countries unconventional water resources are widely used: wastewater in Egypt and Israel; fossil groundwater in Tunisia and Libya; desalinated water in Malta.

At the moment the irrigated area in the Mediterranean countries amounts to more than 16*10^6 ha. In some regions, especially in the South and the East, irrigation uses up the greater part of the water resources.

There is a remarkable difference in the Mediterranean countries when dealing with regulations governing wastewater reuse.

In countries such as Israel, Italy, Spain and Tunisia some general regulations exist; in Italy and Spain the regulations can be adapted by the regional authorities. In some countries some technical recommendations have been set down; in other countries it would seem that there are no specific regulations governing wastewater reuse.

The regulations concerning the reuse of wastewater of some countries (i.e. Israel and Italy) are generally based on the WHO (World Health Organization) guidelines published in 1973 and on Californian guidelines. In 1989 the WHO published some more realistic guidelines on crop types, cultivation practices, treatments and required water quality. These guidelines have been adopted by France, while Spain is in the process of applying them.

In Italy the accepted national level is of 2 or 20 total coliforms/100 ml respectively for crop to be consumed raw or cooked, but in fact in some regions, such as Emilia Romagna and Sicily, less rigorous limits are accepted.

Tunisia has rather comprehensive regulations for the reuse of wastewaters. These regulations highlight the need to plan water resource management, regulate the quality of the discharges and lay down the conditions of use of wastewater in agriculture. In particular the control of water quality is laid down; this control does not take restrictions of a bacteriological nature into consideration (Bahri, 1987; Saied et al., 1990).

In Egypt, where there are many important projects for the reuse of wastewaters, some general technical guidelines have been given concerning kinds of treatment and the quality of the effluents (Abdel-Ghaffar et al., 1985; Soulie et al., 1991).

Maltese regulations concerning the protection of water resources, set down in 1988, take into consideration the possibility of using unconventional resources and, amongst others, wastewater, above all because of the lack of resources for potable purposes (Gauci, 1978).

In Greece the existing regulations mainly concern the protection of the environment and the quality of the discharges (Soulie et al., 1991).

In other Mediterranean countries regulations concerning wastewater reuse contain very general guidelines (Soulie et al., 1991). For example, in Syria some guidelines are given concerning physical and chemical characteristics of water for irrigation, while in Algeria some general regulations define unconventional water resources and require that reuse has to be carried out only after authorization.

The reuse of wastewaters is well-known and widely practised throughout the countries of the Mediterranean basin. This practice has been adopted above all in the agricultural sector in order to overcome the problem of water resources common in arid or semi-arid climates. There have also been many experiments aiming at environmental protection.

The experiments carried out in various countries primarily concerned the treatment techniques of wastewater, irrigation methods, type of irrigated crops, etc.

In wastewater treatment simple techniques such as stabilization ponds seem to permit good technical and economical results, especially when there are small reuse systems (Tamburino et al., 1989). Large areas required by oxidation ponds do not represent a limiting factor near small inland towns generally characterized by a low economic value of land.

The development of irrigation with wastewater is quite different from one country to another in the Mediterranean basin depending on their geographical location. While reuse has been developed mainly for agricultural production in the South and in the East, in the Northern countries it has been employed above all for recreational purposes (irrigation of green areas, forests, golf courses, etc.) or, in general, as a means to protect the environment.

In Algeria, the reuse of wastewaters seems to be limited to cases concerning small areas (Soulie et al., 1991).

In France the reuse of wastewaters has been practised for more than a century and has covered almost all the territory, generally in areas of a few hectars (Soulie et al., 1991).

In Greece, with its hundreds of islands and coastlines about 15*10^3 Km long, irrigation with wastewaters seems to have been practised only on a modest scale despite the need for protecting coastal areas from municipal and industrial discharges (Soulie et al., 1991).

Israel considers wastewater as part of the national water patrimony because the growing demand for water cannot be met by the limited availability of conventional water resources. Almost all the produced effluents are treated. About 18 hm^3/year of treated wastewater, which is equal to about 25% of the total water resources, are reused for agriculture. In some areas 80% of water for irrigation comes from wastewater reuse. In Israel sprinkling irrigation is widely used after the effluents have undergone at least a secondary treatment. There are also many cases of surface and drip irrigation (Tamburino et al., 1982).

In Italy studies and research on wastewater reuse for irrigation have been developed over the years, e.g. those carried out on the municipal sewage of Foggia (1932) and Naples (1971). Studies for the planning of the reuse of wastewater have been carried out in Sicily, Calabria, Emilia-Romagna and other regions. The authorities are not aware of most of the cases of wastewater irrigation and generally the rigid constraints imposed by the regulations are not respected. Consequently, the future of wastewater reuse for irrigation in Italy, despite offering many advantages, must overcome considerable hygienic problems and the psycological opposition that is the cause for which public officials require high treatment levels. The regional governments could come to play an important role in the future of wastewater irrigation in Italy (Indelicato et al., 1982; Tamburino et al., 1989).

In Morocco the reuse of wastewater has been practised in agriculture for a long time, above all in proximity of the big towns. The untreated wastewater is generally discharged in the water courses and is then used mainly to irrigate orchards, fodder and cereals. Owing to the risk of pollution resulting from such practices, many experiments are being carried out in order to define treatment techniques which are suitable for the Moroccan environment (Soulie et al., 1991).

In Syria in some cases, where untreated wastewater reuse has been adopted, epidemics and a high saline content in the soil has been reported (Al-Rifai, 1985).

Spain, despite being one of the countries where the practice of reuse has been going on for a very long time (there are cases reported as far back as 16th century), does not have a specific plan for the reuse of wastewater (Soulie et al., 1991).

In Tunisia an area irrigated with secondary effluent of about 1.5*10^3 hectars in 1988 is reported. Wastewater, 90% of it from domestic origin, has been normally used to irrigate fodder and cereals, and in some cases golf courses and recreational areas (Saied et al., 1990).

Turkey, although its irrigated areas are amongst the most extensive in the Mediterranean basin, does not seem to have examined in a systematic manner the possibility of wastewater reuse, even if pollution problems in the big industrial areas, above all in the coastal areas, could be partially solved with the treatment and the subsequent reuse of wastewater (Soulie et al., 1991).

4. FINAL REMARKS

In arid and semi-arid regions, as most of the Mediterranean countries, the use of unconventional water resources has been seen to play an ever more important role in satisfying the increasing water requirements.

The use of wastewater for irrigation may have important roles to play, as for instance the valorization of nutrients and the liberation of conventional water resources for other uses with more elevated quality requirements.

Environmental effects of wastewater irrigation, the convenience of wastewater reuse and its operation modalities (kind of pretreatment, irrigation methods, etc.) depend on many factors such as: characteristics of wastewater and soil, nature of subsoil and groundwater, cultivated crops, and availabilty and cost of alternative water resources. Therefore, the best technical and economic solution has to be chosen for each individual case. The results of research and the analysis of case-studies lead us to the conclusion that the development of irrigation with wastewaters may have a certain importance in the Mediterranean countries. There are good reasons for updating specific and realistic regulations, which should be based on the recent WHO guidelines and should encourage the diffusion of planned and regulated reuse.

The role of other unconventional resources, such as brackish water, is not to be forgotten. In general, in the management of water resources more attention should be paid to the quality of water and particularly to parameters, such as saline content, which involve high removal costs or significant negative effects on utilization.

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LA RÉUTILISATION DES EAUX USÉES TRAITÉES DANS L'AGRICULTURE

M. A. MECHEBBEK

ALGERIE

LA REUTILISATION DES EAUX USEES TRAITEES DANS L'AGRICULTURE

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HISTORIQUE

Les effluents urbains ont été, depuis longtemps, utilisés pour la production agricole (champs d'épandage du XIXème siècle, en Angleterre, en Allemagne, dans la région parisienne).

A partir de 1910, sous l'influence de l'extension urbaine, des nuisances générées par l'épandage d'eaux brutes, la pratique est entrée en régression, sans que ce déclin soit dû des considérations sanitaires, objectives et précises.

Au milieu du siècle, une meilleure compréhension des phénomènes biologiques et physico-chimiques qui président aux processus de l'évolution et de la dégradation de la matière organique, a favorisé l'éclosion, dans les pays industrialisés, de techniques épuratoires, qui avaient pour but de protéger le milieu naturel et, en particulier, les cours d'eau récepteurs.

Ces techniques ont été ensuite, peu à peu, utilisées pour le recyclage direct ou indirect, dans les pays semi-arides, à déficit hydrique chronique.

C'est ainsi que des Etats comme la Californie, l'Arizona ont développé, à partir des années soixante et, plus radicalement, ces deux dernières décennies, l'irrigation avec les eaux résiduaires, après traitement physico-biologique et la recharge de nappes après traitement avancé de type physico-chimique.

Aux Etats-unis, un milliard de m^3 était recyclé annuellement en 1975, dont 60% pour l'agriculture (7 milliards prévus en 2000). En Californie environ 180 hm^3/an étaient réutilisés dans l'agriculture en 1975.

Des pays du bassin méditerranéen ont suivi, rapidement, l'exemple: Espagne, Chypre, Grèce, Palestine occupée, Tunisie (2000 ha irrigués à partir des eaux épurées, près de Tunis).

(*) Ministère de l'Equipement/DRHR - Kouba Alger (Algerie)

Les Etats arabes et musulmans initient des projets de grande envergure (Arabie, Koweit, Jordanie...).

Plus loin de nous, l'Australie, le Mexique, l'Inde pratiquent la réutilisation à grande échelle.

Possibilité d'approche en Algérie:

Un certain nombre de conditions sont à réunir pour envisager une utilisation planifiée et contrôlée (par opposition à l'usage non déclaré, "spontané", qui existe et existera probablement toujours, y compris dans les réseaux officiels) des effluents urbains.

I. - Caractérisation des rejets urbains:

Il s'agit, avant tout, de connaître la QUALITE des eaux usées, par la QUANTIFICATION des éléments "nuisibles":

. à la santé de l'homme

. à la production végétale et animale

. aux sols

. aux nappes souterraines

. à l'environnement

Ces éléments peuvent être classés comme suit :

A.- Les microorganismes pathogènes :

Deux actions parallèles sont indispensables :

. rassembler les données épidémiologiques, évaluer le degré endémique, d'infestation,

. procéder à des analyses de laboratoires sur échantillons d'eaux usées, pour rechercher : par ordre décroissant de risque , 1.Les oeufs, kystes et larves de vers intestinaux, nématodes, cestodes et autres HELMINTHES représentés par ascaris, trichuris, schistosome, ancylostome infestant directement l'homme; il faut y ajouter le tenia (par l'intermédiaire du boeuf).

Une unité suffit à générer l'infection et il n'y a pas d'immunisation.

Les faibles degrés d'infestations sont considérés comme bénins mais l'objectif final serait, ici, de rompre, si possible, la chaîne de transmission ou, tout au moins, de ne pas l'accentuer par une réutilisation non adéquate; le risque d'accentuation serait alors favorisé par le fort degré de survivance de ces parasites, qui peuvent résister jusqu'à une année dans des conditions défavorables.

La désinfection n'est pas efficace à 100 % ; ils sont éliminés par des temps de séjour de l'ordre de 2 jours.

2. Les bactéries et protozoaires: salmonelles (typhoide, paratyph., salmonelloses), shigellae (dysenteries bact.), E.coli pathogènes, vibrio chol., amibes (dysenteries amibiennes) ...

Le traitement physico-biologique suivi de la désinfection au CL2 produit une élimination à 99,9% , dans de bonnes conditions de gestion de la station d'épuration; les normes proposées par le rapport d'Engelberg (OMS-BIRD 1985) seraient ainsi respectées (moins de 1000 unités de coliformes fécaux /100 ml pour une utilisation sans restriction).

3. Les entérovirus: une centaine d'espèces dont rotavirus, polio-virus, hépatite A ...

Le risque associé aux entérovirus est considéré comme faible dans les pays où sévit déjà l'état endémique, où une immunisation de longue durée s'obtient dès le jeune âge.

Une élimination de 90 à 99 % est obtenue par un traitement type station d'Alger-Baraki. Il faut signaler le risque de recroissance observé, après traitement, chez les espèces bactériennes.

B.- Les métaux lourds:

Ceux-ci sont d'abord nuisibles pour l'activité des microorganismes qui interviennent dans le processus d'épuration biologique.

Ils n'ont pas été détectés à des doses significatives dans les quelques analyses non systématiques disponibles.

Des recherches spécifiques approfondies sont à effectuer à court terme.

Une réglementation est à établir pour les rejets industriels et des dispositifs de surveillance et de contrôle sont à mettre en place.

Les métaux lourds qui franchissent la station de traitement, peuvent :

.s'accumuler dans les sols

.contaminer les nappes

.être phytotoxiques

.nuire à la santé publique

Les déterminations et réglementations doivent porter sur: cyanures, chrome, cadmium, mercure, plomb, zinc, cuivre, fer, arsenic. Les mêmes efforts doivent porter sur le bore.

C.- Les dérivés carbonés:

Par analogie, on peut également classer dans la même catégorie de recherche les composés chimioorganiques et chlorés, produits de détergents, insecticides, pesticides, solvants, hydrocarbures, phénols difficilement biodégradables, pathogènes, par ingestion de très faibles traces, sur de longues périodes (plusieurs dizaines d'années).

Le moyen de se protéger consiste à interdire la commercialisation des produits non biodégradables (comme cela est pratiqué dans les pays developpés) et leur rejet à l'égoût.

D.- Minéralisation:

Les eaux usées sont plus minéralisées que les eaux potables qui les génèrent, le traitement accentue légèrement la salinité. Il faut donc vérifier ce paramètre qui est très variable.

La détermination du SAR, par la recherche des ions Na+, Ca++ et Mg++ est aussi primordiale.

Des valeurs limites des 2 paramètres conduiraient à des restrictions importantes dans la réutilisation.

- LES ELEMENTS NUTRITIFS :

Utiles et nécessaires à la production agricole,les nitrates,phosphates et potassium sont disponibles dans les effluents bruts, mais, parfois en excès (des concentrations correspondants à 200 kg/ha, sur la base de 5000 m^3/ha, sont courantes pour l'azote). L'apport continu, en période d'irrigation, est aussi gênant.

II.- Les populations exposées:

1. Les producteurs: exposés aux larves (ancylostome, schistosome), aux bactéries et virus par contacts, ingestions accidentelles, inhalations (aérosols).

L'irrigation par aspersion est,ici,défavorisée au profit de la raie, de la planche. Le goutte goutte est très indiqué, mais les colmatages des filtres constituent un problème difficile à résoudre.

La meilleure protection des producteurs sera constituée par un ensemble d'aménagements cohérent (par exemple STEP-stockage de longue durée), par un fonctionnement continu et fiable des installations et par des habitudes d'hygiène alimentaire.

Autre type de risque: celui lié à une pollution des terres ou à de mauvais rendements dus à la phytotoxicité.

2. Le voisinage: risque lié essentiellement aux aérosols, dans le cas d'une irrigation par aspersion (sauf s'il s'agit de basse pression).

3. Les consommateurs: exposés aux germes et oeufs fixés sur les feuilles et fruits consommés crus, mal lavés ou mal cuits (y compris pour la viande de boeuf, pouvant transmettre le tenia).

III. - Les moyens de prévention:

L'ensemble des précautions, des normes conseillées comme des risques encourus et des exemples types d'infections connues et répertoriées concernent en fait l'irrigation avec des eaux usées brutes ou mal traitées.

La réutilisation d'eaux, traitées par le procédé physico-biologique pour l'irrigation n'a pas entraîné de cas de morbidité connu et répertorié.

Ainsi, les effluents traités par voie biologique sont recommandés pour l'irrigation sans restriction. Plus précisément, le rapport d'Engelberg (OMS-BIRD 1985) et des études spécialisées menées sous l'égide de la BIRD, du PNUD et de l'IRCWD recommandent, pour les petites et moyennes agglomérations, le système de 4 ou 5 bassins de stabilisation, en série, avec des temps de séjour de l'ordre de 3 à 4 semaines.

Un tel traitement devrait conduire à respecter les nouvelles normes proposées pour l'irrigation sans restriction :

1 unité/ litre pour les helminthes

1000 Coli fec / 100 ml

Pour le cas d'Alger, grande agglomération, la station de Baraki est conçue pour procéder à une décantation (5-6 h), traitement physique, suivi d'un traitement biologique, après aération forcée, par le procédé conventionnel des boues activées, achevé par une clarification et une désinfection au chlore.

Le temps de séjour global sera de 12 à 15 h . Les paramètres objectifs sont la DBO5, la DCO et les Matières en suspension qui seront réduites respectivement de 90-95, 75-80 et 90-95 % . Les bactéries seront fortement réduites ,les virus et les helminthes subsisteront peut- être.

De toute façon, l'élimination des microorganismes n'est pas garantie à 100% , même si elle respectera les normes proposées et même les normes en vigueur (moins de 100 coli tot / 100 ml) pour l'irrigation sans restriction.

L'abattement de la DBO et des MES à 20 mg/l conduira à des taux de 100 kg/ha/an de DBO et de MES, sans stockage intermédiaire.

Si des cultures sans restrictions sont envisagées, il faudra nécessairement réaliser un traitement complémentaire par filtre sable ou, mieux, un stockage de longue durée qui aura ainsi, un double rôle:

. récupérer les rejets de la saison humide, permettant de régulariser environ 50 hm^3/an et de couvrir quelques 10 000 ha. Le stockage peut être complété par une dilution grâce à des apports naturels ou artificiels (par transfert d'un bassin voisin).

. affiner le traitement par:

- élimination des helminthes

- réduction supplémentaire des bactéries et des virus

- réduction supplémentaire de la DBO et des MESet ce, grâce à un temps de séjour qui devrait évoluer de 6 mois en début de saison à 1 mois minimum.

Un inconvénient sera le risque d'eutrophisation de la retenue, et de production d'algues qui pourraient entraîner le colmatage des sols. C'est donc un problème qui devra être testé et étudié.

L'introduction de la réutilisation devrait permettre de développer des cultures actuellement absentes,bien que stratégiques.

En effet,il serait opportun de prendre le moins de risques en envisageant des productions non consommables par l'homme,des produits traités,séchés ou destinés à une transformation industrielle faisant appel à la cuisson,à la chaleur,au séchage... (fibres,graines,...).

Il en est ainsi :

- des cultures industrielles: plantes à huile, sucre, fibre...

- des cultures fourragères destinées à la consommation du betail après séchage (excluant le pâturage et la consommation en vert)

- de certaines plantations d'arbres,arbustes.

L'Etat a ainsi la possibilité d'orienter une vocation agricole locale ou régionale, par le biais d'aménagements spécifiques, de cahiers des charges assortis à une mise à disposition de ressources en eau, de contrats d'achat; on peut même imaginer une opération "type lotissement" réservée à des équipements de pointe (serres, goutte à goutte) pour des productions de "valeur" (cultures florales, essences à parfum, plantes ornementales...)

Des possibilités de "profiter" de la spécificité aussi bien "positive" que "négative" des eaux résiduaires doivent exister.

Autres moyens de prévention :

En plus des possibilités esquissées, d'autres manières de procéder permettent de garantir un usage sûr des eaux épurées:

. arrosage à la raie ou à la planche

. application des doses calculées, "au plus juste"

. récolte, au plus tôt, 2 semaines après le dernier arrosage

La présence d'un horizon non saturé de plus de 3 m est une excellente garantie (dans des expériences d'infiltration, il n'a été décelé aucun virus et une totale disparition des germes a été constatée à une profondeur supérieure à 3 m).

L'usage à la parcelle est donc le palier de sécurité final; une bonne combinaison consiste à choisir des sols profonds, à texture moyenne et équilibrée, la couche non saturée jouant un rôle épurateur incomparable (effet "mécanique" sur les "gros", d'adsorption sur les "fins"); cette action est menée en surface, par la dessication et les effets de la température et des radiations solaires lorsque le terrain n'est pas maintenu dans un état d'humidité élevée, constante et permanente.

Ainsi, il est clair qu'il existe des combinaisons d'actions et de procédures aptes à rendre l'usage de l'eau usée épurée sûr et garanti; c'est ce que les américains appellent la méthode des "barrières multiples".

IV.- Proposition de programme d'action:

* Identification précise des risques par le moyen de:

. Campagnes d'analyses sur les :

- pathogènes , helminthes, bactéries, protozoaires, virus
- métaux lourds et autres toxiques chimiques
- autres éléments essentiels :minéralisation,SAR...

. Etudes d'impact sanitaires et épidémiologiques

* Identification des méthodes et moyens propres à assurer un usage fiable de l'eau usée:

. Procédés de traitement, d'utilisation...

. Propositions de normes nationales

* Etablissement de la réglementation des rejets .

* Recherche des sols aptes et des systèmes de production susceptibles de rentabiliser la réutilisation de l'eau après traitement.

* Expérimentations sur les différents thèmes concernant les flux et échanges EAUX-SOLS-PLANTES-NAPPES-ATMOSPHERE, visant définir les meilleures associations et systèmes les plus fiables .

Un organe de suivi permanent, de coordination et d'incitation serait peut-être utile (*agence spécialisée* ou simplement comité technique permanent).

Les opérateurs et organismes concernés sont nombreux:
Hydraulique-Santé-Agriculture-Environnement-Industries-Universités-Collectivités locales...

Il s'agit, en fait, d'un grand thème "porteur" et non exclusif de portée stratégique, dans un pays où la sécheresse est une habituée de plus en plus insistante.

La réutilisation des boues de traitement est à considérer suivant le même cheminement (la production de la station d'Alger permet l'amendement de 3000 ha de terres, chaque année).

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WATER RESOURCES PLANNING AND DEVELOPMENT IN TURKEY

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TURKEY

WATER RESOURCES PLANNING AND DEVELOPMENT IN TURKEY

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INTRODUCTION

Water is one of the most valuable resources, and a limiting factor for crop production. Agricultural crops are the major consumer of water. Agriculture, with its social and economic aspects, has a dominant role in the nation's life in Turkey. It accounts for nearly 19% of GPD, 9% of exports and 51% of civilian employment.

In the face of population growth and increasing demand for water, deteriorating water quality, increasing environmental degradation, and impending climate change, more effort is required to assess water resources for national planning and management in order to sustain development. Efforts should be directed to overcome the present constraints regarding water resources assessment, and in particular the institutional weakness, inadequate networks, incompatible technologies for field, laboratory and office work. In the present day, there are many handicaps such as deficiency of staff and their capability, and lack of coordination efforts.

In this paper, water resources in Turkey, and the existing level of developement and problems associated with it, will be analyzed.

1. NATURAL RESOURCES OF TURKEY

1.1. Climate

Turkish territory is bounded on three sides by the sea. It is mostly an elevated plateau enclosed by mountains on all sides, except for the west. These mountains act as a barrier to

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the rain bearing wind from the north and south, and leave the interior plains, which make up more than two-thirds of the total area, with an average rainfall of 200 to 500 mm. Average rainfall for all over Turkey is 643 mm. The summers are hot and dry; and the winters may be extremely cold. On the coastal plains a sub-tropical Mediterranean climate prevails. Seventy-five percent of annual rainfall is received in the winter season. Except for the coastal areas, Thrace and Eastern Anatolia, annual rainfall is less than 500 mm, therefore irrigation is of paramount importance. Generally, agricultural production is adversely affected by the shortage in annual rainfall and inconsistency of rainfall during the growing season.

Solar energy in Turkey, which depends on factors such as altitude and seasons, makes it possible to grow arid and semi-arid crops such as bananas and citrus. Also, by allowing 270-day crop growing seasons, it is possible to have 2-3 crops from irrigated areas. However, in Eastern Anatolia with its 60-90 growing days, some crops are harvested before maturation.

1.2. Land Resources

The country has a total area of 77.95 million hectares. Of this area approximately 35 percent is cultivated, 26 percent is grass and pasture, and the remaining 39 percent is forest and unproductive land.

Important changes have taken place with respect to land use in the recent last years. Land use figures are given in Table 1. The area which can be developed for irrigation is estimated by DSI (State Hydraulic Works) at 8.5 million ha gross area (6.4 million ha for major irrigation projects), of which about 4.0 million ha has been developed. The remaining area of about 4.5 million ha is yet to be developed for irrigation. This does not mean that under the present conditions it would be economically feasible to irrigate the whole area. For the Irrigation Master Plan of Turkey, 227 projects covering a gross irrigable area of 2.94 million ha have been analysed. 139 of these covering a gross irrigable area of 2.07 million ha., or 70% of the total area reviewed, have an IRR of 8% or more. If that same percentage is applied to the area still to be developed, a potential additional irrigable area of 3.2 million ha will be added. It is expected that in the period 1992-2001 a net irrigable area of 1.12 million ha will be developed by DSI. So far DSI has developed 1.69 million ha.

Irrigation development is carried out by the private sector (farmers and groups of farmers) and the public sector (DSI and GDRS, General Directorate of Rural Services). Since 1950 irrigation development by DSI has gradually picked up momentum (Table2).

Table 1. Land Resources in Turkey

Land resources	million ha
Total area of Turkey	77.95
Agricultural area	27.70
Total Irrigable area	25.85
Economically potential gross irrigable area	8.5
Present gross irr. area (1991)	4.03
Present net irr. area constructed by DSI	1.69
Source : DSI, 1992	

Table 2. Irrigation Development by DSI in 1000 ha

year	Operated by DSI	Operated by users	Total
1950	123	20	143
1960	185	31	215
1970	521	76	598
1980	755	245	1001
1990	1251	375	1626
1991	1266	422	1689
2001	Projected		2939

Source : DSI, 1991. Irrigation Master plan, Part I. Investment Strategy

1.3. Water Resources

One of the most important aspects of land and water resource developement programs is the determination of the inventory of the resources. If the resources and opportunities are not known accurately before the projects are undertaken, in most cases the installations will not be feasible and failure will result.

The work carried by DSI up to the present time in 26 main drainage basins of the country shows that the annual potential of surface water is 186 billion cubic meters. Of this amount, 95 billion cubic meters can feasibly be developed. On the other hand, the safe groundwater reserve in the country is estimated to be around 12 billion cubic meters. Thus, the combined potential of utilizable water resources in Turkey becomes 107 billion cubic meters a year (Table 3).

Annual average water potential for Turkey's drainage areas shows huge differences. (Table 4).

Table 3. Water Resources in Turkey

Water Resources	
Annual Average Rainfall	642.6 mm
Total Rainfall	501.0 km^3
Surface Water	
Annual Runoff	186.05 km^3
The Ratio of Annual Runoff to Total Rainfall	0.37
Potential Water Use	95.00 km^3
Annual Use (present)	25.6 km^3
Underground Water	
Potential water use	11.6 km^3
Developed Water Amount	6.6 km^3
Annual Consumption	5.4 km^3

1 km^3=1 billion m^3

Source : DSI, 1992. TC. Bayındırlık ve İskan Bakanlığı, DSİ Genel Müdürlüğü

Table 4. Annual Average Water Potential by Watershed Area

Watershed	Annual Runoff (km^3)	% of Total Runoff	(***)Average Annual Output ($l/s/km^2$)
Euphrates (*)	31.61	17.0	8.3
Tigris(**)	21.33	11.5	13.1
Eastern Blacksea	14.90	8.0	19.5
East Mediterrenaen	11.07	6.0	15.6
Antalya	11.06	5.9	24.2
West Blacksea	9.93	5.3	10.6
West Mediterranean	8.93	4.8	12.4
Marmara	8.83	4.5	11.0
Seyhan	8.01	4.3	12.3
Ceyhan	7.18	3.9	10.7
Kızılırmak	6.48	3.5	2.6
Sakarya	6.40	3.4	3.6
Çoruh	6.30	3.4	10.1
Yeşilırmak	5.80	3.1	5.1
Susurluk	5.43	2.9	7.2
Aras	4.63	2.5	5.3
Konya	4.52	2.4	2.5
Büyük Menderes	3.03	1.6	3.9
Van Lake	2.39	1.3	5.0
Northern Egean	2.09	1.1	7.4
Gediz	1.95	1.1	3.6
Meriç-Ergene	1.33	0.7	2.9
Küçük Menderes	1.19	0.6	5.3
Asi	1.17	0.6	3.4
Burdur Göller	0.50	0.3	1.8
Akarçay	0.49	0.3	1.9
Total	186.05	100.0	

(*) Main runoff is 30.25 km^3

(**) Main runoff is 16.24 km^3

(***) These values are obtained from the first base stations

2. EXISTING LEVEL OF DEVELOPMENT

The majority of water resources development projects in Turkey are carried out by DSI and GDRS. Before 1991 there were 141 dams in operation. These dams provide irrigation for 1.648 million hectares (gross) of land and provide 23,598 Gwh hydroelectrical energy. In 1991, nine dams were completed which provided irrigation for 48,451 hectares and annual energy production of 769 Gwh.

Presently 53 dams and hydroelectric power plants are being constructed and should be completed by 1995. Effective use of these huge projects depends on the completion of irrigated infrastructure in these areas. Upon completion 619,881 hectares will be irrigated.

By 1991, 6.5% of the irrigable area, and 20% of the economically feasible area is irrigated. Only 15% of the water potential is currently utilized. Of this utilization, 58% is used for agricultural irrigation, 24% is municipal use, and the remaining 18% is used by the industry.

Areas developed for irrigation by DSI have shown increases over the last ten years. Table 5 shows the irrigated area development between 1980 and 1990.

Table 5. Areas Opened for Irrigation by DSI (1980-1990)

Year	Surface Area (ha)	Ground Water Area (ha)	Total Area (ha)
1980	847277	153297	1000574
1981	866071	185285	1051356
1982	904260	212780	1117040
1983	950380	231605	1181985
1984	1012880	252185	1265065
1985	1109060	261810	1370870
1986	1186540	271095	1457635
1987	1230390	277045	1507435
1988	1254695	281535	1536230
1989	1307318	289855	1597173
1990	1327650	298520	1626170
1991(*)	1372651	316100	1688751

Source : DSI, 1992

During this ten year period, the greatest increase (105,805 ha) was in the 1984-1985 period, and the smallest increase (28,997 ha) was in the 1989-1990 period.

In the areas developed for irrigation, expected land utilization is not realized up to this day. Observed crop pattern in these areas is different than planned. Cereals and cotton are dominant crops in the irrigated areas (cereals, 18.5%; cotton, 35%). However, recently in the coastal areas, secondary crops such as soybeans and corn are planted after wheat is harvsted. This results in more efficient land utilization (Table 6).

3. SOUTHEAST ANATOLIA PROJECT

The most important and ambitious water resources development project in Turkey so far is the South East Anatolian Project, or in short the GAP Project. It is a regional based development project in the lower Euphrates and Tigris region covering an area of about 74,000 km^2. The project covers most of the provinces of Diyarbakir, Sanliurfa, Mardin, Gaziantep, Adiyaman, Siirt, Batman, and Sirnak. The project involves integrated development of irrigated agriculture and agro-industry and supporting services, including communications, health and education.

GAP project is a multipurpose integrated project, and will include dams and hydroelectric power plants constructed on the Euphrates and Tigris, irrigation systems, and various infrastructure investments such as transportation, telecommunication, industrial investments, education and health centers, and related development investments.

Fundamental reasons for the planning of the GAP project are irrigation and hydroelectric energy systems which are intended to develop the natural water resources of the area. The construction started in 1976. The largest unit of the GAP is the Lower Euphrates project whose construction is still continuing. This subproject includes the Atatürk dam which is

Table 6. Land Utilization in DSI Irrigation Areas and Crop Pattern

						Crop Pattern in Actually Irrigated Area (%)						
Year	Irrigation Quantity	Area Opened for Irrigation (ha)	Area Actually Irrigated (ha)	Irrigation Ratio* (%)	Cereal	Sugar Beet	Cotton	Rice	Fodder Crops	Citrus	Fruits and vegetables	Other
1970	82	521482	284775	54.6	27.1	5.0	37.2	3.6	3.8	0.7	6.5	16.1
1975	108	671242	420003	62.6	14.7	6.2	42.9	3.7	3.2	1.2	7.6	20.5
1978	116	763119	496845	65.1	16.3	6.9	39.1	3.6	3.0	1.3	9.0	20.8
1979	118	779119	508090	65.2	18.3	6.5	35.5	4.6	3.3	1.4	7.7	22.7
1980	120	755459	493604	65.3	11.7	6.6	43.9	2.8	4.0	1.6	8.0	21.4
1981	115	773410	561397	72.6	11.6	8.6	39 5	4.3	3.9	1.5	7.7	17.9
1982	119	813585	605647	74.4	18.5	8.2	32.6	3.9	3.6	1.6	8.2	23.4
1983	131	879210	622869	70.8	18.9	8.8	33.9	2.2	3.4	1.8	8.3	22.7
1984	139	964565	706795	73.3	15.6	7.6	42.4	2.6	3.2	1.6	7.8	19.2
1985	150	1060440	794850	75.0	17.9	6.2	35.6	2.3	2.7	1.3	8.2	25.8
1986	159	1115240	831600	74.6	23.0	6.7	27.7	1.9	2.6	1.8	7.6	28.7
1987	172	1156990	806715	69.7	19.3	7.7	26.6	1.7	2.8	2.1	7.7	32.1
1988	181	1201340	816274	67.9	16.4	7.0	36.0	1.9	3.2	2.2	8.0	25.3
1989	181	1231100	935344	75.9	24.9	7.0	27.0	2.3	2.8	1.9	8.3	25.8
1990	193	1251251	857499	68.5	23.7	9.0	24.2	0.9	3.0	2.3	8.2	28.7

* Irrigated Area/Irrigable Area

Source: DSI, 1992

the largest water structure ever built in Turkey. Besides increasing energy and agricultural production, it will have significant effects on the social structure of the region.

In the southeast plains, besides the deficient soil resources and the climatic conditions, the main factor that adversely affects the agricultural development is the insufficient rainfall especially during the summer months. By supplying water to overcome water deficiency which is the major factor that inhibits the growth of various kinds of plants, productivity will increase. By employing contemporary agricultural methods work opportunities will increase, and it will encourage the growth and improvement of other sectors and services.

Natural resources potential of the GAP is given in the table below. Table 7 clearly shows the vast natural resources potential of the region. The population growth rate of the region is much higher than the national average, and the literacy level is much lower than Turkey's average. The total number of villages in the area is 4110.

Table 7. Natural Resources Potential of the GAP*

	Potential of Turkey (%)
Project Area	10
Population	9
Irrigable Area	25
Surface Waters	25
Ground Waters	25
Hydroelectric Energy	25
Petroleum	100
Phosphate	100

* Balaban, A., 1990

The GAP system consists of 13 subprojects, 7 on the Euphrates and 6 on the Tigris rivers (see Tables 8 and 9)

Table 8. The GAP subprojects

	Energy Production (Gwh/year)	Project Irrigated Land (hectares)
The Euphrates Projects:		706.208
Lower Euphrates	8.245	
Karakaya	7.354	
Border Euphrates	3.170	
Suruç-Baziki	107	146.500
Göksu-Araban	82.685	82.685
Adıyaman-Kahta	509	74.410
Gaziantep	89.000	89.000
The Tigris Projects :		
Dicle Kralkızı	444	126.080
Batman	483	37.749
Batman Silvan	670	213.000
Garzan	315	60.000
Ilisu	3.830	
Cizre	1.000	121.000
Total	26.127	1.656.632

The irrigation and energy production units of the system consist of 22 dams and 19 hydroelectric power plants. Following the completion of the project, 1.65 million hectares of land will be irrigated (including grounwater irrigation), and 27 Kwh of energy will be obtained annually. This energy is equal to Turkey's total energy production for 1981. The area which will be irrigated is more than the total public irrigated land since the beginning of the Republic. A 30-year period is foreseen for the completion of the physical structures of the whole project. The investment cost is equal to the national annual budget, and 60%

of this amount will be spent on the irrigation systems, and 40% for the construction of the power plants.

Table 7 shows that 2/3 of the development potential is in the Euphrates, and 1/3 in the Tigris subsystems.

The largest units of the GAP project are the Atatürk Dam and Hydroelectric Power Plant, together with the Sanliurfa Tunnels. The total hydroelectric power capacity of this project is going to be 8.1 billion kwh/year, and the total irrigation area covered by five projects will be 706.208 hectares. The two most important irrigation projects are the Sanliurfa-Harran and Mardin-Ceylanpinar Irrigation Projects which envisage the irrigation of 470.000 hectares. The water necessary for these projects will be supplied through 26.4 km of two parallel tunnels with an inner diameter of 7.62 m each.

Table 9 gives summary data on the 13 major irrigation projects in the GAP Project. Though 37% of the projected investment has been completed already, mainly for the construction of dams and hydro power plants, less than one percent of 1.635 million ha targeted for irrigation has so far been developed.

4. PROBLEMS ASSOCIATED WITH LAND DEVELOPMENT

In order to obtain the maximum benefit and cover the increased production costs, the project must be based on a reasonably efficient system, supplemented by application of fertilizers and accompained by disease and pest control as well as by appropriate crop rotation. The cost of intensification is high and can only be recovered by ample yields of high value crops per unit areas. In addition, the project area must also be supplemented by the creation of such facilities as roads, electricity and domestic water supply systems, means of transportation, storage depots and socio-cultural institutions like education centers, schools and clinics.

The history of agriculture irrigation shows us that success of an irrigation project depends, in addition to engineering structure, on the solution of land, water and human problems in the project area.

Table 9. GAP Project

Southeastern Anatolian Project

	Euphrates Projects	Southeastern Anatolian Project	Tigris Projects
Hydroelectric Power	5 304 MW	7 476 MW	2 172 MW
Energy Production	20 098 Gwh	27 345 Gwh	7 247 Gwh
Irrigation Area	1 091 203 ha	1 693 027 ha	601 824 ha
No. of Dams	14	22	8
HES (Hydroelectric Station)	11	19	8
Units in Operation			
Hydroelectric Power	1 800 MW	1 800 MW	-
Energy Production	7 354 Gwh	7 354 Gwh	-
Irrigation Area	7 330 ha	7 330 ha	-
No. of Dams	2	2	-
HES (Hydroelectric Station)	1	1	-
Units in Construction			
Hydroelectric Power	2 450 MW	2 852 MW	402 MW
Energy Production	9 024 Gwh	9 951 Gwh	927 Gwh
Irrigation Area	162 051 ha	214 051 ha	52 000 ha
No. of Dams	3	6	3
HES (Hydroelectric Station)	2	5	3

Source DSI, 1992

In Turkey, up to the present time, the phase of irrigation development has not drawn sufficient attention in project planning and implementation in comparison to engineering structures, i.e. storage, diversion, conveyance and distribution systems. Until recent years, under the lure of immediate gains, most of the major irrigation projects have been put on service even before their main distribution and drainage networks are completed.

In these projects, even at the end of their assumed development period, the area actually irrigated was not more than a small fraction of the area initially planned.

4.1. Farm Irrigation Distribution System

The main objective of farm distribution systems in irrigation projects is to convey the water form the tertiary outlet to the plots without waste, and to provide the controlled application of water to the field. Not mentioning the land development works recently begun in two major projects (Seyhan and Gediz), engineered farm irrigation distribution systems are lacking. A study made on earth field ditches on three irrigation projects in Central Anatolia has shown that seepage losses were 7.2 to 42.9 percent per hundred meters of field ditch length. Considering the relatively greater length of field ditches in an irrigation project, seepage losses may create lots of damage.

4.2. Field Drainage

Until recently, the importance of drainage was not recognized till salinity-alkalinity became a problem. Today, in the newer projects the need of drainage is recognized, and provision for the principal drainage system is incorporated in the project planning. But again, in most of the irrigation project, except where the topography and soil conditions are such that natural drainage suffices, field drainage is lacking.

4.3. Land Preparation for Irrigation

In irrigation projects, the land must be prepared to receive the water before efficient application of irrigation can be accomplished. Therefore land preparation is an important item of irrigation development. Attempting to irrigate land with an uneven surface results in low efficiency of water use, soil erosion, excessive labor requirements, in salinization of the soil. The fields that have adequate surface drainage often do not require subsurface drainage (17). Excluding the Seyhan and Gediz projects, in which extensive land preparation works are undertaken, inadequate leveling and preparation is prevalent in all irrigation projects in Turkey.

4.4. Salinity Control

In recent centuries vast areas of salt-affected soils have developed from man-made causes such as irrigation without provision for adequate drainage, application of an insufficient amount of irrigation water, or from a combination of these. Saline and alkaline problems arise even when drainage facilities are adequate, unless sufficient irrigation water is applied to provide for both crop needs (consumptive use) and accessory leaching of excess salts out of the root zone of soil.

In some older projects (Cumra, Menemen, Seyhan, etc.) detrimental changes have occurred in the soils as a result of inadequate drainage. Resultant salinization has discouraged farmers from changing dry land practices to irrigation farming. For example, in the oldest irrigation project of the country (Cumra) 42 percent of the land is still left to fallow.

4.5. Management of Irrigation Water

The method of water application finally adopted, whether it be surface, sprinkler or subsurface, must satisfy the following criteria:

1) Uniform distribution of water, 2) minimum erosion or other damages to the land, 3) maximum efficiency in the use of water, and 4) practical and economical performance from the aspects of crop, labor requirement, cost of land preparation, and maintenance. High application efficiency and uniform distribution of irrigation water on the fields are prerequisites of good irrigation.

CONCLUSION

Under Turkish conditions, successful amalgamation of land and water is of primary importance in the development of the country. Considering the limitation imposed with respect to water resources, the country has 8.5 million hectares of irrigable land potential. With the full development of this potential, if the production can be increased four times over to the dry conditions, this increase could be equivalent to plowing and additional 25.5 million hectares of dry land.

To have a successful irrigation project with high productivity the following measures are required: comprehensive survey and analysis of the soils; selection of productive crops and animals that are adaptable to the regional conditions, and the continuity of production once the project is complete; proper determination of the total amount of land opened for irrigation; deterrence of land use for purposes other than irrigation; efficient distribution of the irrigation water; education of the public on modern agricultural methods; effective drainage adaptable to the region, and effective education for the growers.

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6

GESTION DES RESSOURCES EN EAU EN CONDITIONS D'ARIDITÉ CAS DE LA TUNISIE

CH. LAROUSSI - H. HABAIEB

TUNIS

GESTION DES RESSOURCES EN EAU EN CONDITIONS D'ARIDITÉ CAS DE LA TUNISIE

CH. LAROUSSI (*) et H. HABAIEB (**)

ABSTRACT

After presentation of the hydrologic characteristics of TUNISIA and the potential of groundwater resources, authors make a comparision between this potential and mobilized resources.

The balance between needs and possibilities in natural water is presented. The projection of water needs at the end of this Century is calculated according two scenarios and water deficit in natural water is deduced.

In conclusion, some recommendations concerning the use of unconventional resources are presented.

I - PRÉSENTATION DE LA TUNISIE :

La Tunisie se présente dans le prolongement de la chaîne montagneuse de l'Atlas qui commence au Maroc. 55% de la superficie de la Tunisie a moins de 200 m d'altitude. Toutefois sa localisation à l'extrémité du Sahara fait que malgré sa large ouverture sur la Mer Méditerranée, elle demeure aride à semi-aride sur les 3/4 de son territoire. Cette aridité conjuguée aux caprices du climat méditerranéen font de l'eau une ressource à la fois rare et mal répartie dans l'espace et dans le temps.

La Tunisie a une population de 8 Millions d'habitants et une superficie de 160000 km^2; d'où une densité de 50 hab./km^2.

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II- RÉPARTITIONS SPATIALE ET TEMPORELLE DE LA PLUVIOMÉTRIE

Le régime général des pluies est le régime méditerranéen, mais il est loin de présenter un caractère uniforme. La Tunisie comme toute l'Afrique du Nord étant placée sur une zone de discontinuité climatologique sur laquelle des faibles causes peuvent produire des effets excentriques très importants par rapport aux normes (par exemple les pluies de Septembre-Octobre-Novembre 1969, de Mars 1973 et de Janvier 1990).

On peut distinguer deux saisons du point de vue pluviométrique :

- Une saison pluvieuse : de Septembre à Mai
- Une saison sèche : de Juin à Août

On peut distinguer quatre zones pluviométriques (Fig.1) :

* Une zone très pluvieuse recevant annuellement plus de 600 mm avec 120 jours de pluie.
* Une zone pluvieuse recevant 400 à 600 mm de pluie avec 60 à 100 jours pluvieux.
* Une zone peu pluvieuse recevant 200 à 400 mm de pluie avec 40 à 70 jours pluvieux.
* Une zone très peu pluvieuse recevant moins de 200 mm avec environ 30 jours pluvieux.

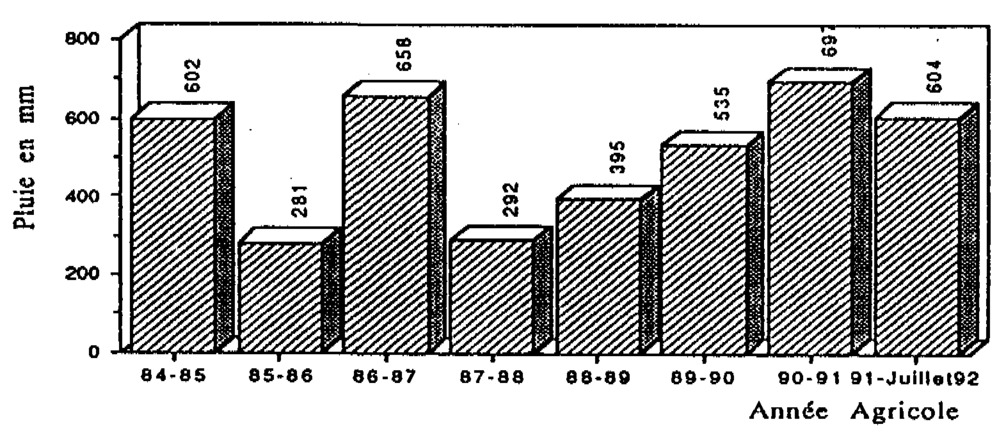
A cette importante répartition spatiale de la pluviométrie vient s'ajouter la répartition temporelle. A titre d'exemple, nous prenons la station du Centre de Gestion des Ressources en Eau de l'INAT où nous avons dressé la pluviométrie annuelle (Fig.2 et Tab.1).

Pour ce graphique et ce tableau, nous avons considéré l'année agricole qui s'étale de Septembre à Août.

Tab.1- Variation temporelle de la pluviométrieStation du Centre de Gestion des Ressources en Eau de l'I.N.A.T, Tunisie

Année Agricole	Pluie totale en mm
84- 85	602
85 - 86	281
86 - 87	658
87 - 88	292
88 - 89	395
89 - 90	535
90 - 91	697
91 - Juillet 92	604

Fig.2- Variation temporelle de la pluviométrie Station du Centre de Gestion des Ressources en Eau de l'I.N.A.T. Tunisie



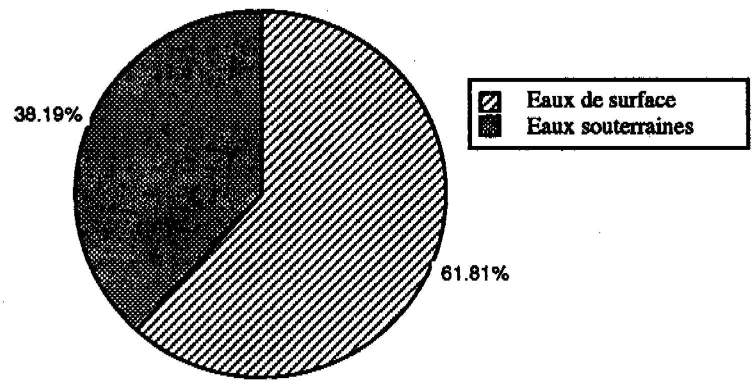
III - LES RESSOURCES EN EAU :

Le potentiel des ressources en eau de la Tunisie se présente comme suit (Fig.3) :

- eaux de surface: 2630 Millions de m^3/an soit 62%
- eaux souterraines: 1725 Millions de m^3/an soit 38%

Total: 4355 Millions de m^3/an soit 100%

Fig.3- Le potentiel des ressources en eau de la Tunisie



III.1- SITUATION ACTUELLE DES EAUX DE SURFACE :

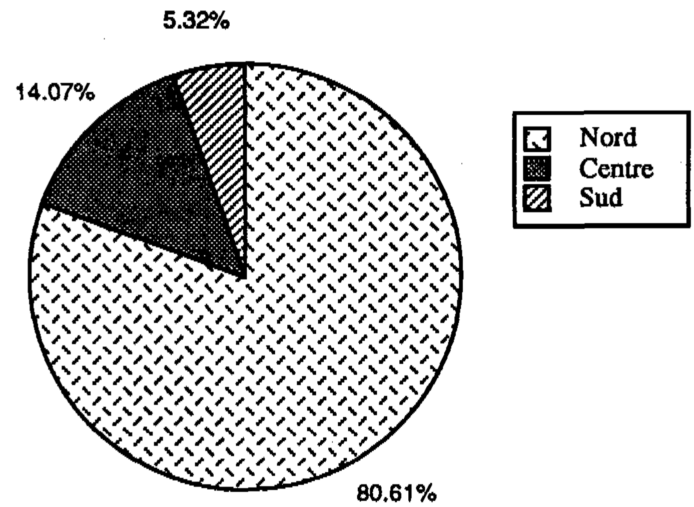
Le potentiel en eau de surface du pays est déterminé grâce au réseau national de mesures pluviométrique et hydrométrique des différents bassins versants du pays. Ce réseau a subi une certaine évolution durant ces dernières années :

- en 1970 ce potentiel était de 2000 Millions de m^3/an.
- en 1980 ce potentiel était de 2580 Millions de m^3/an.
- à partir de 1985 ce potentiel vaut : 2630 Millions de m^3/an.

La répartition régionale de ces ressources s'établit comme suit (Fig.4):

Tunisie du Nord :	2120 Millions de m^3/an soit 81%
Tunisie du Centre :	370 Millions de m^3/an soit 14%
Tunisie du Sud :	140 Millions de m^3/an soit 5%
Total	2630 Millions de m^3/an soit 100%

Fig.4- La répartition régionale des ressources en eau de surface



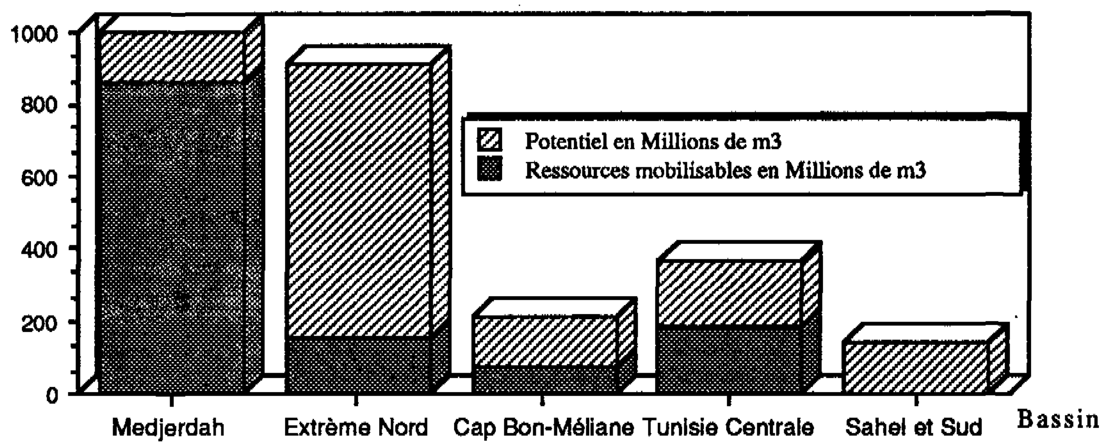
Sur un potentiel de 2630 Millions de m^3/an, les ressources en eaux de surface mobilisables sont de 2100 Millions de m^3/an soit 80% du potentiel. Toutefois, le volume actuellement mobilisé n'est que de 1285 Millions de m^3/an soit 61% des ressources mobilisables.

Les ressources actuellement mobilisées se répartissent entre les différents bassins hydrologiques du pays comme suit (Tab.2 et Fig.5) :

Tab.2 - Les ressources actuellement mobilisables

Bassin	Potentiel	Ressource mobilisées	Pourcentage
Medjerdah	1000	866	87%
Extrême Nord	910	157	17%
Cap Bon Méliane	210	75	36%
Tunisie Centrale	370	185	50%
Sahel et Sud	140	0	0%
Total	2630	1285	49%

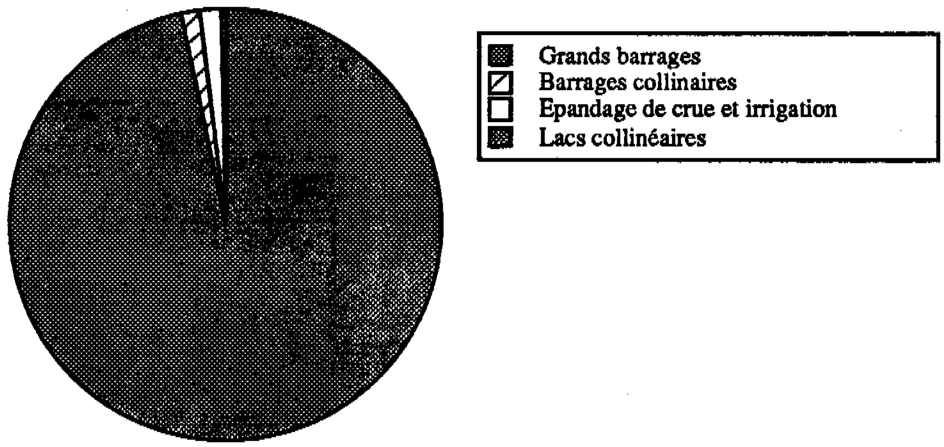
Fig.5- Les ressources actuellement mobilisables



L'état actuel de la mobilisation des eaux de surface se résume comme suit (Fig.6) :

- Les grands barrages (17) :	1242 Millions m^3/an
- Les barrages collinaires (24) :	17,66 Millions m^3/an
- Les ouvrages d'épandage des eaux de crue et principaux cours d'eaux pour l'irrigation de 13100 ha :	23,00 Millions m^3/an
- Les lacs collinaires (50) :	2,86 Millions m^3/an
Total	1285,52 Millions m^3/an

Fig.6- Etat actuel de mobilisation des eaux de surface



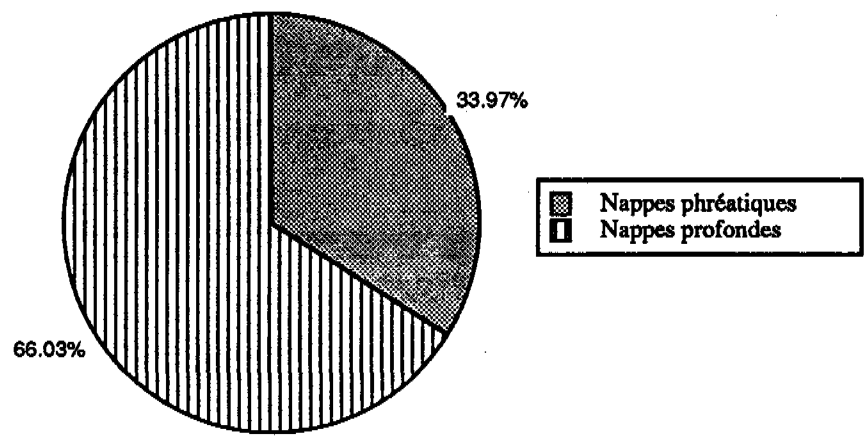
Il y a lieu toutefois de remarquer que sur les 1345 Millions de m^3/an (différence entre le potentiel des eaux de surface et les ressources mobilisées), seuls 815 Millions de m^3/an sont techniquement mobilisables par les barrages d'ici l'an 2000.

III.2 - LES RESSOURCES EN EAUX SOUTERRAINES :

Le potentiel des ressources en eaux souterraines se répartit comme suit (Fig.7) :

- nappes phréatiques :	586 Millions de m^3/an
- nappes profondes :	1139 Millions de m^3/an
	1725 Millions de m^3/an

Fig.7- Le potentiel des ressources en eaux souterraines



La répartition régionale de ces ressources s'établit comme suit (Tab.3 et Fig.8 à 10) :

Tab.3- Répartition régionale des ressources en eaux souterraines

Région	Nappes phréatiques Millions m^3/an	Nappes profondes Millions m^3/an	Total M m^3/an
Tunisie du Nord	325	148	473
Tunisie du Centre	194	267	461
Tunisie du Sud	67	724	791
Total	586 1139	1725	

Fig.8 - Répartition régionale des ressources des nappes phréatiques

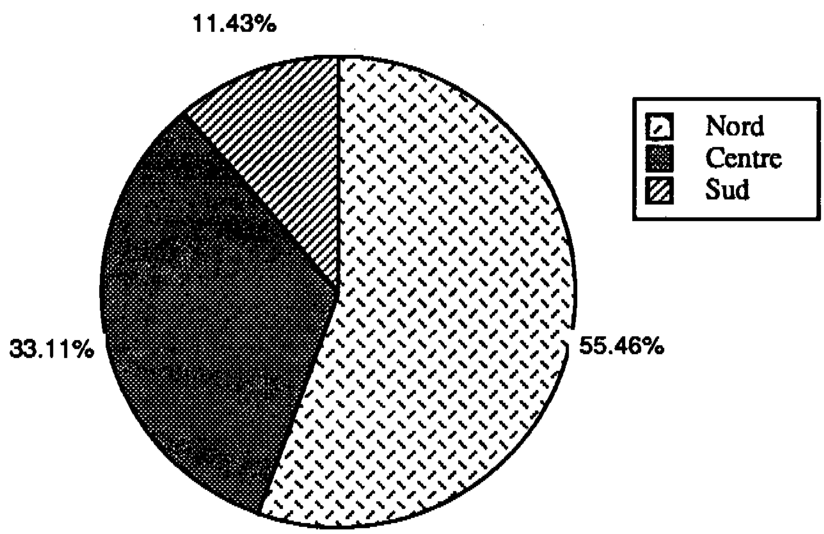


Fig.9 - Répartition régionale des ressources des nappes profondes

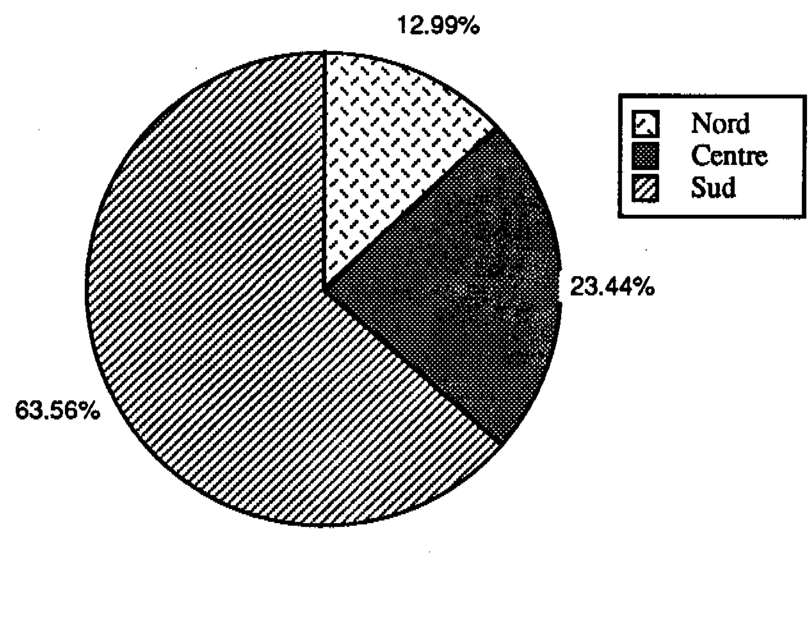
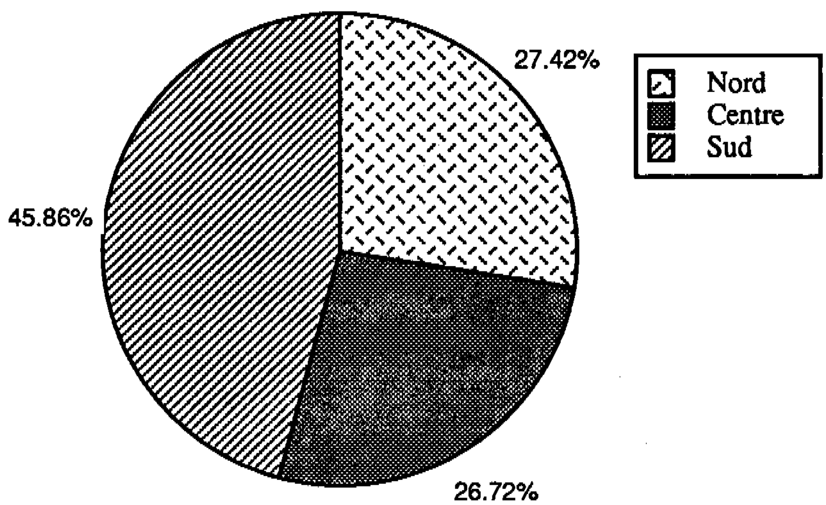


Fig.10 - Répartition régionale des ressources en eaux souterraines

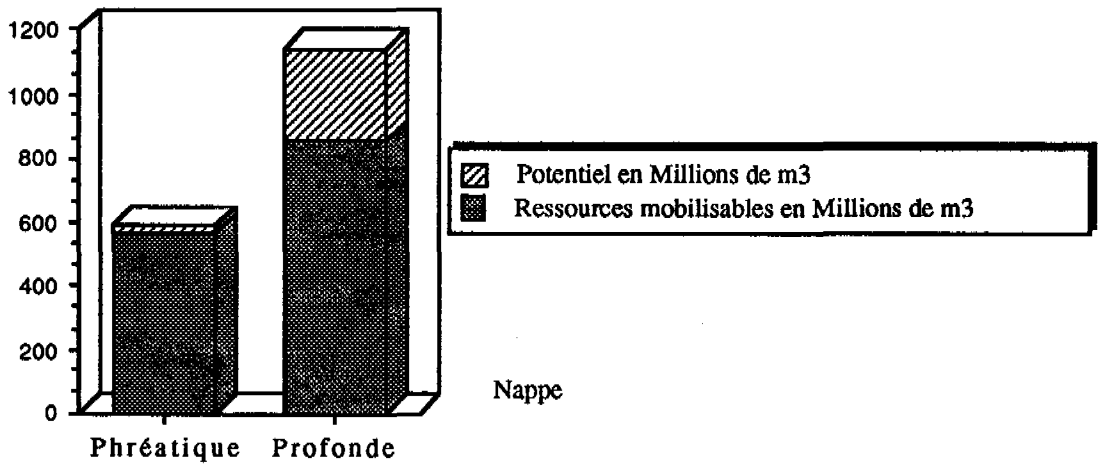


Alors que les ressources en eaux de surface mobilisables représentent 80% du potentiel (soit 2100 Millions de m^3/an), les ressources en eau souterraines mobilisables représentent 100% du potentiel soit 1725 Millions de m^3/an.

Actuellement, les ressources en eaux souterraines qui sont mobilisées représentent pour (Fig.11) :

- les nappes phréatiques : 563 Millions de m^3/an soit 96% du potentiel
- les nappes profondes : 851 Millions m^3/an soit 75% du potentiel

Fig.11 - Les ressources souterraines actuellement mobilisables



L'effort fourni au cours de la prochaine décennie est orienté essentiellement vers la mobilisation des 25% qui restent à prélever des nappes profondes du pays soit un volume global de 288 Millions de m^3/an (79 au Nord, 54 au centre et 155 au sud).

IV - CONCLUSION :

En Tunisie, nous recevons 33 Milliards de m^3/an de précipitations, le potentiel de nos ressources en eau n'excède pas les 4355 Millions de m^3/an

- 1725 Millions m^3/an vont alimenter touts les ans les nappes qui constituent les ressources renouvelable en eaux souterraines.
- 2630 Millions de m^3/an représentent les eaux de ruissellement qui sont mobilisées au moyen de barrages, retenues colinéaire et ouvrages de collecte d'épandage des crues.

Il est peu probable que d'ici l'horizon 2000, sauf découvertes imprévisibles à ce jour, les ressources soient sensiblement différentes de ce chiffre.

Mais quels sont les besoins de la Tunisie?

Pour un climat méditerranéen (type pays du Nord de la Méditerranée) les besoins par habitant se répartissent comme suit:

- Besoins domestiques : 30 m^3/an
- Besoins industriels : 20 m^3/an
- Besoins agricoles : 400 m^3/an

450 m^3/an

Actuellement la population de la Tunisie est de 8 Millions d'habitants.

Pour une population de l'an 2000 (estimée à 10 Millions d'habitants), le bilan des ressources/besoins s'établit comme suit :

a) Scénario 1 :

Un niveau de vie du français actuel (besoin de 510 m^3/an/ht pour une agriculture de pays tempéré).

Bes. 10 Millions d'habitants*510m^3/an/ht	5,1Milliards de m^3/an
Ressources (estimation 1990)	4,35 Milliards de m^3/an
Déficit	0,75 Milliard de m^3/an

à combler par des ressources non conventionnelles

b) Scénario 2 :

Un niveau de vie du français actuel (besoin de 1200 m^3/an/ht pour une agriculture intensive et en tenant compte de l'aridité).

Bes. 10 Millions d'habitantsx1200m^3/an/ht	12,0 Milliards de m^3/an
Ressources	4,35 Milliards de m^3/an
Déficit	7,65 Milliards de m^3/an

à combler par des ressources non conventionnelles.

Pour la Tunisie, la réalité se situera dans un scénario intermédiaire. Donc, d'ici l'an 2000, nous aurons un déficit qui pourra être important. C'est pour cette raison qu'il faut mettre en exécution une stratégie qui s'articulera sur la recherche de ressources non conventionnelles et l'économie de l'eau.

V- RECOMMANDATIONS :

- Réutilisation des eaux usées et traitées:

Les rejets des eaux usées des stations d'épuration dépassent 100 Millions de m^3/an (et pourront atteindre 180 Millions de m^3/an en 2000). Cette eau de "seconde main" est toujours disponible indépendamment des saisons. Le recyclage de ces importantes quantités d'eau en agriculture (culture fourragères et de certains arbres fruitiers) est une solution judicieuse. La réutilisation de ces eaux traitées débouchera sur deux profils capitaux pour l'agriculture (en tenant profit des éléments fertilisants que l'eau usée peut apporter à la plante) et pour l'environnement (en éliminant une eau traitée présumée encore dangereuse pour certains milieux récepteurs).

- Réutilisation des eaux de drainage :

Les eaux de drainage constituent une ressource non négligeable. Les superficies irriguées sont estimées pour l'an 2000 à 360000 ha, qui représentent 7% de la superficie agricole utile, tout en mobilisant presque 1500 Millions de m^3/an d'eau d'irrigation. Approximativement nous pourrons récupérer de ces eaux d'irrigation 150 Millions de m^3/an qui pourront être surveillés (qualité) et réutilisés.

- Développer les techniques d'économie d'eau :

L'ensemble des pertes entre la production de la ressource et son utilisation est estimé à 30%. Si on ajoute les différents gaspillages afférent à une mauvaise ou sous-utilisation de la ressource, on peut estimer à 40% du volume global de la ressource, les quantités d'eau qui sont actuellement perdues. En estimant à 29% de la ressource, les pertes et gaspillages irréductibles, les quantités d'eau qui pourront être économisées s'élevent à peu près à 780 Millions de m^3/an.

Pour les recommandations, nous proposons :

- Pour le secteur agricole :

. la modernisation des conduites d'adduction et des réseaux d'irrigation.

. l'amélioration de la gestion de l'eau à la parcelle : technique d'irrigation par exemple l'utilisation de l'irrigation goutte à goutte.

. l'introduction des techniques nouvelles de contrôle de l'irrigation (irrigation déclenchée par mesure automatique du stock d'eau dans le sol, ferti-irrigation permettant de valoriser au mieux les intrants, contrôle de fertilisants dans le sol, etc...).

. l'encouragement des associations d'agriculteurs ayant pour tâche le partage et la gestion des eaux.

- Pour l'eau potable :

. la modernisation des conduites d'adduction et des réseaux de distribution d'eau ainsi que l'instauration des systèmes de détection et de contrôle de fuites (la SONEDE en 1989 sur un volume produit de 265,8 Millions de m^3, seuls 194 Millions de m^3 ont été facturés aux abonnés du fait que 73,4 Millions m^3 sont perdus).

. l'amélioration des caractéristiques des accessoires sanitaires (robinetterie, chasses d'eau)

. la sensibilisation des utilisateurs en commençant par les gros consommateurs (hôteliers, administrations, usines, etc...)

. la révision de la tarification des eaux : taux progressifs en fonction du volume consommé, taux modulé en fonction de la qualité des eaux rejetées, etc...)

Enfin nous mettons l'accent sur le volet législatif sur la réglementation d'allocation et concession des eaux et la police des eaux qui ont pour actions :

. la révision du cadre des eaux et des textes d'application y afférents de manière à faire face aux problèmes posés par la pollution et l'exploitation abusive de l'eau

. la mise en place d'un corps d'inspecteurs qui ont essentiellement pour tache le contrôle des exploitations abusives des nappes par puits et le prélèvement de grosses quantités d'eau à partir des oueds.

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7

LES ASPECTS INTERSECTORIELS DE LA PLANIFICATION ET DE L'UTILISATION DES RESSOURCES HYDRAULIQUES

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SPAIN

ASPECTS INTERSECTORIELS DE LA PLANIFICATION ET DE L'UTILISATION DES RESSOURCES HYDRAULIQUES

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1. INTRODUCTION

La structuration des emplois sectoriels est fréquemment le résultat du devenir historique récent où certains emplois traditionnels (production agricole et hydroelectricité en particulier) et une conception des ressources hydrauliques associée à des valeurs sociologiques ont formé des équilibres intersectoriels spécifiques pour chaque pays et territoire, mais qui en général présentent une structuration des emplois maximisée en faveur des emplois sectoriels plus traditionnels qui, généralement, en raison de l'évolution des prix relatifs entraînent actuellement une rentabilité moindre de l'eau en tant que facteur spécifique.

La conception de l'eau en tant que facteur productif commence à prendre corps au fur et à mesure que se produit l'épuisement des ressources hydriques et que les demandes nouvelles sont satisfaites à des coûts marginaux très croissants. C'est à ce moment là que la planification comprise comme la gestion intégrée des ressources hydrauliques acquiert une capacité exécutive et incorpore deux principes économiques de base (la productivité marginale de l'eau et les coûts moyens et marginaux de l'offre et de ses accroissements) et également, mais pour des raisons opposées, dans une certaine mesure, la nouvelle évaluation sociale des ressources hydrauliques qui s'aligne avec des options evironnementales et de conservation des ressources naturelles.

Cependant, bien que ces changements conceptuels se soient déjà manifestés dans presque tous les pays et bien entendu au sein des organismes internationaux qui ont abordé ces sujets, la planification se trouve confrontée aux intérêts presque intacts qui surgissent depuis les plans sectoriels, privés, institutionnels et territoriaux correspondant à des

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droits acquis dans le passé, de sorte que l'activité planificatrice requiert une instrumentation à travers un processus de concertation avec les agents (privés, institutionnels et territoriaux) qui détiennent des droits sur les ressources hydrauliques ou qui attendent des bénéfices futurs pour des motifs d'accès à cette ressource, surtout quand à cause de l'activité promotrice du secteur public on maintient des spectatives d'utilisation des ressources hydrauliques à des prix qui internalisent tous les coûts encourus par les nouvelles offres.

Actuellement le cas espagnol est particulièrement intéressant du point de vue de la planification sectorielle et ce, en fonction de deux faits remarquables:

1. Les grands déséquilibres territoriaux entre disponibilités de l'eau et demande de plus grande rentabilité.

2. Disposer d'un instrument légal, un Plan Hydraulique National et les Plans Hydrauliques de Bassin qui, au plus haut rang légal possible dans l'ordonnancement juridique espagnol, prétend établir un cadre planificateur aux horizons de 10 et 20 ans, avec le double critère de respecter les conditions de base des droits acquis et d'incorporer des critères d'efficience sous des formules de gestion intégrée tant sur les plans sectoriels que territoriaux.

Ce processus planificateur a terminé son étape technique; celle-ci sera suivie de son approbation parlementaire.

Dans les pages suivantes les aspects techniques relatifs à la planification sectorielle de l'eau sont détaillés, spécialement les paramètres de demande qui sont, sans aucun doute, les plus exportables. Les critères de base qui, dans l'actualité, instruisent sur le processus planificateur espagnol doivent également être utiles pour la perspective méditerranéenne, puisqu'ils viennent corroborer les plus actuels critères internationaux de gestion des ressources hydrauliques dans un contexte de manque et de coûts croissants.

Les solutions possibles d'offre[1] présentent des caractéristiques plus nationales et donc de moindre intérêt international.

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1 Acrroissement de la capacité hydraulique de régulation, adoption de technologies de gestion et, en particulier, de solutions techniques d'interconnexion des systèmes territoriaux de distribution.

2. PARAMÈTRES DE LA PLANIFICATION DES DEMANDES SECTORIELLES

2.1. Demande urbaine

Aux effets d'assignation et de réserve des ressources hydriques sont adoptées les dotations maximums suivantes aux horizons de planification de l'an 2002 et 2012.

TABLEAU N°1

DOTATIONS MAXIMUMS À L'HORIZON DE L'AN 2002

(POPULATION PERMANENTE) (LITRES/HABITANT/JOUR)

Taille de la zone de population approvisionnée (Municipalité, aire métropolitaine, etc.)	Niveau d'activié industrielle et commerciale de la zone de population		
	Élevée	Moyenne	Basse
Moins de 10.000 habitants	270	240	210
De 10.000 à 50.000 hab.	300	270	240
De 50.000 à 250.000 hab.	340	305	280
Plus de 250.000 habitants	410	370	320

TABLEAU N°2

DOTATIONS MAXIMUMS À L'HORIZON DE L'AN 2012

(POPULATION PERMANENTE) (LITRES/HABITANT/JOUR)

Taille de la zone de population approvisionnée (Municipalité, aire métropolitaine, etc.)	Niveau d'activié industrielle et commerciale de la zone de population		
	Élevée	Moyenne	Basse
Moins de 10.000 habitants	280	250	220
De 10.000 à 50.000 hab.	310	280	250
De 50.000 à 250.000 hab.	350	325	300
Plus de 250.000 habitants	410	380	350

Ces dotations comprennent les pertes en conductions, dépôts et distribution. Elles se réfèrent donc au point de captation ou sortie des bassins, c'est à dire à des volumes fournis.

Le rapport croissant des dotations en fonction de la population est justifié par la réalité actuelle qui établit cette circonstance pouvant être expliquée par le niveau de revenu inférieur des zones moins industrialisées, des plus grandes pertes dans les réseaux de distribution plus grands, la concentration d'activités industrielles et commerciales non segrégées des systèmes de distribution urbains et la plus grande dotation des équipements urbains de type public.

En ce qui concerne les dotations relatives à la population non permanente, en grande mesure liée au secteur touristique on fixe des paramètres spécifiques pour les différents types d'établissements touristiques:

TABLEAU N°3

DOTATIONS MAXIMUMS À L'HORIZON DE L'AN 2012

(UTILISATIONS TOURISTIQUES) (LITRES/PLACE/JOUR)

Établissement	Dotation
Camping	120
Hôtel	240
Appartement	150
Villa	350

La demande urbaine est une priorité de la planification hydraulique à laquelle sont données les garanties maximums. En effet on considère seulement cette demande satisfaite quand une des limites suivantes n'est pas dépassée:

a) Le déficit en un an ne dépasse pas 5-10% du niveau de demande correspondant au noyau de population.

b) Durant deux années consécutives, la somme des déficits annuels ne peur être supérieure à 10-16%.

c) Durant dix années consécutives, la somme des déficits annuels ne sera pas supérieure à 16-30%.

Vu qu'en Espagne il existe une profonde diversité hydraulique entre les bassins des grands fleuves on admet la possibilité que le Plan Hydraulique de chaque bassin adopte un critère concret parmi les trois critères cités, après avoir justifié les raisons de son adoption qui seraient basées sur des indices démographiques, sociaux et économiques et sur les conditions hydrauliques de la région de provenance des ressources hydrauliques.

Une fois dépassée la limite de déficit adoptée on devrait mettre en oeuvre des mécanismes de planification tendant à corriger, à travers de nouvelles offres, la situation de manque structurel.

En contrepartie à la priorité de cette demande urbaine, on lui fixe les volumes de retour à partir de données réelles, avec spécification et contrôle de qualité de l'eau retournée. Si ces données réelles ne sont pas disponibles, on considère un volume de retour équivalent à 80% de la distribution.

Nous devons observer que, pour des raisons démographiques différentes, en Espagne et dans beaucoup de pays méditerranéens il existe une dynamique de population qui oblige, à échéances relativement brèves, à modifier et augmenter la structure territoriale des ressources hydriques affectées à la demande urbaine, de sorte que la planification de l'offre dans ce cas doit être assumée avec une certaine marge d'instabilité.

2.2. Demande agricole

Aux effets de l'assignation et réserve des ressources hydriques pour les irrigations existantes et comme référence de la planification de futures irrigations, on adopte des dotations maximums en fonction de la typologie des cultures dominantes et des conditions d'évapotranspiration des cultures de référence (ET_O). Parmi les différents procédés essayés en Espagne pour la détermination de l'ET_O on a adopté les résultats de "Penman Modifié" (Symposium sur les besoins hydriques des cultures et distribution Madrid 1987) du moment que localement on dispose des données climatiques nécessaires la formule Penman Modifiée par la FAO est recommandée car il s'agit de celle qui s'approche le plus aux valeurs réelles.[2]

Le tableau suivant presenté un détail de ces dotations maximuns établies selon le type de culture:

TABLEAU N°4

DOTATIONS MAXIMUMS POUR LES TYPES DE CULTURE LES PLUS REPRÉSENTATIFS DANS CHAQUE BASSIN HYDRAULIQUE.

(m^3/ha. et an)

BASSIN	CULTURES EXTENSIVES	CULTURES FOURRAGEROS	CULTURES HORTICOLES	CULTURES LIGNEUSES	BASSIN
NORA	3.500	6.800	3.400	4.700	4.300
DUERO	4.200	8.500	4.500	6.500	5.700
TAJO	5.800	10.200	5.700	8.500	7.300
GUADINA	7.000	11.000	5.200	8.000	7.300
GUADALQUIVIR	7.500	11.000	7.700	6.700	7.500
SUD DE L'ESPAGNE	5.000	11.300	5.200	9.200	7.800
SUGURA	6.300	11.800	5.000	8.300	7.700
JUCAR	8.500	10.000	5.000	6.200	6.700
EBRO	5.700	10.300	4.500	7.500	6.700

Les dotations indiquées se réfèrent à des volumes distribués et comprennent la totalité des pertes (en conduction, distribution et application) considérant une efficience globale de 0,6. Elles correspondent à un hectare représentatif du bassin de chacun des groupes de culture et

2 Cependant après l'emploi généralisé de la méthode Penman Modifié, l'opinion la plus répandue dans le milieu technique national est que cette méthode surestime souvent les résultats, en partculier dans les bassins méridionaux.

à l'hectare représentatif de la totalité du bassin, en pondérant les dotations avec les superficies significatives des différents cultures existantes dans les dernières campagnes.

Sur le plan des garanties pour les demandes agricoles on a adopté les suivantes références quantitatives pour la détermination des déficits:

a) La disponibilité en un an doit être supérieure à 80-60% de la dotation maximum établie.

b) En deux ans consécutifs, la disponibilité ne doit pas être inférieure à 70-40%.

c) En dix ans consécutifs, la disponibilité doit être supérieure à 60-20%.

Le Plan Hydraulique de chaque bassin spécifiera le critère adopté parmi les possibilités antérieures en le justifiant par les caractéristiques agroclimatiques de la zone et par les caractéristiques hydrauliques du système d'exploitation des ressources correspondantes.

Aux effets de la planification globale, on estime que la demande agricole génère des retours dont l'évaluation est réalisée à travers des études spécifiques qui tiennent compte des caractéristiques pédologiques et géologiques du sol ainsi que des conditions normalisées d'irrigation. Faute de quoi, ce qui est fréquent pour le moment, on adopte les valeurs paramétriques suivantes:

TABLEAU N° 5

RETOURS DE L'IRRIGATION

Dotations brutes d'irrigation (m^3/Ha/an)	Retours (% de la dotation)
Moins de 6.000 m^3	0 - 5
De 6.000 à 7.000 m^3	5 - 10
De 7.000 à 8.000 m^3	10 - 20
Plus à 8.000 m^3	20

2.3 Demande industrielle

La demande des industries non connectées au réseau urbain et des polygones industriels sont identifiées avec les consommations réelles. Cette identification a été rendue possible grâce à l'effort réalisé aux effets de la formulation des Plans Hydrauliques.

Cette référence paramétrique de la planification de la demande se matérialise dans les dotations suivantes:

TABLEAU N°6

DOTATIONS DE DEMANDE INDUSTRIELLE

(CHIFFRES EN MÉTRES CUBE PAR EMPLOI ET JOUR)

PREMIER ET SECOND HORIZON

SECTEUR		**DOTATIONS**
Raffinage Pétrole		14,8
Chimie	Fabrication produits de base sauf produits pharmaceutiques	16,0
	Reste	5,9
Alimentation	Industries, alcools, vins et dérivés de la farine	0,5
	Reste	7,5
Papier	Fabrication pâte à papier transformation papier et carton.	20,3
	Art graphiques et édition	0,6
Tannages		3,3
Matériaux de construction		2,7
Transformés de caoutchouc		1,8
Textile	Textile	0,6
	Textile branche de l'eau	9,2
Transformés métalliques		0,6
Reste		0,6

Dans les nouveaux polygones industriels on pourra établir la demande en considérant une dotation annuelle de 4000 m^3/ha.

La garantie de la demande industrielle non connectée aux réseaux urbains ne peut pas être supérieure à celle adoptée pour les demandes urbaines, mais en principe elle ne sera pas non plus inférieure.

En ce qui concerne la demande industrielle on fixe les volumes de retour à partir de données réelles, en spécifiant la qualité de la ressource retournée. En cas d'absence d'une évaluation du volume de retour, on adopte une valeur paramétrique équivalente à 80% de la demande brute correspondante, sauf en cas de processus de réfrigération avec un système de circuit ouvert pour lequel ce paramètre atteint 95%.

2.4. Demande environnementale

La considération, en termes de planification exécutive, de débits minimums pour des raisons de type environnemental est un élément nouveau dans la planification hydraulique espagnole. D'ailleurs, dans le passé, ces débits minimums ont eu une considération très faible tant du point de vue strictement quantitatif de la ressource que de sa qualité environnementale.

Dans le processus de planification actuelle, la demande environnementale semble garantie sur le plan normatif jusqu'au point que des accroissements de 10% se formulent à l'horizon de l'an 2002 et de 14% à l'horizon de l'an 2012.

Cependant, cette demande environnementale se trouve dans l'actualité faiblement identifiée, étant prévue l'identification des tronçons de fleuve ou points hydrauliques qui sont considérés d'intérêt (barrages, dérivations importantes, déversements significatifs et autres analogues) pour lesquels on détermine la distribution temporelle et les débits minimums qui doivent circuler en circostances hydrauliques normales.

Dans ce sens, les eaux souterraines méritent une considération spéciale, étant prévue la détermination des débits maximums de décharge des aquifères dans les lieux ou zones d'intérêt pour l'environnement, avec une attention particulière aux zones côtières méditerranéennes et aux aquifères qui soutiennent les parcs naturels.

2.5. Demande énergétique

Les besoins non consomptifs d'eau sont importants dans le cas espagnol, concrètement ceux qui correspondent à la réfrigération en circuit ouvert de centrales thermiques et nucléaires s'élèvent à 4.500 Hm^3 et à 16.000 Hm^3 les utilisations hydro-électriques (16.700 mégawatts de puissance installée).

Heuresement, ces besoins n'entrent pas en concurrence totale avec les autres utilisations sectorielles des ressources hydrauliques puisque les plus grandes centrales se trouvent installées près de la frontière portugaise sur les fleuves Duero, Tajo et à l'embouchure du fleuve Ebro, c'est à dire à la limite du territoire national et donc avec une marge très faible en ce qui concerne la possibilité de faire l'objet d'un autre type d'utilisations sectorielles.

Cependant, de façon générale, bien que la consommation nette soit pratiquement nulle pour ce genre de demandes énergétiques, le besoin de disposer des ressources dans le moment et lieu requis limite ou conditionne les alternatives des différentes utilisations consécutives. De par ce fait l'option planificatrice mise sur la transformation en circuits fermés des grandes industries et de quelques centrales thermo-électriques ce qui permettrait de diminuer les besoins en réfrigération de 90%.

Dans le cas des utilisations hydro-électriques, la planification hydraulique est subordonnée à la planification énergétique qui dispose d'un Plan Energétique National jusqu'à l'an 2.000 dans lequel une croissance de 10% de la puissance installée est prévue. Cependant, à cause de circostances spécifiques de la demande énergétique en Espagne et des prix relatifs, il semble peu probable que les prévisions di PEN se matérialisent de forme immédiate, et ce tant que les circostances du marché énergétique ne seront pas modifiées.

3. CRITÈRES SECTORIELS ET FONCTIONNELS DE LA PLANIFICATION HYDRAULIQUE

Le contexte de manque, actuel ou futur, qui constitue le cadre de la planification dans la qasi totalité des régions méditerranéennes induit, entre autres possibilités, à adopter des critères spécifiquement sectoriels ou des critères qui, bien qu' étant fonctionnels ou de type horizontal, affectent la structuration sectorielle de l'utilisation des ressources hydrauliques. Evidemment, l'adoption de ce genre de critères, vu le caractère dramatique qui accompagne les mesures restrictives de l'eau, demande une délimitation très précise dans le temps et donc seulement certains de ces critères peuvent être adoptés sur des plans territoriaux très concrets.

L'Espagne est prête à adopter des changements dans les critères sectoriels qui, dans le passé récent, ont instruit la politique hydraulique nationale. Malgré la concrétion pour le cas espagnol, il est vraisemblable que ce type de trasformations puisse résulter d'application fréquente dans le territoires méditerranéens actuellement ou dans un futur proche.

Les aspects suivants sont spécialement déterminants de la nouvelle dynamique de la politique hydraulique, et donc déterminants du processus planificateur:

Prix. Face à la traditionelle politique publique d'effectuer l'offre de base des ressources sans contrepartie de prix, on prétend l'application d'un système de tarification pour les services de base de l'eau. On l'instrumentalisera avec un double objectif. D'une part la tarification constitue une alternative au financement public traditionnel des infrastructures hydrauliques, et d'autre part, elle constitue le mécanisme d'internalisation des coûts y compris ceux de type environnemental et les diséconomies produites par les infrastructures et par l'utilisation de l'eau, par les agents et emplois sectoriels qui privatisent les bénéfices dérivés de l'emploi des ressources hydrauliques.

Un système de tarification adéquat demande que le consommateur, soit final, soit intermédiaire, paie le prix égal au coût de la distribution du service. Or le véritable coût économique et environnemental de la ressource, ainsi que les diséconomies dans lesquelles on encourra comme conséquence d'un accroissement de la consommation, doit être reflété par le coût marginal à long terme. Celui-ci comprend tous les coûts d'opportunité:

a) Emploi de ressources économiques qui résultent explicites à travers les coûts d'opérations variables et les coûts fixes de capital (investissement en infrastructures de base, investissement en infrastructure d'investissement et les coûts fixes associés aux deux infrastructures).

b) Coûts d'épuisement de la ressource naturelle qui comprend ceux dérivés des dépenses destinées à garantir le maintien de la disponibilité en quantité et qualité des ressources hydrauliques.

c) Diséconomies résultant du processus de production et distribution des services de l'eau.

L'utilisation du coût marginal à long terme est la contrepartie inévitable en ce qui concerne une ressource naturelle limitée. En outre et pour justifier cela, il faut ajouter que si ce prix n'était pas appliqué, la consommation ne pourrait pas avoir de reférence du manque croissant de la ressource.

Dans une situation de coûts marginaux croissants, le prix constitue chaque fois davantage, un mécanisme de gestion des demandes sectorielles. Ceci est particulièrement vrai si on considère les élasticités-prix spécifiques des divers emplois sectoriels, qui logiquement sont en rapport étroit avec la productivité marginale obtenue de l'eau par les différentes alternatives locales de l'utilisation sectorielle.

Par conséquent, l'application d'un système de tarification peut être de début d'une dynamique pour une assignation sectorielle et territoriale efficiente des ressources hydriques.

Offre. Face à une attitude dans le passé, systématiquement maximaliste de l'offre, on voit apparaître de nouveaux critères basés sur la conservation du patrimoine hydraulique et sur le développement de processus de gestion plus efficients.

L'Espagne a consolidé dans les cinquante dernières années un patrimoine hydraulique important qui demande un volume de ressources annuelles elevé pour sa conservation, en particulier quand on détecte des processus d'aterrement des réservoirs et des obsolescences dans les systèmes de distribution.

L'adoption de nouvelles technologies de gestion des services de l'eau s'est révélée hautement efficace, en particulier dans les territoires qui montrent un niveau d'irrégularité élevé, tant en pluviométrie qu'en distribution temporelle des demandes (irrigations méditerranéennes et tourisme).

Demande. Parmi les mesures spécifiquement sectorielles de demande nous devons distinguer celle qui concerne les irrigations.

Aux raisons traditionnelles, accroissement de la production agricole, développement agricole et intensification du secteur travail dans l'agriculture qui ont instruit et promu les attitudes publiques pour le développement de cette infrastructure hydraulique, deux nouveaux facteurs, dont il faut tenir compte dans le processus planificateur, s'y ajoutent: la rentabilité des transformations en terres irrigables et la disponibilité de ressources hydrauliques.

On ne discute pas la validité de l'irrigation en tant qu'instrument stratégique de la politique de structures agricoles, espagnole et communautaire, capable de promouvoir des objectifs plus amples de développement intégral. La marge de discussion est centrée sur l'intensité des ressources appliquées au développement des transformations en terres irrigables.

En effet, dépasser un niveau critique en ce qui concerne l'irrigation pourrait supposer une diminution de la rentabilité sociale des ressources publiques espagnoles, favoriser les déséquilibres des marchés européens des produits agricoles et même, contribuer à long terme à la détérioration des revenus agricoles vu les effets finaux sur les prix relatifs; au contraire, ne pas atteindre ce niveau supposerait pour l'Espagne ne pas profiter du potentiel agro-industriel qui résulte de ses avantages comparatifs par rapport aux pays de l'Europe continentale.

La relative maximalisation de la production hydro-électrique et le succès d'objectifs publics en ce qui concerne l'environnement sont d'autres critères sectoriels. Pour ces deux objectifs on prévoit des croissances importantes, à un rythme da 1% annuel accumulatif.

La conservation de la qualité des ressources hydriques mérite une référence spéciale, tant parce qu'il s'agit d'un objectif environnemental requis même par la CEE que parce que c'est une mesure remarquable pour la disponibilité des ressources hydriques. Cette action sera celle qui emploiera presque 50% des ressources économiques prévues à l'horizon des 10-20 prochaines années, atteignant un niveau proche des 20 milliards de dollars de nos jours.

Annexe. Bilan hydraulique espagnol

Actuellement le bilan de l'utilisation hydraulique espagnol et des emplois sectoriels répond aux macro-grandeurs moyennes annuelles suivantes:

Précipitation: 670 mm. qui totalisent 340 Km^2.

Ressources hydriques potentielles: 230 mm., 116 Km^3 (3.000 m^3/habitant).

Ressources utilisables: (40% des ressources potentielles), 46 Km^3 à travers 1.000 réservoirs avec un contenu de 50 Km^3 qui fournissent 40,5 Km^3 et 500.000 puits qui fournissent 5,5 Km^3 (desquels 1 Km^3 provient des aquifères surexploités qui ne peuvent être maintenus en tant que situation permanente).

Utilisations consomptives: 30 Km^3 qui sont distribués en 6,3 Km^3 (21%) pour l'approvisionnement urbain et industriel et 23,7 Km^3 (74%) pour arroser 3,1 millions d'ha.

Besoins non consomptifs: 22,9 Km^3 distribués en 4,5 Km^3 (réfrigération en circuit ouvert), 2,4 Km^3 (besoins de l'environnement) et 16 Km^3 (débit hydro-électrique).

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INTEGRATED WATER RESOURCES MANAGEMENT IN THE MEDITERRANEAN REGION - ACTIONS IMPLEMENTED BY PAP/MAP-UNEP

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INTEGRATED WATER RESOURCES MANAGEMENT IN THE MEDITERRANEAN REGION - ACTIONS IMPLEMENTED BY PAP/MAP-UNEP

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ABSTRACT

Water supply represents a long lasting problem in the Mediterranean region, and particularly on the islands and in isolated areas. This conclusion was reached after several years experience in solving these problems, within the activities of the UNEP Center for Priority Actions on the Mediterranean. The shortage of water imposes increasing demands upon the water management and on the policy makers, since this problem is not only technical but is becoming a socio economic problem of wide interest. The paper presents the activities of the UNEP-MAP Center, the gained experience and the suggestions for solving the problems related to water resources management as a part of an integrated environmental management system. The paper also presents the main characteristics of two pilot projects.

1. Regional Activity Center for Priority Actions Programme and Priority field Water Resources

1.1. Introduction

United Nations Environmental Programme - UNEP was established by the General Assembly resolution No. 2997 in 1972. UNEP realizes one part of its activities through a special programme for regional seas. Today there are ten regional seas programmes, the Mediterranean region being the first one of the regional seas programme.

This programme of pollution protection and environmental management of the

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Mediterranean has been implemented by the Mediterranean Action Plan - MAP. The Mediterranean Action Plan is a programme for all Mediterranean countries and the European Community in the implementation of Barcelona Convention of the Mediterranean sea against pollution and its related protocols. The Convention has been in force since 1978.

The MAP consists of four components: Integrated Planning; Programme for Research, Monitoring, Assessment of the State of Pollution and Protection Measures (MED POL); Legal Component; Institutional Arrangements; co-ordination by the co-ordinating units for MAP (MEDU), Athens.

The Integrated Planning component of MAP is expected to deal with the problems of development and its impact on the environment. It has been agreed that this particular component should consist of and operate on two planes:

- Long-term development of the Mediterranean and the problems of development in relation to the environment (the Blue Plan - S.Antipolis).

- Current and acute problems of development in the Mediterranean, the use of its resources, and the impact of both factors on the state of environment (the Priority Actions Programme - Split).

The investigation of the current problems and conflicts between the development and the environment, as well as the assessment of the possible use of available resources in conformity with the environmental protection principles is the primary task of the Priority Action Programme - PAP. It is a practical action - oriented programme based on available Mediterranean and international knowledge. The objectives of the programme are to contribute to the exchange of experience among the Mediterranean countries through:

- Network of experts and institutions,

- Substantive documents (national reports, case studies, seminar and workshop reports, guidelines, codes of practice, methodological documents, etc.),

- Training (expert meetings, seminars, workshops, training courses),

- Expert missions to interested Mediterranean countries.

The objective of the programme is also to cooperate with the national and local authorities and institutions in strengthening the national and local capacities for planning and management in the coastal zones through:

- Provision and dissemination of tools and techniques for integrated planning,

- Training of national and local experts,

- Formulation and implementation of multilateral Mediterranean cooperative projects,

- Direct cooperation within site - specific country projects.

PAP realizes this programme through six priority fields: water resources, human settlements, soil protection, tourism, aquaculture, and renewable sources of energy.

1.2. Priority field: Water resources

In the course of PAP development, the priority action relative to water resources management was steered to the water supply problems of smaller Mediterranean islands. As a result, the 1984-1985 PAP programme on water resources issues envisaged the launching and implementation of the action entitled "Water Resources Development of Islands and Isolated Coastal Areas".

At the end of this period PAP in collaboration with WHO/EURO and Gobierno de la comunidad autonoma de las islas Baleares, cosejeria de obras publicas y ordenacion del territorio, organized the seminar on water and sanitation on small Mediterranean islands and isolated coastal areas, which discussed development of the programme. In the period 1986-1987 this action was expanded to water resources development of large

Mediterranean islands and coastal zones. The results of this period were presented and discussed on the seminar "Water and Sanitation Problems in Big Mediterranean Islands and Isolated Coastal Areas with Fluctuating Population due to Tourism", Malta 1987. After this period the major activities of this action were related to wastewater reuse for agriculture and other purposes. One of the activities was also the preparation of the Malta Water Resources Project.

The experience gained through this period can be summarized like this:

Water resources

Typical elements of islands and isolated coastal areas water resources are perched aquifers, aquifers in contact with sea water, islands mean sea aquifers and karstic aquifers. Rivers are very rare, although the rivers with temporary flow during wet season are common. Lakes are also very rare, but reservoirs are numerous with a wide range of size.

On the majority of islands, the available quantities of water resources have almost completely been exploited; hence, the shortage of water is the main problem and a limiting factor in the development of the islands.

Water utilization

Water is mostly used for domestic purposes, followed by agriculture, with only a small part for industry on the small islands and significant quantities on the large islands. There is a continuously increasing trend in water use for all purposes: population, tourists, industry and agriculture. Today ca. 16,000,000 ha of agricultural land in the Mediterranean region are irrigated and the prediction for 2025 is ca. 40,000,000 ha. The shortage of sufficient water quantities is characteristic for all islands and isolated coastal areas on the temporary basis, while the lack of water for agriculture is permanent during the dry period. However, much worse situations can be expected in the future.

Water resources management

Intensive exploitation and management of water resources has resulted in a great number of structures which should be connected into a unique management system to optimally exploit the available quantities and infrastructure in order to satisfy the increasing demands. The essential condition for the optimal management of water resources, in addition to good organization, is the availability of necessary basic data, which is still missing on most islands. Thus special attention should be paid to gathering and processing of necessary data.

Non-conventional sources of fresh water (desalination, waste water reuse, tankers, under sea pipelines) are already being used, and in the future, will represent the only additional sources of water supply along with the measures for water conservation. Some islands, like Malta, already use these sources of water significantly, and on some small islands the water supply during the summer depends only on these sources.

Special problem in water exploitation is the unfavorable distribution of precipitation with respect to demand which is much greater during the dry period (summer) due to tourism and climatic conditions. Another big problem is a high fluctuation of demand due to tourism activities which results in water consumption in summer 2 to 30 times bigger than in winter. Smaller settlements in general have bigger fluctuation. This situation makes it difficult to provide sufficient quantities of water especially on small islands, and generally requires the construction of reservoirs for water storage, as well as a more complex organization of management which is still non-existent on most islands. Hence the water resources management in the Mediterranean islands and isolated coastal areas is a very difficult task.

Protection of the water resources

The protection of water resources from pollution is not satisfactory, primary due to insufficient and nonadequate sewer systems and treatment plants. This problem, together with the problem of over-use of aquifers and the problem of sea intrusion, represent the greatest constant dangers and threats to these islands water resources. There is also lack of analysis related to the impact of nonconventionl water sources use on the local water resources. Generally, the major sources of pollution are agriculture and urban wastewater. Frequently local water resources are not used due to their pollution.

Other uses and water-related problems

Protection from floods is not a significant problem although some problems related to this field can be considerable on some large islands. Special problem is the temporary flooding of urban areas caused by the absence of a system for storm water collection and disposal.

The situation presented here is very similar to the situation in the entire coastal area of the Mediterranean. This particularly applies to the southern and eastern part of the Mediterranean.

2. DroughtWater Management

As we said, the shortage of sufficient water quantities is characteristic for all islands and coastal areas on the temporary basis, while the lack of water for agriculture is permanent during the dry period. However, much worse situations can be expected in the future.

Past experience shows that the shortage of the water in the region is mainly the result of:

a) High demand as the result of:

- increasing human population,
- technological advancement,
- increasing standard of living,
- development, especially tourism development,

b) Insufficient capacity of water resources

c) Changing environment

- pollution,
- devastation,
- changing hydrological conditions.

Thus, way this is a complex natural and socio-economic problem which we cannot view as a traditional disaster or natural hazard. Consequently drought management is a difficult task which includes issues of comprehensive water management, ecosystemic interdependencies, and risk-based management approaches.

The shortage of water (drought) is expressed by several different types of drought. The kind of drought which we can have in the region are:

- **Meteorological drought** (period without enough rain) described by location, beginning time , precipitation levels and time variations.

In the Mediterranean region the meteorological drought is a seasonable phenomenon, but it has historically consistent conditions. Such a situation most frequently results also in other types of drought.

- **Hydrologic drought** means the shortage in the streamflow, reservoir storage or aqufirs.

The hydrological situation in the Mediterranean area has been comprehensively and in detail analyzed in the Project Blue Plan (J. Margat). This project analyzes also the possible states in the future in accordance with several development scenarios. Some Results of this project are presented in Figures 1,2, and 3.

- **Agricultural drought** depends on soil moisture level determined by precipitation and plant use.

As we have already mentioned this shortage of water on the islands and in the coastal area is constantly expressed, particularly in the summer period.

- **Socio-economic drought**, resulting in shortages, often results from poor preparation and excessive demand rather than lack of rain.
Inadequate planning, lack of financial means, insufficient personnel and improper organization result in an inadequate state of water supply, particularly in the summer period.

Many water managers are dealing with this problem trying to find solutions for on-going droughts and approaches to drought on long-term basis.

Water managers must overcome the complexity and conflict in order to have a chance to successfully apply management methods. Preparation for water management requires planning, design and implementation of water control system, including operations and maintenance, regulatory oversight and coordination. The management of water shortages integrates all facets of water resources management, including water supply, water quality management, irrigation and farm drainage, energy generation, fisheries enhancement, recreation and general aesthetics, as well as flood control.

In such a complex task, there is confusion about who should do what in order to be ready to handle the problem. It is especially true for islands and isolated areas, located generally far from governmental centers.

Responsibilities of water management organizations are direct as:

- Water supply
- Wastewater management
- Environmental water quality
- Irrigation supply
- Energy

and indirect as:

- Water use and discharge regulation
- Information activities

- Policy development
- Financial assistance
- Emergency response.

The general situation is such that water management is a direct and indirect responsibility of more than one organization which makes the problem more complicated.

What should be done to improve the situation and be ready to overcome future shortages of water? It is very difficult to speak generally, but some improvement can be done using past experience and accumulated knowledge through past PAP activities.

According to our experience the topics to be taken into account in order to alleviate the problem of water shortage during a short term and long term periods are, as follows:

We need to improve information activities because they are very important, but generally the most neglected ones. They include:

- Data collection and management
- Analysis and planning
- Coordination
- Research
- Technical assistance
- Training
- Public information/education.

Data management is a critical information activity in the situation of shortage of water. To be sucessfull, data management must be integrated with regulation, water supply assurance, water allocation, planning for development, and comprehensive water management.

In order to overcome the problems of water shortages, the management of water resources should be a continuous process and not a project which starts when we have a drought and finishes when water supplies are back to normal.

The education of the public and officials needs constant attention. To be able to do it we need to improve our knowledge of the problem and local situation and especially interrelationships of natural and man made phenomena.

The administrative structure and communication between water managers in different organizations ,must be very efficient vertically and horizontally, to be able to improve integration of regional water management.

Also, we must improve the general planning and contingency planning and introduce new and adequate techniques for risk assessment and decision making.

However the most important task is to respect nature by using strategies that increase resilience and sustain our resources base. Such strategies include improved agricultural practices , wise water management, strong conservation measures, and institutional changes.

We should try to achieve all this within the existing administrative and governmental system. It means that effective planning and management require imaginative problem-solving and implementable decision-making.

Technical measures which can be used to improve water supply in the future can be summarized in three groups:

- improvement of the use of existing resources,
- water import, and
- use of non-conventional sources.

The improvement of the existing water resources can be generally achieved through: efficiency uses, construction surface retentions, conjunctive use of surface and ground water, conservation and protection of water resources, rain harvesting, and others.

Water import can be realized by import of bottle water, by development of regional water supply systems (inland and off shore systems) and by tankers.

Typical non-conventional water sources are: desalination of sea water, waste water reuse, rain harvesting, widely used in the Mediterranean region.

All of these possibilities have already been implemented in the Mediterranean region so that there is some experience which can be beneficial to those who plan to carry out similar activities.

3. Integrated approach and actions implemented by PAP/MAP-UNEP

All the previously mentioned facts should be taken into account in solving the problem of water resources management, in an organized manner which integrates, on one hand, the developemtn and its water demand, and on the other hand, the natural characteristics and the capacity of the area, including the water resources.

The problem can be solved in the long term period only if it is considered and solved by an integrated approach. This is particularly true for the Mediterranean islands and the coastal zones, where the environment is specially vulnerable, and it presents a natural basis for the development.

Understanding that the protection and enhancement of coastal areas and their ecosystem can be achieved only through a rational development which uses integrated planning as its major tool, PAP placed a special emphasis on its priority action "Integrated Planning and Management of the Mediterranean Coastal Areas".

In order to verify in practice the knowledge and experience gained in all priority actions, and based on the principle of integrated planning and management of resources, PAP started in 1988 the implementation of 4 country pilot projects as a new form of advanced collaboration of PAP and other MAP programmes with national and local institutions and experts aimed at creating conditions for introducing or developing the process of integrated planning and management of coastal resources.

The objective is to achieve an optimal Management Policy which ensures the social goals : equity, efficiency and environmental quality starting from: physical environment, economic criteria , and social and legal decision-making processes.

In the text we will present primary characteristic of two Projects which are in an advance stage.

3.1. Country pilot Project - Malta

Background

At the seminars (Palma de Mallorca, October 1986, and Malta Malta, December 1986) it was recommended that, in the course of the future activities within the priority actions, several pilot projects should be organized in order to analyze the methodology and gather the necessary knowledge and experience of interest for the Mediterranean area and wider areas.

Starting from these recommendations the Government of Malta suggests that the island of Malta should be considered a pilot area.

Consequently a project was suggested; within this project methodologies for an integrated water management system should be developed, both for the watershed and water supply system.

The proposal of the Project was submitted for international competition, and preliminary proposals for the study were received from four firms. After the review of the preliminary proposals the firm Bureau de Recherches Geologiques et Minieres was selected as the most appropriate one.

The agreement for a Study of the Fresh Water Resources of Malta was signed at the Secretariat for Water and Energy in Valetta on June 17, 1989.

UNEP-PAP would be using the Study of the Fresh Water Resources of Malta as a pilot for similar studies on aquifers in other countries. Malta would in the future become the center for seminars on groundwater organized by UNEP-PAP/RAC.

General Project objective

The general Project objectives can be summarized like this:

- To safeguard human health by the protection of the natural resources of the Malta Island.

- To protect the quality of the environment, particularly the fresh water resources, by introducing the necessary administration and infrastructure to ensure the continuing operational control of fresh water utilization.

- To promote the introduction of system engineering practice made suitable for the optimal control of fresh water utilization.

- To develop mathematical models which will permit effective management of aquifers, particularly with regard to: minimization of salt water intrusion; maximization of nett recharge of the aquifer; identification of a well field configuration which will maximize groundwater extraction for the supply; development of a management strategy for the protection of water quality from the surface sources of pollution.

- To provide expertise capable of monitoring previously mentioned items.

- To secure protection of water supply sources against pollution by unidentified factors to be taken into account in the national land-use policy.

- To propose a suitable organization, and advise appropriate legislative and other measures to meet the objectives of the project.

Results and follow up

The Project is in the final phase and the achieved results satisfy the proposed objectives.

One of the results of this Project is a completely new legislation with a new organization of water management resulting from the knowledge that the fresh water on the Island is a finite and vulnerable environment, and that water has an economic value in all its competing uses.

The second result of the Project is the Water Conservation Project for the Island Malta. Namely, in the case of Malta the Water Conservation is the only long term measure which can ensure sustain life, development and protection of environment on the Island.

3.2. Rhodos project

Background

Within the activities carried out for the realization of the MAP Coastal Area Management Programme is the Rhodos Project.

The priority activity is the development of the Water Resources Master Plan for the island of Rhodos. This plan should present an integrated presentation of all the water resources characteristics and would be used to define the optimal exploitation and protection of the resources in accordance with the present and subsequent long-lasting demands on the island. Thus, it would be possible to carry out a sound and efficient management of the both water resources and other natural resources on the island.

Objectives

The long term objective of this study is the protection of the water resources of the island and their optimal utilization.

The immediate objective is development of the Water Resources Master Plan and solution of the current problems in protection end exploitation of fresh water resources.

The expected benefits are a harmonized development and protection of the natural resources of the island of Rhodos.

Results

The project is in the preparatory phase and it is expected that it will be completed by the end of 1993.

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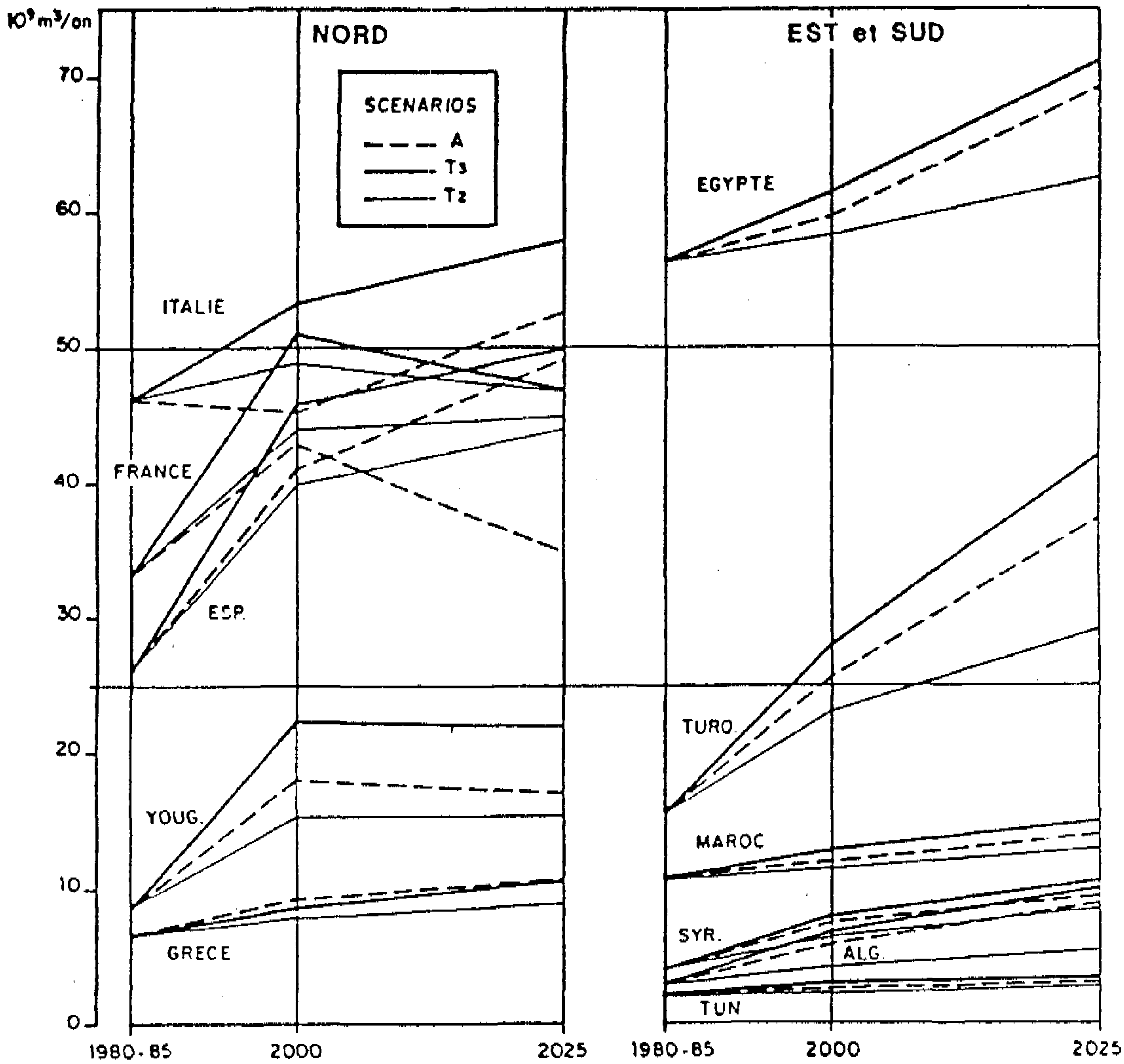

Figure 1. Prospective changes in total water withdrawals generated by needs calculated for the major user countries in 2000 and 2025, for each scenario.

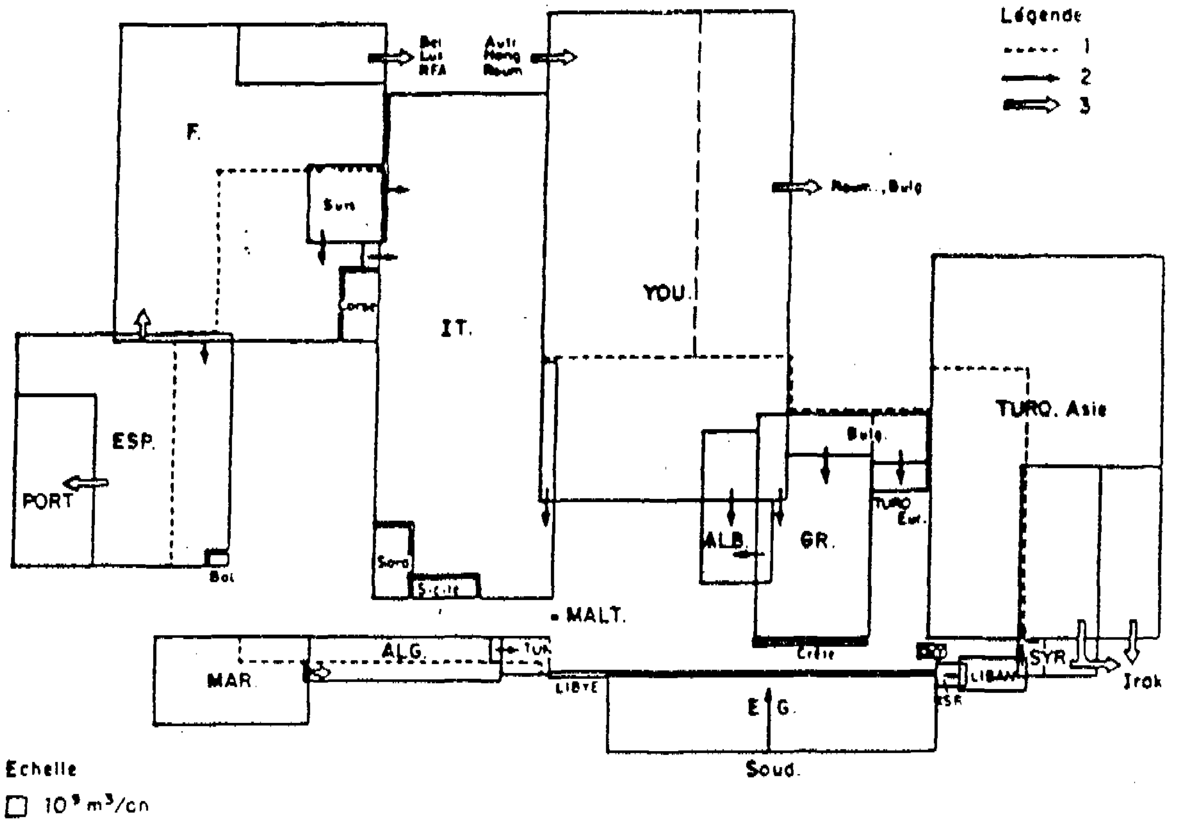

Figure 2 . Comparative "natural water resources in the countries along the Mediterranean (global mean annual volumes of water flow). Cartographic anamorphosis. The intersections correspond to common resources;

1. Boundary of the Mediterranean Basin
2. Natural internal transfers in the Mediterranean Basin
3. Natural transfers to or from outsde the Basin

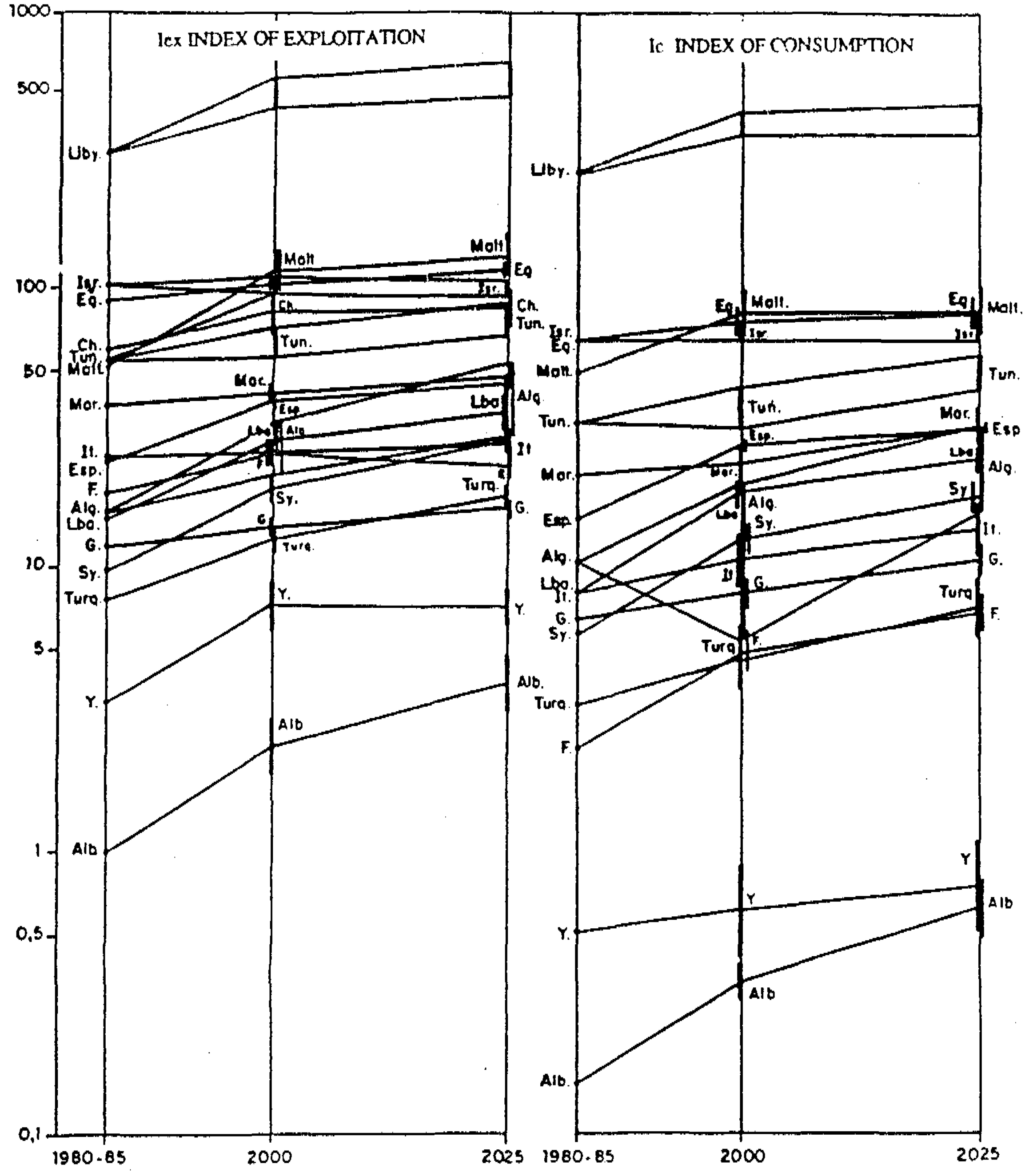

Figure 3. Prospects for indices of exploitation and irretrievable consumption of renewable natural resources in the Mediterranean countries in 2000 and 2025 (averages for each scenarios).

9

THE APPLICATION OF OPTIMIZATION TECHNIQUES TO WATER RESOURCES PROBLEMS

M. AIT KADI

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THE APPLICATION OF OPTIMIZATION TECHNIQUES TO WATER RESOURCES PROBLEMS

M. Ait Kadi (*)

INTRODUCTION

The need to conserve and manage water is not new, although in the past most countries could meet their requirements for domestic, industrial and agricultural supplies well within the water resources available to them. As population numbers increase, coupled with demands for high per capita domestic and industrial consumption resulting from improved standards of living, the sustainable upper limit or "carrying capacity" of water resources utilisation will be approached very rapidly over the next two or three decades in many countries. The situation is most acute in countries which are already heavily dependent on irrigation to meet their domestic food needs. This impeding crisis is unlikely to be recognised as an absolute resource constraint unless planning methods are adopted which are designed to investigate water resources in a comprehensive manner. Hence, in the context of the current critical water shortages and the serious and growing threat they pose to sustainable development and protection of the environment, the Dublin Statement calls for "fundamental new approaches to the assesment, development and management of fresh water resources, which can only be brought about through political commitment and involvement from the highest levels of government to the smallest communities. Commitment will need to be backed by sustainable and immediate investments, public awarness campaigns, legislative and institutional changes, technology development, and capacity building programs...". Underlying all this is the recognition that current water resources planning and management procedures are inadequate to address either the problems of impeding critical water shortages or current concerns about sustainability. There is therefore a felt need for a fundamental reassesment of the methods of analysis and water management adopted and the development of a new framework and new techniques.

Well, during the last 20 years, one of the most important advances made in the field of water resources engineering is the development and adoption of optimization techniques for planning, design, and management of complex water resources sytems. Extensive literature review of the subject reveals that many succesful applications of these techniques have been made. Therefore, the use of optimization techniques for water resources systems planning and management is not new; what is, new however, is the need to make these methods more transparent so that they can find widespread acceptance among all those concerned by the rational development and use of increasingly scarce water resources.

This paper is not intended to be a review and evaluation of the state-of-the-art of optimization techniques applied to water resources systems. Rather it is intended to introduce readers to some of the simplest optimization techniques that have seen successful field applications. The tone of the paper reflects our conviction that courses in these techniques should become commonplace in our training programmes as they can significantly contribute to the needed cultural for a better management of our nations' most vital resources. It is hoped that it will extend the use

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of optimization techniques to a wider audience concerned with water resources planning and management. However, the application of mathematical optimization techniques should not occult the complexity of the multiple demands now being made upon our scarce fresh water resources and the far-reaching impacts which many water use activities are having. This forces us to consider water management in fully comprehensive manner.

ON THE COMPLEXITY OF WATER RESOURCES MANAGEMENT

Water resources in many respects defy rational description. Water is a vital and unique resource in relation to human societies and economies and in the management and protection of the world's natural and ecological resources. Not only is it impossible to substitute another substance to fulfjl water's vital biological functions within living organisms, including human beings, but its complex multifaceted, multifunctional characteristics set it apart from any other natural resource and place it beyond the scope of most of the established approaches for planning and managing the rational utilisation of these resources. It is even debatable whether water should be regarded as an entirely "manageable" resource or whether its quantification will ever be achievable in a comprehensive and precise manner.

The formal and informal means by which water resources are controlled, both politically and economically are complex and varied. In most instances the current sytems are unsuited to resolve the conflicts of interest or priority which arise and may even exhacerbate them. they have also been criticised because they lead to inefficient use of resources and fail to protect the resource base and the environment. Although some people have argued the need for a method of evaluation and control based on monetory values as a prerequisite to efficient resource management, it is questionable whether this can be universally applied in the case of water.

In facing this complexity, it is not surprising that governments and professionals have drawn back from adressing water management in a comprehensive manner. In most cases, they have concluded that it is sufficient to specialise in a small part of the overall water economy in order to meet specific short-term needs. Planners in many of our countries have concentrated particularly on the efficient deployment of capital believing that the main constraint to efficient water management is the lack of infrastructure constrained by the lack of capital. Another way in which planners and managers have sought to achieve a simplification of the complex task they face has been simply to limit the time scale.

Water resources systems are biological, physical, sociological, economic, political, legal, geological and agricultural as well. The relative ease with which one of these aspects might be quantifiable as compared to another, does not in any way reflect a correspondingly greater importance. An approach that does not recognize and integrate these many quantitative and non quantitative dimensions of the system to the greatest extent possible can only produce an academic exercise at best. A more likely result will be a serious, perhaps irreversible, mismanagement of this vital resource. It is with reference to this complexity that the reader is invited to put the application of the optimization techniques described in the following sections into perspective.

GENERAL REQUIREMENTS AND CHARACTERISTICS

Quantitative methods for defining and evaluating alternative water resources plans include a variety of mathematical techniques. These techniques are drawn from the subject area that has been labeled systems analysis, systems engineering,operations research, or management sciences. for most purposes these terms are synonymous.

There are five major steps in using optimization models in practice:

1- Understanding the real problem;
2- Formulating the model;
3- Gathering and generating the input data for the model;
4- Solving the model;
5- Implementing the solution.

In general there is a certain amount of iteration over the five,e.g., one does not develop the most appropriate model the first time around. Of the above steps 1,3 and 5 are if not the most difficult, at least the most time consuming. Formulating good models is an art bordering on a science. It is an art because it always involves approximation of the real world. The artistic ability is to develop simple models which are nevertheless good approximation of the reality.

In the mathematical models used to describe water resource system, the design and operating variables are called decision variables for it is the best values of these variables which are to be determined. They may include, for example, the capacities of various reservoirs and pipelines of a water supply distribution system, or the allocation of land and water to various crops at an irrigation project, or the location and capacity of various flood control reservoirs and levees along a developed river.

Typical optimization models generally include at least one objective function that is either to be maximized or minimized and which serves to rank the alternative solutions or plans. In virtually every case the objective function is a scalar function; that is usage has limited the term to the determination of those quantitaive objectives which are fully commensurate. Water resources systems are particularly troublesome in this regard because there are many noncommensurate and nonquantitative objectives as previously discussed.

In addition to an objective, optimization models incorporate a number of requirements which are formulated as constraints. It is important to distinguish the different roles played by the objective function and the constraints. The optimal solution is a plan that achieves the largest (or smallest) value of the objective while satisfying all the constraints. Constraints can be of two kinds. One type of constraint expresses an actual physical limitation that cannot be violated at any cost. Such limitations may include the conservation of mass, the magnitude of fixed resources, or the capacity of existing or proposed facilities. The second type of constraint is in some sence an implicit objective or goal which in fact could be violated, although the cost of such violation may be high. Such constraints include restrictions on minimum streamflows to maintain water quality, schedules of water deliveries, and budgetary limitations. When goals are formulated as constraints, all feasible solutions must satisfy these goals. There is no explicit incentive for overfulfilling these goals, nor are the goals permitted to be reduced if the cost of meeting them is too high. These adjusments are often made after an examination of the optimal solution of the problem as initially formulated. Occasionally, deciding whether a requirement should be a constraint or an objective is difficult, simply because objectives are not well defined at the beginning of the formulation process.

There are two basic approaches for solving water resource systems problems: optimization and simulation. Optimization includes a diverse set of techniques among which Linear programming and Dynamic programming are the most commonly used. Simulation relies on trial-and error to identify near-optimal solutions. The value of the decision variable is set, and the resulting objective values are evaluated. the difficulty with the simulation approach is that there is often a frustratingly large number of feasible solutions or plans. Even when combined with efficient techniques for selecting the values of each decision variable, an enormous computational effort may lead to a solution that is still far from the best possible.

The choice of methods depends on the characteristics of the problem being considered, on the avilability of data and the on the objectives and constraints specified. Combinations of different methods have also been reported in the literature. Linear and dynamic models and simulation procedures are considered in the following sections.

LINEAR PROGRAMMING

Linear Programming (LP) has been one of the most widely used techniques in water resources management. It is concerned with solving a special type of problem: one in which all relations among the variables are linear, both in constraints and in the objective function to be optimized.

A typical LP model is

$$\text{Min } Z = C^t X$$

subject to

$$AX >= b \quad X >= 0$$

in which

- C n-dimensional vector of objective function coefficients;
- X n-dimensional vector of decision vaiables;
- b m-dimensional vector of right hand sides;
- A m x n matrix of constraint ("technological") coefficients;
- t transpose operation.

the application of LP to water resources management vary from relatively simple problems of straightforward allocation of resources to complex situations of operation and management. Under certain assumptions, nonlinear problems can be linearized and solved.

The essential advantages of LP include (1) its ability to accomodate relatively high dimensionality with comparative ease, (2) universal optima are obtained, (3)no initial policy is needed and (4) standard computer codes are readily available[2]. The irrigation planning example given in appendix I illustrates an application of linear programming. This example has been selected to demonstrate the integration orientation of optimization models and the need not only of an adequate knowledge of resources and the constraints within which the resources must be managed but also of an adequate and reliable database without which management is a difficult task.

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2 Unlike most other optimization techniques, commercial Linear Programming packages are available even on microcomputers. Hence to use linear programming it is not necessary to understand all the details of the linear programming solution procedures. This a distinct advantage over most other types of optimization which has created the incentive to structure many nonlinear as well linear water planning problems as linear optimization models.

DYNAMIC PRORAMMING

Dynamic programming (DP), a method formulated largely by Bellman [1957], is a procedure for optimizing a multistage decision process. DP is used extensively in the optimization of water resource systems. The popularity and success of this technique can be attributed to the fact that the nonlinear and stochastic features which characterize a large number of water resources systems can be translated into DP formulation. In addition, it has the advantage of effectively decomposing highly complex problems with large number of variables into a series of subproblems which are solved recursively.

It is not unusual to find that a problem can be formulated in more than one way, and part of the art of DP lies in deciding the most efficient formulation for the problem at hand. For example, stages may represent different points in time or in space, and states may be continuous rather than discrete.

Following closely the notation of Bellman, it is assumed that the problem system may be modeled through a st of the following mathematical concepts of objective function, state variables, control or decision variables and transformations. Formally then we consider a state vector $X_t = (x_t(1), x_t(2),... x_t(n))$ which describes the system at the start of the i^{th} stage. Each element (1,2,..,n) of the vector X_t measures a different property of the system, n being the dimension of the state vector. The policy or decision vector $Q_t = (g_t(1),g_t(2),...g_t(r))$ is the vector of r decision variables to be selected at each stage from the set of allowable vectors $S(Q_t)$.

The state of the system at the t+1 stage is then determined by the vector of stage-to-stage transformation equations T_t whereby:

$$X_{t+1} = T_t(X_t,Q_t)$$

For an n stage decision problem we concern ourselves here with the problem of maximizing an objective function of the form:

$$R(X_1,X_2,....X_N,Q_1,Q_2,....Q_N) = \sum_{t=1}^{N} h_t(X_t,Q_t)$$

The problem is to select a sequence of decision vectors $Q_1,Q_2,....Q_n$ which maximize R.

The maximization procedure results from applying the principle of optimality:"an optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision."

Let the maximum value of R, which depends only on N, the number of stages and X the initial state, equal $F_N(X)$. Then by the principle of optimality the basic functional equation is obtained:

$$F_1(X) = \max_{Q_1} h(X_1,Q_1$$

$$F_N(X_1) = \max [h(X_1,Q_1) + F_{N-1}(T(X_1,Q_1))] \quad N>=2$$

The solution is then determined by making repeated use of the above functional equations. The procedure is demonstrated in the example given in appendix II where DP is applied to the determination of reservoir releases.

SIMULATION

Simulation is perhaps the most powerful of all the tools available to water resource systems analysts, but the reason of its extraordinary power lies in its mathematical simplicity rather than its sophistication. It is a modeling technique that is used to approximate the behavior of a system on the computer, representing all the characteristics of the system largely by a mathematical description. It is different from a mathematical programming technique. Mathematical programming techniques find an optimum decision meeting all system constraints while maximizing or minimizing some objective. On the other hand, the simulation model provides the response of the system for certain inputs, which include decision rules, so that it enables decision maker to examine the consequences of various scenarios of an existing system or a new system without actually building it. A mathematical programming model usually requires assumptions on model structure and system constraints for practical implementation, whereas a simulation model is more flexible and versatile in simulating the response of the system. On the other hand, optimization looks at (implicitly) all possible decision alternatives, while simulation is limited to finite number of input decision alternatives. A typical simulation model for a water resources system is simply a model that simulates the interval-by-interval operation of the system with specified inflows at all locations during each interval, specified system characteristics and specified operating rules.

Simulation models have been successfully used by various practitionners often in conjunction with streamflow synthesis. Indeed the two techniques are close partners among the arsenal available to water-resource planners. In recent years a tendency has been toward incorporating an optimization scheme into a simulation model to perform certain degrees of optimization. It has been quite common to have a few optimization routines nested in a simulation model. Because of the complexities of water resources systems and noncommensurable objectives in water resources management, simulation is an effective tool for studying the operation of the complex water resource system incorporating the experience and judgment of the planner or design engineer into the model.

CONCLUSION

The application of systems methods such as mathematical optimization and simulation can significantly aid in the definition, evaluation and selection of water resources investments, designs, and policies. There is increasing use and documentation of successful field applications of these techniques. Although this is still a very active area of research, a large amount of knowledge and practical experience is already available as a basis for action.

It is an important task for us within CIHEAM to make these techniques known and to develop them so that they can be applied by all those concerned by the rational development and use of our water resources especially in the context of impeding water shortages and growing concerns about sustainability in the Mediterraneen region. More specifically, it is our belief that incorporating courses on these techniques in the training curricula of our institutions will contribute to improving the water consciousness and water management ability of the future decision-makers and practioners as it will make them:

(a) Better informed as to the full dimensions of water resources development, the benefits as well as the costs;

(b) More sensitive to the desirable and undesirable effects of resources development including environmental impacts;

(c) Familiar with each component of the analysis;

(d) More confident of their ability to offer judgements and make decisions.

It is hoped that CIHEAM will take the necessary actions to promote training and research in this important field which has already proved to be an indispensable aid to managerial decision making.

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APPENDIX I

A LINEAR PROGRAMMING MODEL FOR AN IRRIGATION PLANNING PROBLEM[3]

Consider a hypothetical irrigation district containing various soil types in various areas of the district. If there is a variety of crops that can be grown in the irrigation district, one must decide which crops should be grown on which soil types in which area. The crop yield that can be expected will depend, in part, on (1)the physical characteristics of the irrigation area, (2)the crop type, (3)the amounts and timing of water and fertilizer applications, (4)the available labor and machinery, and on (5)how effectively these resources are used (i.e., the farm practices).

In order to estimate how much of each resource input should be allocated to each area, and to decide the type and quantity of each crop that should be planted and where each crop should be planted, it is convenient to divide the whole irrigation district into compartments or subareas. Each designated subarea should exhibit similar physical characteristics. In other words, each subarea should be confined to a single, specific soil type and to a relatively local and homogeneous region of the district. The latter restriction is necessary to ensure that cost of transporting any resource input to the subarea and of operating within the subarea are essentially uniform throughout the designated subarea.

It is assumed in this example that it is possible to use groundwater to supplement surface water supplies, or as a source of water in times of surface water shortage.

The irrigation planning model can provide estimates of the quantities of all resource inputs (labor, fertilizer, pesticides, seed, machinery, capital or credi, etc.) and their costs; the location, quantity, and types of crops to plant; and, if appropriate, their market price that together maximize net income.

Resource Inputs

First several indices or subscripts must be defined. Let subscript j represent a particular subarea. If the area of the subarea is denoted as A_j then $\sum_j A_j$ is the total area of the district.

Next, let subscript f distinguish among various farm types. For planning purposes, existing or potential farms can be grouped into various types charcterized by their size, their level of technology, their productivity or efficiency, and their financial resources.

Fianlly, let the index c represent a particular crop, such as maize, cotton, rice, sugar cane, or whatever is appropriate for the particular subarea and farm type. If any particular crop can be grown under different management practices by a specific farm type f, then each crop management combination is denoted by a different index c.

Having defined these three indices, it is now possible to ask how many hectares in subarea j should be planted with crop c. These are unknown decision variables, and will be denoted as X_{jfc}. If farms already exist in the irrigation district, then within each subarea j the areas AF_{jf} of each farm type are known. In this case the total area planted in crop c by any particular farm type f

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[3] Reported by D.P. Loucks et al in Water Systems Planning and Analysis, Prentice-Hall

cannot exceed the area operated by each farm type in each subarea j,

$$\sum_c X_{jfc} <= AF_{jf} \quad \text{all j,f} \tag{c1}$$

where of course, $\sum_f AF_{jf} <= A_j$. In situations where new farms must be developed, and hence the farm typeis unkown and to be determined, each farm type area AF_{jf} is unknown, and instead of equation (c1) constraint c2 is required

$$\sum_f \sum_c X_{jfc} <= A_j \quad \text{all j} \tag{c2}$$

Given specific resource inputs and use of these inputs by each farm type, the expected or target yield of each crop c per unit area in subarea j must be estimated from crop production functions or from experience. Denote this yield per hectae as Y_{jfc}. Then the total yield of crop c on farm type f in subarea j is simply the product $Y_{jfc} * X_{jfc}$. The gross income I_f of all farms in each farm type is the sum of the total yield times the price P_c per unit of each crop c.

$$I_f = \sum_j \sum_c P_c Y_{jfc} X_{jfc} \quad \text{all f} \tag{c3}$$

To obtain these yields, specific resources must be available. Each hectare of crop c will require various quantities of seed, fertilizer and pesticides, labor, machinery, and water. of course, these resource inputs will vary somewhat in practice, but for irrigation planning, it is convenient to assume that they are fixed and known. This assumption implies that shortages in one or more resource inputs will limit the hectares of crops rather than the yield per hectare.

Water - In each period t of the growing season, let the total quantity of water required per hectare of crop c in each subarea j of each farm type f be designated as W_{jfct}. Thus the total ground and surface water required, $Q_{jft}^{GW} + Q_{jft}^{SW}$, by each farm type f in each subarea j in each period t equals

$$Q_{jft}^{GW} + Q_{jft}^{SW} = \sum_c W_{jfct} X_{jfc} \tag{c4}$$

This water can be obtained from surface water allocations q_t or from groundwater pumping g_t, if conjunctive operation of both surface and ground water supplies is appropriate or acceptable. In this case the total quantity of water w_t required in each period t of the growing season is the sum of the groundwater (Q_{jft}^{GW}) and surface water (Q_{jft}^{SW}) allocations.

$$\left.\begin{array}{lll} \sum_j \sum_f Q_{jft}^{GW} = g_t & \text{all t} \\ \sum_j \sum_f Q_{jft}^{SW} = q_t & \text{all t} \\ g_t + q_t = w_t & \text{all t} \end{array}\right\} \tag{c5}$$

There may also be limitations on canal capacities and the maximum amounts of surface and groundwater available in each period t. These restrictions, if any, can be included as constraints.

Fertilizer and Pesticides - The total quantity F_f^k of fertilizer or pesticide type k required in the growing season by each farm type f will equal the quantity required per hectare F_{jfc}^k times the hectares in that category X_{jfc} summed over each subarea and crop type.

$$F_f^k = \sum_j \sum_c F_{jfc}^k X_{jfc} \quad \text{all f and k} \tag{c6}$$

Labor - The total person-hours of labor L_{ft}^{k} of skill type k required by each farm type f in each period t of the growing season will equal the sum over all subareas and crop types of all person-hour requirements per hectare L_{jfct}^{k} times the total respective land areas X_{jfc}.

$$L_{ft}^{k} = \sum_j \sum_c L_{jfct}^{k} X_{jfc} \qquad \text{all } f,k,t \tag{c7}$$

There may also be some restrictions on the total person-hours of labor available for one or more skill types k.

Equipment - The total hours E_{ft}^{k} of equipment type k required by each farm type f in each period t of the growing season depends on the given hourly requirements E_{jfct}^{k} per hectare and on the unknown hectares X_{jfc}.

$$E_{ft}^{k} = \sum_j \sum_c E_{jfct}^{k} X_{jfc} \qquad \text{all } f,k,t \tag{c8}$$

The number of units U_f^{k} of equipment type k required for irrigation activities by each farm type f in the irrigation district may be of interest if the equipment is to be purchased by each farm. This number can be estimated from a knowledge of the average number of hours H_{kt} each unit of type k equipment will be used per period and the total hours of required use E_{ft}^{k} by each farm type f.

$$U_f^{k} >= E_{ft}^{k} / H_{kt} \qquad \text{all } f,k,t \tag{c9}$$

Seed - The quantity of seed or planting stock S_{fc} of crop c required by each farm type f can be estimated from a knowledge of the seed requirements per hectare s_{jfc} and the total hectares of crop c planted by farm type f.

$$S_{fc} = \sum_j s_{jfc} X_{jfc} \qquad \text{all } f,c \tag{c10}$$

A lack of any resource input may restrict the values of these unknowns areas X_{jfc}. If any of the required resource inputs, such as water, labor, equipment,etc., are limited, or if their use is restricted (as pesticide use might be for environmental reasons), then upper bounds should be placed on the quantities of those resources that are limited or restricted.

It is to be mentioned that crop diversification can be accounted for by introducing appropriate constraints.

Annual Costs

The total cost of each resource for each farm type can now be estimated. These resources include land in addition to the above-mentioned water, fertilizer, pesticides, equipment, labor and seed.

Land - If the irrigated land incurs a cost C_{jf}^{D} per unit area that is dependent on its location and soil type j, and perhaps also the farm type f, then the total land cost TC_f^{D} for farm type f is

$$TC_f^{D} = \sum_j \sum_c C_{jf}^{D} X_{jfc} \qquad \text{All } f \tag{c11}$$

Water - The cost of water TC_f^{W} for each farm type f may include an allocated portion δ_f of the fixed costs $C_g^{W}(g)$, $C_q^{W}(q)$,and $C_w^{W}(w)$ associated with the channel capacities g, q,and w, respectively and groundwater pumps. The cost will also include the fraction τ_{jf} of the cost $C_j(q_j)$of channel capacity q_j to farm type f. In addition, there are variable costs associated with each water allocation Q_{jft}. These variable costs include the cost to obtain and transport water to each subarea j in each period t. Denoting the variable cost per unit quantity of groundwater as C_{jt}^{GW}, and those of surface water as C_{jt}^{SW}, the total cost of water for each farm type f is

$$TC_f^W = \sum_j \{\delta_f [C_g^W(g) + C_q^W(q) + C_w^W(w) + \tau_{jr} C_j(q_j)] + \sum_t (C_{jt}^{GW} Q_{jft}^{GW} + C_{jt}^{SW} Q_{jft}^{SW})\} \quad \text{(c12)}$$

If some cost functions are nonlinear, they need to be made piecewise linear for inclusion in any linear optimization model.

__Fertilizer and Pesticides__ - The cost of fertilizer TC_f^F and/or pesticides for each farm type f will depend on the unit cost C_k^f for each type k of fertilizer or pesticide. Recalling that F_f^k is the quantity of type k required by farm type f, the total cost is

$$TC_f^F = \sum_k C_k^F F_f^k \quad \text{all f} \quad \text{(c13)}$$

__Labor__ - The cost of labor TC_f^L for each type farm f may include wages per unit of time worked or fixed salaries per individual, or a combination of both depending on the type of job and skill level k required. Assume that labor of type k is paid an hourly wage rate of C_k^L. Recalling that L_{ft}^k are the required person-hours of the kth type labor for farm type f in period t, the total labor cost for each farm type f is

$$TC_f^L = \sum_t \sum_k C_k^L L_{ft}^k \quad \text{all f} \quad \text{(c14)}$$

__Equipment__ - The cost of equipment TC_f^E for each farm type will depend on the fixed annual costs $FC_k^E(U_f^k)$ of each unit of equipment U_f^k and on the variable hourly operating costs VC_k^E multiplied by the hours E_{ft}^k of type k equipment usage by each farm type f in each period t.

$$TC_f^E = \sum_k [FC_k^E(U_f^k) + \sum_t VC_k^E E_{ft}^k] \quad \text{all f} \quad \text{(c15)}$$

__Seed__ - The cost of seed or planting stock TC_f^S for each farm type f will depend on the unit cost C_c^S of each type c of seed and the quantity S_{fc} used.

$$TC_f^S = \sum_c C_c^S S_{fc} \quad \text{all f} \quad \text{(c16)}$$

__Capital__ - It may be necessary to borrow money at the beginning of the growing season in order to have sufficient cash to be able to pay those costs which occur prior to the receipt of income from the sale of crops. If this is the case, it is appropriate to include a budget constraint limiting the total cost TC_f to be no greater than the available capital M_f^A plus the borrowed capital M_f^B.

$$TC_f =< M_f^A + M_f^B \quad \text{all f} \quad \text{(c17)}$$

The capital that can be borrowed by any farm type may itself be limited to some some amount M_f^{Bmax}

$$M_f^B =< M_f^{Bmax} \quad \text{(c18)}$$

Assuming an interes rate of r_f for borrowed capital, over the period borrowed, which might vary for different farm types f, the cost of borrowed capital will be $r_f M_f^B$.

<u>Total Cost</u> - The total cost TC_f for each farm type f is the sum of all the individual annual costs of all resource inputs plus the cost of any borrowed capital.

$$TC_f = TC_f^D + TC_f^W + TC_f^F + TC_f^L + TC_f^E + TC_f^S + r_f M_f^B \quad \text{all } f \qquad \text{(c19)}$$

Annual Net Income

The annual net income for each farm type f will equal the total annual gross income I_f (eq. c3) less the total TC_f.

The Irrigation Planning Model

Assuming an objective of maximizing total net income from the irrigation district, this objective can be written

$$\text{maximize } \sum_f (I_f - TC_f)$$

This objective function subject to constraints and definitions c1 to c19 as appropriate, constitute the irrigation planning model that can be solved by linear optimization techniques. The solution of the model will provide estimates of each X_{jfc}, the hectares of subarea j of crop c managed by a farm of type f.

APPENDIX II

A SIMPLE EXAMPLE OF APPLICATION OF DYNAMIC PROGRAMMING: DETERMINATION OF RESERVOIR RELEASES

In applying DP to the determination of reservoir releases, the state variable is the storage and the decision variable is the release. The stage is represented by the time period i. The stage-to-stage transformation is chaaracterized by the continuity equation:

$$S_{i+1} = S_i + I_i - R_i - e_i$$

subject to

$$S_{min} =< S_{i+1} =< S_{max}$$

and constraints on releases

S_i storage at the begining of time period i

I_i the inflow during time period i

R_i release during time period i

e_i evaporation during time period i

Suppose an objective function J(S,R) has been chosen for maximization. Note that J in general is a function of release as well as storage. A typical forward DP recursive equation can be written as

$$F_{i+1}(S_{i+1}) = \max_{R_i}[J(R_i,Sav_i) + F_i(S_i)] \qquad i = 0,1,2,....T$$

where S_0 is the given initial storage and Sav_i the average storage given by:

$$Sav_i = (S_{i+1} + S_i)/2$$

The state variable (storage) is generally discretized into a number of feasible states.

Suppose that the inflow sequence is given and the evaporation term is temporarily ignored; the continuity equation now becomes

$$S_{i+1} = S_i + I_i - R_i$$

If S_{i+1} and S_i are chosen, R_i can be directly computed from the above continuity equation.

The optimization is over the proper choices of the R_i's. The problem of interpolation is avoided, since the R_i's are computed by fixing the states S_{i+1} and S_i. Solutions are imbeded in the discretized states. The infeasible transitions are discarded in the solution process.

The inclusion of the evaporation term e_i poses no difficulty, since evaporation is a function of the average storage Sav_i.

The recursive equation is carried out until the final stage T is reached. The optimal solutions can then be traced back to determine the consequent releases and storages.

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ENVIRONMENTAL IMPACTS OF WATER RESOURCE DEVELOPMENT AND MANAGEMENT

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ENVIRONMENTAL IMPACTS OF WATER RESOURCE DEVELOPMENT AND MANAGEMENT

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INTRODUCTION

Environmental issues in the Southern of the Mediterranean, like in most other developing countries, have received limited attention in the past. However, with increasing human activities, protection of land and water resources of the region is becoming a priority consideration.

A reasonably clear and detailed picture of environmental issues confronting the land and water sector did not exist. Nor any accurate estimates on the cost of land and water degradation to the national economy. The cost is already significant at present, and if no drastic action are taken, the existing trends show that it is likely to become even higher during the 1990s,

Water pollution already is a serious problem in certain countries of the Mediterranean. While a reasonable clear picture exists in terms of salinity of water, availability of usable information on other water quality parameters is very limited. Time series data on various water quality parameters are basically non existent. Some data are available on a few parameters, but their potential use for water quality management is extremely limited since they are collected at long intervals, often in a random time sequence, and only at a few selected places.

In the nineties, the main challange facing the water resources profession is how to maximize all the positive impacts of any water development present, planned or already operational and minimize the adverse impacts.

Therefore, this paper will concern with the fundamental issue of how to accomodate water resources development within the context of environmental preservation and improvement.

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AREAS OF ENVIRONMENTAL IMPACTS

Primary impacts
- caused directly by project inputs

- attributed directly to a project activity
- Easy to measure

Secondary impacts
- caused by output projects (water flow regulation channelization)
- indirectly attributed to the project activity
- more difficutl to predict and measure

Tertiary impacts
Are the resultant of secondary impacts

The distinction between primary secondary and tertiary impacts could be often arbitrary.

In the ecosystem, impacts are usually complex and one impact may lead to another, resulting in chain-actions. For example deforestation could contribute to increased reservoir siltation wich could lead to a loss in down stream fishery, causing malnutrition which in turn may increase sickness and a major impact may be often due to a combination of factors. The causal linkages between impacts may not be direct or clear-cut.

Impacts could be also conceptually divided into two brand categories:

ENVIRONMENTAL IMPACT CATEGORIES

Short term impact occur during planning, constructing and immediate post construction phases
Many adverse impacts: noise, soil disturbance, air pollution, disruption of transport.
Serious environmental social and sanitation problems

Long term impact stem from the presence of:
- Large man made lakes
- Development of perennial irrigation instead of seasoneal one
- alternation in the ecosystem of the area
- changing in the socio-economic

Long term impacts could be grouped in the followings:

LONG TERM IMPACTS

Physical-chemical impacts

- Impacts on water quality:
  siltation, depletion of dissolved oxygen, nutrients accumulation, salt control
- Impacts on ground water:
  Salt content;
  Contamination of fertilizers and pesticides;
  Ground water table rais
- Impacts on soils:
  Soil degradation hazards;
  Water logging and salinity;
- Earthquakes
- Ground water mining
  excessive ground water table with drawal
- Effects on climate:
  New microclimates created by large reservoirs

Biological impacts

- Impacts of living organisms:
  Flooding of reservoirs area;
  Fishery in the reservoir;
  Nutrient level in water and acquatic weeds;
- Impacts on heath
  water related diseases

Socio-economic impacts

- Impacts on the economy
- Impacts on archeo-logical sites
- Impacts on socio-cultural structures

ENVIRONMENTAL EFFECTS OF WATER RESOURCES DEVELOPMENT

Environmental issues related to water resources encompass a wide range of concerns, including public health, pollution of surface and ground waters, lowering of ground water tables, salt water intrusion, reduced sedimentation in flood plains, changes in river hydrographs, reduction of wetland area, increased riverbed erosion and costal and marine pollution.

Concerning the Mediterranean region, broadly, several types of environmental effects of water surface development may be recognized.

The first one is disruption of human settlements and human activities. For example, the formation of lake Nasser in Egypt and Lake Nubia in Sudan necessitated the displacment of more 100.000 people. Occasionally, particularly, when a drought occurs, such disruptions are very large.

A second type of environmental effects associated with water development in some parts of the Mediterranean region is the creation of favorable habitats for the parasitic and water-borne diseases, such as schistosomiasis, malaria, filiariasis and river fluke infections.

Large water resources devolopment projects in Africa (such as a Lake Karabia in Zambia/Zimbabwe, lake Volta in Ghana, lake Kainji in Nigeria and Lake Nasser in Egypt) have almost invariably to considerable increase in the incidence of water based infections and those caused by water related insect vectors (Hughes and Hunter 1971; Miligan and Thomas 1986; Obeng 1978).

Among diseases spread by water development projects, schistosomiasis (Bilharziasis) [Sub-Sahara Africa, Arabian peninsula, the Nile valley Egypt, Iran a part of the Midle East, Brazil, Venezuela, China, Japan and the Phillipines]. The number and its victims is currently to be estimated to be 200 million. In Egypt the estimates for the increase in the schistosomiasis cases due to the Aswan High dam are between 2.6 to 6 million (Thani and Tam, 1990). Malaria, whose victims in the world number 200 million, is also often associated with water development projects. The construction creation of the Volta River Dam resulted in the creation of a serious potential mosquito breeding area (Lambrecht 1981).

A third type of environmental disruption is of physical or chemical nature, resulting from the alteration of land use, and/or changes in the surface and groundwater regimes, as a consequence of the construction of irrigation projects or flood control works, such as dam or levees. Soil salinization and water logging due to the lack of adequate drainage facilities is a classic example of such environmental problems. In the Euphrates valley in Syria and the lower Rafadain plain in Iraq, over 50 percent of irrigated land suffers from these effects.

In Iran such problem affect 15 percent of the total area of the country. In Pakistan, more than 13 million hectars out of about 15 million irrigated hectars are severly affected by soil salinization and water logging (El-Gabaly, 1977). More than 20% of 30 million hectars of irrigated land in Egypt, Iran, Iraq and Pakistan are affected by water logging and salinization problems. It is estimated that between 1985 and 2000 the irrigated land area of the world will double, and the problems of salinization and alkalinization will increase proportionally. Globally water-logging and salinization are reducing the fertility of sum 1 to 1.5 million hectars of fertile soil annually (Biswas 1978).

Another of the most serious environmental disruption of this category is siltation. Reference is frequently made to reservoirs that were built for flow control or generation of hydroelectric power where the rate of accumulation of sediment was so rapid that a major reduction of reservoir capacity occured within a few years of the construction of the associated dam.

The sanmen Dam on the Huang He River in China provides an especially dramatic illustration. By 1984 the generating capacity of the associated hydroelectric plant had been reduced by more than 75% of that available 24 years earlier. The useful like of the Ambukloo Reservoir in the Phillipines has been reduced from 60 to 32 years due to increasing sedimentation. Similar difficulties have been experienced with water projects in various parts of Asia and Africa (Biswas 1984).

Finally, the fourth category of environmental effects of water resources development deals with flora and fauna, including impacts on ecological systems taken in a broad sense in this term. For example, ecological problem that resulted from dam construction in certain countries of Mediteranean is that of the spread of aquatic weeds. Serious difficulties have been encountered as a result of weed growth in the Aswan reservoir. Various types of aquatic weeds covered more than 80 percent of the reservoirs in Egypt. In 1990, 13.000 Km of canals and drains were estimated to have been infected by submerged aquatic weeds, and another 1.900 Km were covered by water hyacinths (Abu Zeid and Rady 1991). The spread of weeds has a number of secondary impacts, notably water losses through evapotranspiration. Costs of weed clearing may be in the order of millions of dollars, and sometimes the effects of the remedy may be even more destructive and hazardous than the weeds themselves. The use of herbicides is an example.

It is clear from the foregoing that environment has a wide variety of meanings and that environmental disruption can take many forms. In some instances, water projects may even result in the destruption of the resource on which they depend. But it is also apparent that severe damage of water resources may be inflicted by activities other than those directly related to water resources development. Unfortunately many essentially "non-water" activities are decided on without due consideration given to their potential impacts on the aquatic environment. In fact, sometimes they just happen as a result of specific social and economic conditions, for example, the uncontrolled expansion of the urban areas caused by migration of population from the poverty stricken rural regions. The excessive use of fertilizers and pesticides to increase crop yield is another problem of a "non-water" activity having serious consequences for water quality. This is effecting the more productive agricultural areas in the Mediterranean countries. It is important, therefore, to consider linkages between environmental problems. Of an important to point, that remedial measures must be spread over a number of "non-water" sectors and activities, taking into account primary and secondary environmental effects as well as their cumulative impacts.

The environmental effects of water resources development are real and it seems likely that man can cope with them effectively only through a very close integration of natural and social sciences, which should be adequately reflected in educational processes and institutional arrangements.

ENVIRONMENTAL IMPACTS OF WATER DEVELOPMENT IN THE MEDITERRANEAN REGION

Analysing the situation in the Mediterranean Countries, it seems obvious that there is increasing pressures on International Institutions to take the lead in responding to concerns about environmental deterioration. No real efforts are devoted by the institutions to develop policies that ensure taking the initiative in dealing with these problems, instead of being seen as merely reacting to specific challenges as they arise.

From the environmental point of view much unhappiness with water projects stems from the casual way in which environmental consequences are handled as a last minute consideration, rather than being integrated into project design from the beginning. Big offenders include irrigation projects in which drainage issues are neglected in the initial planning, navigation projects in which the disposal of dredged materials is haphazard, and flood control projects which ignore flood plain fisheries. In all of these cases adequate pre-planning guidelines could substantially reduce the environmental impacts. There are other projects, for example large dams, which have major environmental impacts that cannot be mitigated, such as loss of habitat, loss of fertile bottom lands, destruction of forests, and sediment trapping, in addition to the social impacts of moving large numbers of people from their homes and farms.

IMPLICATIONS OF WATER DEVELOPMENT ON THE ENVIRONMENT

There are three important issues that should be noted in any discussion of the implications of water development on the environment. First, the impacts of water development on environmental health are many. Some of these impacts are direct and comparatively easy to identify and to predict in advance. Others could be indirect and project-specific and thus often prove to be difficult to foresee and even more difficult to quantify. Most water resources projects produce a mixture of these two types of impacts. As is to be expected, it is less difficult as a general rule to predict and control primary impacts than secondary and tertiary impacts. Thus for impact analysis of any medium to large-sized irrigation project a substantial number of specific and interrelated factors have to be analysed, both concurrently and sequentially, in a coordinated manner within an overall framework, by a variety of professionals, based often on incomplete or unreliable data. Considering the methodological limitations that are inherent in such impact analysis, it is a difficult task under the best of circumstances.

Secondly, environmental impacts of projects, both direct and indirect, are never confined within the project boundary. Many of the impacts occur far from the project area. Accordingly, it is not possible to define a precise geographical boundary which could be said to contain all the impacts.

Thirdly, the time dimension of the impacts is another complicating factor. Certain impacts can be immediate, and thus can be identified during the implementation phase or soon there after. Other impacts, however, could be slow to develop, and thus many not be visible in the early stages. For example, some unanticipated changes in the ecosystem and the environment could take more than a decade of operation of a project before they begin to appear. For many impacts it is not possible to forecast the timing of their occurrence with any degree of reliability. A typical case is salinity development in irrigated areas, which could take 15-25 years in certain projects, but in others the problem may appear within 2-3 years, depending on physical condition, drainage facilities, operation and maintenance procedures, and managment practices. The time dimension also makes direct comparision of the impacts of different water development projects a difficult process.

IMPACTS ON THE ENVIRONMENT AND HEALTH OF THE INCREASED USE OF WATER IN THE MEDITERRANEAN COUNTRIES

Water resources are continuously subjected to development presure in almost all countries, particularly in arid countries. As a result, the quantities of available water are declining and the quality of water is rapidly deteriorating.

Declining supplies are obliging cities to seek water furtheraway from their countries. Water is being transferred over long distances which is very costly and can lead to interregional or even international conflicts.

Urban water supplies are also experiencing a decline in quality. Rivers and streams which supply cities also receive urban waste water and industrial effluents, which means that they cannot be used anymore as a water supply. Toxic chemicals from industry, pesticides, nitrates and phosphates from agriculture are all contributing to the contamination of the fresh water resource.

Groundwater is usually the best source of water because of the filtering capacity of the soil, and it is usually the first used. As such it is therefore under increasing pressure. The quantity of water available is declining as a result of overpumping, leading to a drop in the water table. In costal areas this can lead to salt water intrusion and subsequent salt contamination of the aquifer. Also when the water table has dropped the soil may subside, damaging infrastructures. Groundwater quality is also deteriorating because of human pollution from wastewater and industrial discharges as well as from nitrate, herbicides and pesticides contamination. Groundwater bodies sometimes undergo irreversible deterioration when polluted by bacteriological and toxic pollution from waste water in urban areas with no sewage systems. For these reasons, many aquifers bodies cannot be used directly for human consumption and require costly treatment.

The construction of large reservoirs for water storage can have a serious and complex impact on the environment that is often difficult to quantify and identify. When large dams are built, the river regime changes and influences the behaviour of the whole hydraulic system from the headwaters to the outflow. Flora and fauna living along the river suffer the effects of this change, whills the population living in the area to be flooded must move elsewhere permanently. Some adverse effects can sometimes appear years after the start of reservoir operations. Reservoirs are also vulnerable to the inflow of nitrates and phosphates and toxic chemicals. Fertilizers, such as phosphates, are creating eutrophic systems in reservoirs and the degraded water quality makes for inferior water supplies.

WATER QUALITY

An assessment of water resources is incomplete without knowledge of the quality characteristics as assessed by their physical, chemical and biological constituents. These constituents may originate naturally from the environment (e.g. soils and geological formation) or from wastes discharged as a result of agriculture, human settlements and industrial activities. They are introduced either from point sources (mostly industrial and municipal), which are manageable, or from non-point sources (mainly agricultural), in which case management is more difficult.

The concentrations of the constituents simply express the status of the water in physical, chemical and biological terms, but quality can only be discussed meaningfully when it is related to a specific use. In such cases, guidelines must be given on the concentrations of various constituents which should not be exceeded in order to avoid impairing the water for any particular use.

Until 1987 no attempt had been made to assess globally the quality status of regional fresh waters. This was due to lack of data from most countries, particularly from the developing countries, where water quality data were not collected on a regular basis.

POLLUTION PROBLEMS COMMON TO ALL WATER BODIES

The common contaminants were found to be heavy metals and organic micropollutants. The pollution problems were classified into those that were common to all the fresh water bodies and those were specific to rivers, lakes/reservoirs or groundwater. The classification is presented in Table 1.

Table 1. Occurance of major pollution problems in different types of water body (source: WHO/UNEP, 1989)

Type of water body	Water pollution problem	
	Specific to water body	Ubiquitous occurance
Rivers	Pathogens Organic matter Suspended matter Acidification	Heavy metals
Lakes and reservoirs	Eutrophicatio Acidification	Organic
Grounwaters	Salinization Nitrates	Micropollutants

In the remainder of this century water quality issues will become increasingly important. Monitoring and environmental management measures to preserve the quality of existing groundwater and surface water resources will take a prominent place on the agenda of overall water resource use planning. Recently, different views have been expressed concerning the relative importance of water quantity versus water quality for health improvement, and this on going discussion will have to result in balanced view on the issue, taking into account local epidemiology, ecology and economy.

New technologies will need to be applied to detect and monitor water resources in an integrated manner. Water quality is being checked through the Global Environmental Monitoring system by a network of national institutions. These data may be complemented by Remote Sensing (RS) observations of watersheds and river basins, and they will be increasingly analyzed with the use of Geographic Information Systems (GIS). It is of great importance to create intersectorial networks in which countries can apply these new technologies for a sound and integrated management of their natural resources. Ministries of health will have to step up their health monitoring and epidemiological assessment activities to provide such systems with adequate data so as to elucidate the linkages between environmental change and human health status.

WATER QUALITY IMPACTS ON ENVIRONMENT AND HEALTH

Deterioration in the quality of this vital resource has very serious implications for health and the quality of life. Access to it becomes a right requiring equitable distribution to all society. Attempts have been made in most countries to ensure that even the poorest sections of the population have access to good quality drinking water, but much effort is still needed to attain this objective. Globally, there are at present 1.2 billion people suffering from diseases caused by drinking polluted water or transmitted by inadequate sewage equipment. Some 15 million children under five years old die annually in developing countries, mainly following an illness caused by water. These diseases also play a significant role in adult mortality and sickness. Poor health caused by water-related diseases and unsanitary practices is very costly to the economy in terms of work days lost and reduced productivity. The pollution of water supplies may be aggravated if drinking water supply programmes are not accompanied by appropriate sewage systems.

Many developing countries of the meditteranean do not have the operational means to assess their water quality. Without this information, they may be unaware of problems and perhaps endangering their population's health. However, some pollutants bioaccumulate and the health effects may not be detected for some time. Therefore, the monitoring and quality control of water is of prime importance for human health and in those countries, much effort is now being directed towards preventing pollution and treating polluted water since new and sophisticated methods of water treatment are available. Monitoring and control must be carried out systematically, especially in areas where there is a lot of industrial activities.

The increased use of water in cities is inevitably increasing discharges of waste water (the average percentage discharged into the sewage system amounts to 80 per cent). The volume of waste water will thus continue to increase, with a resultant proportional rise in expenditure on collection network and wastewater treatment plants. The self-cleaning capacity of recieving water is rapidly diminishing. In many countries, the water supply has run ahead of waste water management system. A great effort must now be made to close this gap and preserve the environment through waste water treatment.

Increasing water pollution from industrial and domestic sources, if allowed to grow un checked, is likely to reduce the amount of water available for various uses in future. In addition, the total economic and health costs to the country due to unchecked pollution would be sustainable. For example, the second pumping station Rehabilitation Loan of the World Bank conlcuded that excessive pollution of drainage waters around Alexandria reduced the lifespan of irrigation pumps from 20 years to only 4 and required more sophisticated pumps and piping at higher costs (Abu Zeid adn Rady 1991). The irrigation system in Egypt, is currently kept functional by some 675 pumping stations, which clearly cannot be allowed to deteriorate due to water pollution.

ENVIRONMENTALLY - SOUND WATER MANAGEMENT

Any attempt to develop water resources results in some modification of the environment. Sometimes the impact is confirmed mainly in the river region, aquifer or lake itself, as in an alternation in the normal flow or the quality of the water body. In other instances the effects are much more widespread and may result in considerable alterations in land resources, forests or fisheries. Beyond this, water development may have major impacts on human settlements and economic activities. The seriousness of these impacts depends upon the ability of the various physical, natural and human systems to absorb them, as well as human perception about them (Biswas, 1984).

To a significant extent the environmental impacts of water management are beneficial, particularly when they open up new avenues for economic development or social improvement without serious impairment of the resource base or the ecological system. Often, however, environmental consequences are adverse, varying in the degree of their intensity and social acceptability.

It should be clear that environment has a wide variety of meanings and that environmental disruption can take many forms as said before. Severe damage may be sustained by other resources or by activities in addition to those directly related to water development. At the same time experience across the world indicates that many of the problems of reconciling development and environment result from a failure to consider them simultaneously.

Environmentally-sound water management implies that:

1. development be controlled in such a way as to ensure that the resource itself is maintained and that adverse effects on other resources are considered and where possible ameliorated;

2. options for future development are not foreclosed; and
3. efficiency in water use and in the use of capital are key criteria in strategy selection.

Recognizing these ideas is one thing; translating them into action is another. More specifically, what is required to foster the adoption of the three elements noted above in planning and policy making are: namely, the recognition of concepts of environmentally - sound development and resilience, the incorporation of a more comprehensive perspective and the pursuit of higher levels of efficiency.

CONSTRAINTS TO ENVIRONMENTALLY SOUND MANAGEMENT

A comprehensive and critical analysis of existing literature on environmental aspects of water development in the Mediterranean indicates that there are many constraints which limit the potential application of available knowledge by water professional and decision-makers in developing countries. On the basis of this analysis, the following four major constraints can be identified:

1. incomplete framework for analysis;
2. lack of appropriate methodology;
3. inadequacy of knowledge; and
4. institutional constraints.

It should be noted that the four major constraints identified are not independent. On the contrary, they are often closely interrelated.

INCOMPLETE FRAMEWORK FOR ANALYSIS

The framework currently used for analysing and considering various environmental impacts associated with water development projects is overwhelmingly biased towards assessing only the negative impacts.

Concerning large scale water development, for instance the newly built Aswan High Dam, a lot of articles were published concentrating only on the serious negative impacts of the Aswan High Dam, such as the loss of the Mediterranean fishery, an increase in schistosomiasis, salinity development, a reduction in the fertility of the Nile

Valley through the absence of silt deposition, and coastal erosion of the Nile Delta. But, still this does not mean that this dam should have not been built. It has doubled Egypt's electricity generating capacity, helped prevent disastrous floods, improved river navigation, created a vast potential fishery in the reservoir that has more than compensated for the sardine loss in the Mediterranean, attracted more tourism and made the water resources use much more reliable in municipal, industrial and agricultural development.

What is thus needed is a balanced framework for analysis which will identify both positive and negative impacts. The next step should then be how to maximize the positive impacts and minimize the negative ones. A framework that considers only the negative impacts and ignores the positive ones is both incomplete and counterproductive.

LACK OF METHODOLOGY

A review of the processes currently used by developing countries to incorporate environmental issues in water management indicates that the methodologies available at present do not appear to satisfy the special requirements of those countries. While the environmental impact asessment (EIA) process was made mandatory in several industrialized countries, its actual use so far in developing countries has been somewhat slow. The reason for this slow acceptance is the lack of an operational methodology that can be successfully applied in the developing countries with limited expertise, resources, data and time. The EIA methodologies that are being used in industrialized countries are not directly transferable to developing countries for various socio-economic and institutional reasons (Biswas and Kindler 1989).

The complex, lengthy, expensive and time-consuming EIAs as practised in developed countries are not the right tool to assess the impact of water development projects in developing countries. It is also important that in addition to being appropriate to local circumtances they should be affordable in terms of cost and maintenance. Many hydrological services in the developing Mediterranean Countries have not been guided on these latter aspects. It is not uncommon to find that equipment has been acquired without ensuring that it can be operated and maintained properly. Hence, the life span of equipment is unduly shortened, thereby wasting scarce resources.Also it is necessary to develop guidelines which can actually be used by professionals for water management in planning and managing projects.

LACK OF ADEQUATE KNOWLEDGE

The results presented so far show that there is some working knowledge available about the Mediterranean's water. However,as can be seen from a comparison of the various estimates, differences exist with regard to the water balance components and the water resources at the various levels.

Those scientists who have made contributions to this knowledge, pointed to the lack of adequate data on the hydrological cycle, the lack of sufficient areal coverage of the data and their representativeness, the gaps in data, the quality of data, and in some cases problems of access to data even if they are available. In addition, there are questions raised about the adequacy of the scientific basis, methods and techniques used in making the assessments.

There are many areas where adequate technical knowledge may not exist for getting reliable answers. Equally, there are areas where "conventional" knowledge can at best be dubious and at worst totally erroneous.

The other problem is the absence of data on pre-project conditions in terms of environment- and health-related factors. Even now, when some baseline surveys are being carried out on pre-project conditions, environmental and health issues receive virtually no attention.

INSTITUTIONAL CONSTRAINTS

A sectorail approach to water development is a major institutional constraint in all developed and developing countries, and this has an important bearing on the sustainability of projects.

There are many reasons for this situation, but one of the most important is the division of responsabilities between the various ministries that look after various water-related issues. Because of long-standing rivalries, the coordination and cooperation between the various ministries leave much to be desired. And yet in any large-scale water development project all these issues must be integrated within the project area. While it is easy to point out this necessity, how this integration can be effected in reality in the field is a very complex and daunting task.

As a matter of fact there are many constrains to achieve environmentally sound water management in most developing countries of the Mediterranean. Their importance could vary from one country to another, and sometimes even from project within the same country. Often the constraints are closely interrelated: one contributing to the other and vice versa. To over come those constraints, it is primary needed to fullfill the following existing gaps:
- Lack of appropriate and consistent policies of water development for both large- and small-scale projects.
- Absence or inadequacy of monitoring, evaluation and feedbacks at both national and international levels.
- Lack of proper policies on cost recovery and water pricing or, if policies exists, absence of their implementation.
- Lack of professional and technical manpower and training facilities.
- Lack of beneficiary participation in planning, implementation and operation of project.
- Lack of knowledge, and absence of appropriate research to develop new technologies and approaches, and absence of incentives to adopt them.
- General institutional weaknesses and lack of coordination between various ministries such as water, agriculture, environment, planing and other.

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11

LES TECHNIQUES MODERNES D'IRRIGATION ET LES ECONOMIES D'EAU

L. RIEUL

FRANCE

LES TECHNIQUES MODERNES D'IRRIGATION ET LES ÉCONOMIES D'EAU

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ABSTRACT

Irrigation performances improved by technical involvement and maked water savings possible.

In surface irrigation, a better control of water distribution on the head of the parcels is possible, using modern mechanic devices (siphons, flexible sheath, gated pipes). Performances (70 - 80%) can be reached with this devices, with a correct land levelling and a good irrigation control.

Sprinkle irrigation involved to solid set systems, without movable parts, or to self propelled irrigation machines (enrouleurs, center pivot systems). Large areas can be spinkled by these systems, without manual operation. Good performances (85 - 90%) can be reached with these systems but without wind.

With micro-irrigation (drippers, mini-diffusers, calibtrated orifices) water supplies can be furthermore precisely controled. This system need less pressure and so less energy than sprinkler irrigation. But they need clean water and they are expensive.

Progress have been reached for all sort of irrigation (surface, sprinkler, micro). All of these offer advantages and disadvantages. All of the farm constraints should be regarded for a system selection.

INTRODUCTION

Les économies d'eau ont une grande importance dans les recherches d'amélioration des techniques d'irrigation, tout particulièrement dans les pays arides. En effet plus le climat est aride, plus la ressource en eau est limitée et plus les besoins en irrigation sont importants pour la production agricole. Il faut donc valoriser au mieux l'eau dont on

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dispose. L'évolution des techniques d'irrigation y contribue grâce aux meilleures performances des équipements, à condition que ces équipements soient bien choisis et bien utilisés.

Une analyse de cette évolution pour chacun des trois modes d'irrigation (de surface, par aspersion, micro-irrigation) met en évidence l'intérêt des progrès technologiques *(1)*.

1.-Irrigation de surface

L'irrigation de surface ou irrigation gravitaire consiste à répartir l'eau sur la parcelle cultivée par ruissellement sur le sol dans les sillons (irrigation à la raie) ou en nappe (irrigation par planche ou calant) ou encore par submersion contrôlée (irrigation par bassin.s).

Peu coûteux en investissement, nécessitant peu d'énergie, c'est le mode d'irrigation le plus ancien et le plus répandu dans le monde.

Sous la forme traditionnelle, l'eau est amenée au niveau de la parcelle, puis distribuée en tête de celle-ci dans des canaux en terre. L'alimentation des raies, des planches ou des bassins se fait par ouverture de brèches dans les berges de ces canaux. Les pertes par infiltration dans les canaux en terre ainsi que la difficulté de contrôler les débits délivrés à travers les brèches conduisent à un gaspillage de l'eau et à une grande hétérogénéité des arrosages.

Dans le midi de la France, on a constaté sur des vieux réseaux de cette espèce, des prélèvements de l'ordre de 20 000 m^3 par ha et par an, alors que les besoins ne sont que de l'ordre de 4 à 5 000 m^3 par ha et par an.

Les techniques actuellement disponibles permettent d'apporter une solution à ce problème.

Au niveau de la parcelle, des dispositifs mécaniques permettent de mieux contrôler la répartition de l'eau en tête de parcelle et les débits délivrés dans les raies ou sur les planches et dans les bassins.

1.1.-*Modernisation de l'irrigation à la raie*

Pour ce qui concerne l'irrigation à la raie, les dispositifs les plus courants sont les siphons, les gaines souples, les tubes à vannettes, les systèmes dits "californiens" et les dispositifs automatiques appelés "transirrigation" *(2)*.

Les siphons sont des tuyaux de petit diamètre (20 à 50mm) d'une longueur comprise entre 1m et 1m50. Il sont réalisés en matériaux rigides ou semi-rigides, les plus courants étant en PVC.

Ils nécessitent une faible charge de 10 à 20 cm et permettent, sous ces charges, de délivrer un débit pouvant varier de 0,4 l/s à 2 l/s environ. On peut modifier les débits en plaçant des bouchons percés à la sortie du siphon ou en utilisant des siphons de diamètres différents ou encore en jouant sur le nombre de siphons.

Les siphons présentent l'avantage de ne pas coûter cher, ils permettent d'assurer une bonne répartition des débits. Néanmoins le transport et l'amorçage des siphons nécessitent une manutention relativement importante. Il faut d'autre part surveiller les risques de désamorçage en cours d'irrigation.

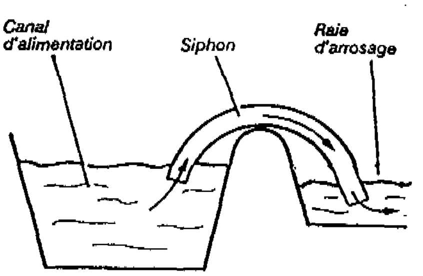


fig.1-siphon

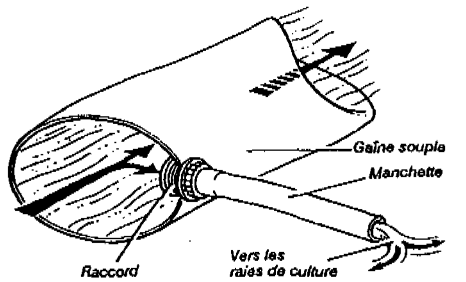


fig.2-gaine souple

Les gaines souples sont constituées d'une manche souple en matière plastique placée en tête de parcelle sur laquelle sont fixées des manchettes de dérivation qui alimentent les raies. Ces manchettes sont souvent munies d'un dispositif permettant d'écraser plus ou moins le tube pour limiter les débits. Les pièces de raccordement de ces manchettes à la gaine ainsi que limiteurs de débits sont en polyéthylène. On trouve en France des gaines de 150mm de diamètre et de 50m de long ou de 105mm de diamètre et de 30m de longueur. Les manchettes de dérivation ont un diamètre de 50mm et une longueur de 0m50. Plusieurs éléments de gaines peuvent être raccordées avec des manchons en PVC. Lorsque l'installation n'est pas en service, la gaine est aplatie sur le sol.

L'utilisation correcte des gaines nécessite une charge de 40 cm à 1m de colonne d'eau. A titre indicatif, le débit à pleine ouverture d'une dérivation est de l'ordre de 2 l/s pour une charge de 50 à 60 cm.

Les gaines souples présentent l'avantage de pouvoir être installées rapidement et de ne pas créer d'obstacles au passage d'engins agricoles. Elles peuvent être pliées et rangées aisément en fin de campagne. L'inconvénient majeur est de ne pas permettre un réglage précis des débits admis dans les raies. Il faut d'autre part veiller à les stocker à l'abri des rats.

Les tubes à vannettes sont des tuyaux en PVC rigide traité contre l'ultra-violet sur lesquels on fixe des vannettes coulissantes à l'écartement souhaité en fonction de l'espacement des raies. Les tuyaux utilisés en France sont des éléments de 6m de long et de 200mm de diamètre. Plusieurs éléments peuvent être raccordés entre eux facilement. Les tubes sont disposés sur un sol préalablement régalé en tête de parcelle en alignant toutes les vannettes. Le raccordement des tubes au canal d'irrigation ou à la pompe peut être réalisé soit avec des pièces en PVC ou au moyen de gaines souples ou de raccords en acier.

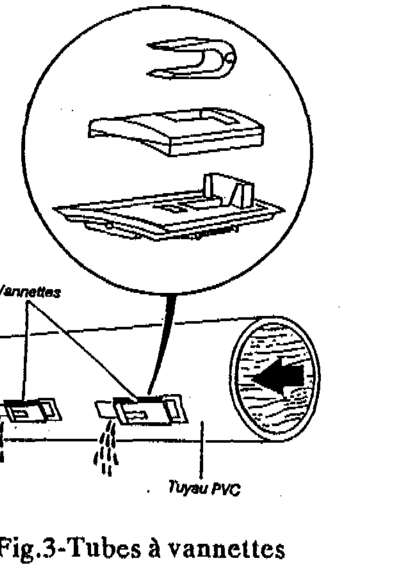


Fig.3-Tubes à vannettes

Cet équipement exige une charge minimale disponible en tête de parcelle de l'ordre de 30cm; les joints sont étanches jusqu'à 1 bar de pression. Avec des ouvertures de vannettes de 10 à 40mm et des charges sur la vannette de 10 cm à 1m de colonne d'eau, on peut obtenir des débits variant de 0,35 à environ 4 l/s.

Les tubes à vannettes permettent de régler et de contrôler les débits admis dans des raies de manière précise et fiable. Ils présentent par ailleurs l'avantage de pouvoir être posés et déposés aisément en début et fin de campagne. Ils constituent néanmoins un obstacle au passage en tête de parcelle et leur stockage doit être organisé en fin de campagne d'irrigation.

Les systèmes "californiens" sont constitués de tubes rigides en PVC enterrés en tête de parcelle, sur lesquels on fixe des petites cheminées de sortie ou cannes qui alimentent les raies. Les tuyaux enterrés ont un diamètre de 160 à 300mm et les petites cannes un diamètre de 70 à 100mm. Les cannes de sortie peuvent être munies d'un dispositif permettant de régler le débit, tel que des manchettes souples avec pinces, ou des caches coulissants qui obstruent l'orifice de sortie.

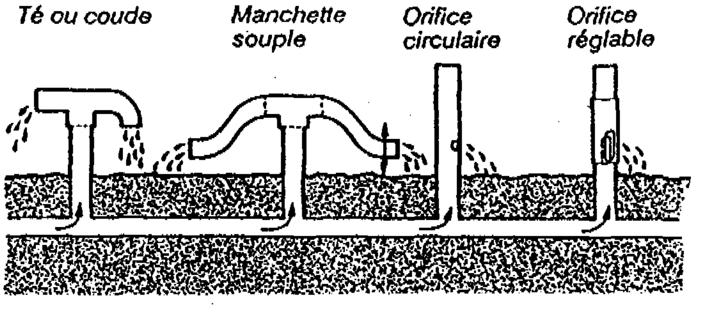


Fig.4-Système "californien"

Le système présente l'avantage d'être fixe, ce qui supprime toutes les manipulations de pose et de dépose. L'installation étant enterrée, elle ne crée aucune gêne pour les travaux agricoles. Il est facile d'utilisation. Il doit néanmoins être dimensionné correctement et le processus d'installation nécessite une étude hydraulique correcte.

Le système "transirrigation" (câble irrigation aux USA) est constitué d'un tuyau rigide posé avec une pente régulière en tête de parcelle et percé d'orifices calibrés qui alimentent les raies. Le déplacement automatique d'un piston à l'intérieur du tube entraîne le déplacement de la main d'eau sur l'ensemble de la parcelle. Le nombre de trous alimentés est toujours le même, et le débit de chaque trou décroît progressivement jusqu'à s'annuler au fur et à mesure que le piston se déplace vers l'aval du trou.

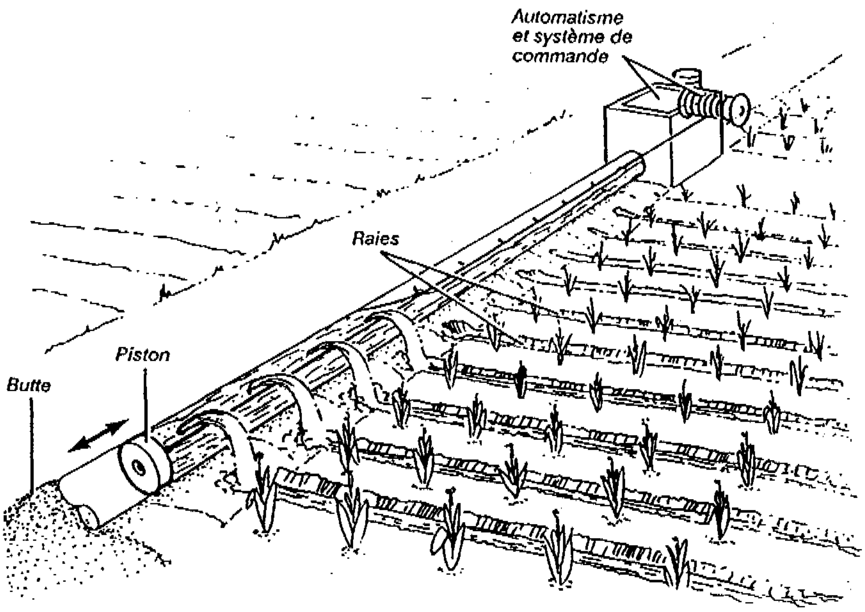


Fig.5-Transirrigation

Le tuyau est en PVC rigide traité anti ultra-violet de diamètre de 150mm, il est posé avec une pente comprise entre 2,5 et 6mm par mètre et les orifices sont calculés en fonction du débit que l'on souhaite obtenir. L'avancement du piston est commandé par le déroulement d'un câble. A la fin de l'irrigation, le piston est relevé et ramené en tête et le câble est réembobiné. Le déroulement du câble peut être réglé manuellement ou dans les systèmes automatiques, par l'intermédiaire d'un micro-ordinateur et de balises qui contrôlent le déroulement de l'irrigation. La main d'eau délivrée est de l'ordre de 30 à 50 l/s.

Ce dispositif présente l'avantage de nécessiter peu de travail pendant l'irrigation. Il permet par ailleurs une très bonne maîtrise de la dose apportée grâce à la modulation automatique des débits décroissants à chaque trou ; ce qui permet de réduire les pertes en colature. C'est néanmoins une installation onéreuse qui nécessite une étude hydraulique préalable correcte et beaucoup de soins dans la mise en place. L'installation peut être en surface ou enterrée avec des cannes de sortie sur chaque orifice.

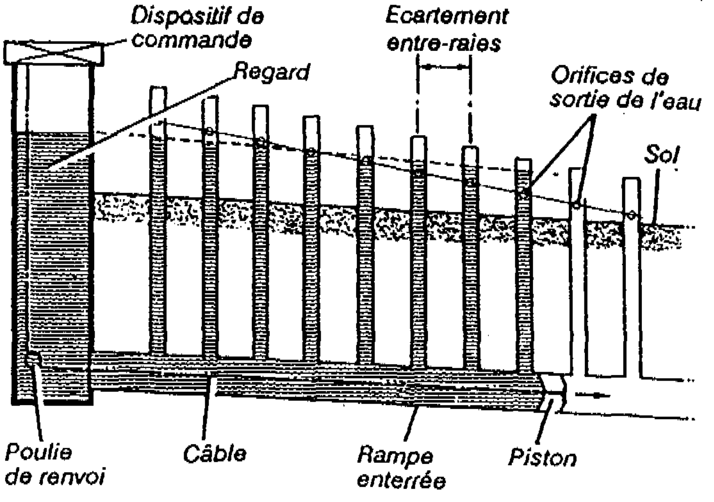


Fig.6-Transirrigation enterrée

Le coût d'investissement de ces matériels est fonction du coût au mètre linéaire des dispositifs de distribution en tête de parcelle. Dans l'ordre décrit ci-dessus, les coûts vont croissant du siphon au système automatique "transirrigation". Le coût à l'hectare est par ailleurs pour un même dispositif d'autant plus faible que les raies sont longues.

1.2.-Modernisation de l'irrigation par planches ou par bassins

La modernisation des systèmes d'irrigation par planches ou par bassins consiste à étancher le canal qui distribue l'eau en tête de parcelle et à l'équiper de vannes de régulation qui permettent d'alimenter successivement les biefs de ce canal, et de vannes de prises latérales qui alimentent les planches ou bassins *(3)*.

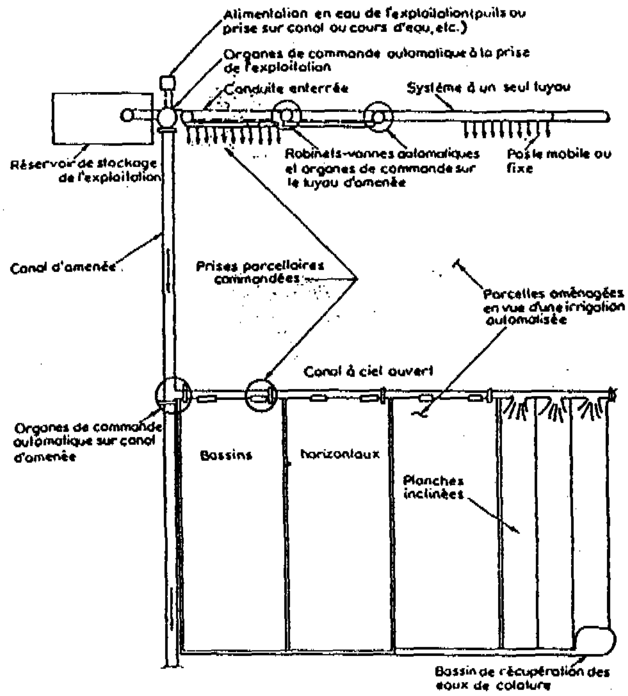


Fig.7-Schéma de réseau d'irrigation de surface modernisé

Un investissement peu coûteux consiste à utiliser des vannes de régulation mobiles que l'on déplace le long du canal d'alimentation. Lorsque le canal d'alimentation a une pente suffisamment forte, les prises latérales peuvent être constituées de simples seuils disposés en marche d'escalier le long des biefs horizontaux.

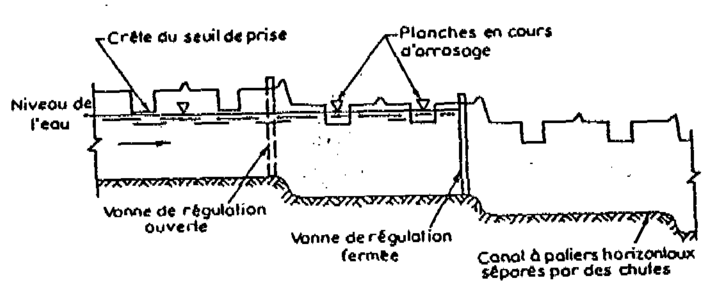
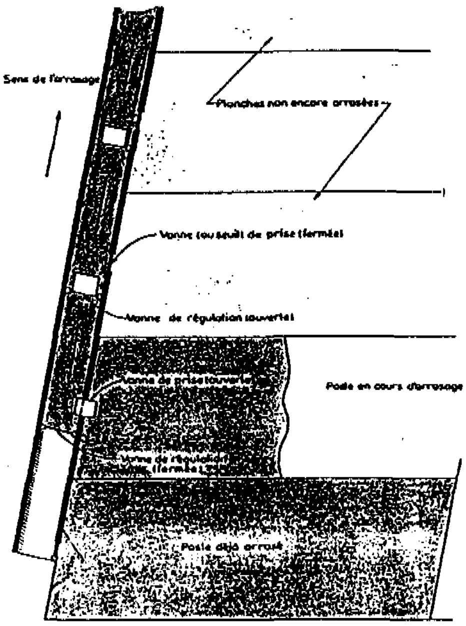


Fig.8-Coupe d'un canal à biefs horizontaux

Le fonctionnement du système peut être organisé pour commencer l'arrosage, soit par l'extrémité aval ou progressant de poste en poste vers l'amont ou vice-versa.



Fug.9-Arrosage de l'aval vers l'amont

Dans le premier cas, le canal est équipé de vannes ouvertes au départ, sauf la dernière en aval. Ces vannes sont fermées progressivement pour déplacer les postes de l'aval vers l'amont.

Au contraire dans l'irrigation de l'amont vers l'aval, toutes les vannes de régulation sont fermées au départ et elles sont ouvertes progressivement de l'amont vers l'aval.

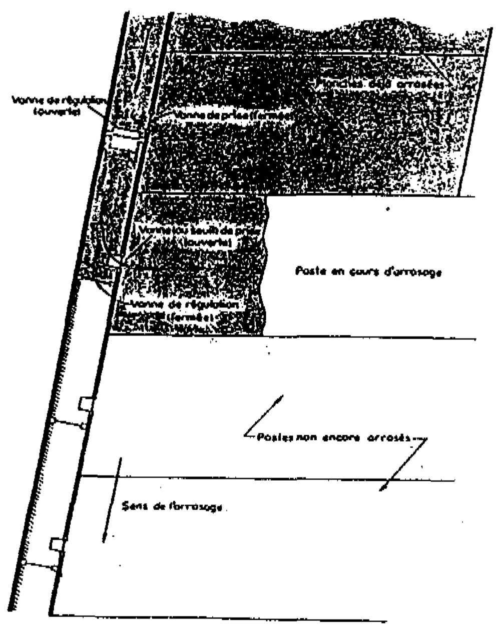


Fig.10-Arrosage de l'amont vers l'aval

L'ouverture ou la fermeture des vannes qui sont basculante ou coulissante peut être automatisée. Les vannes peuvent être manoeuvrées par des dispositifs mécaniques, électro-mécaniques ou pneumatiques. Le déclenchement des dispositifs peut être commandé soit par des horloges mécaniques ou électroniques ou encore par des programmateurs.

Pour améliorer l'efficience des canaux de distribution en tête de parcelle, on est souvent conduit à revêtir ces canaux ou à les remplacer par des canaux préfabriqués. Quoique cela améliore sensiblement l'efficience du système, les canaux en surface du sol présentent le gros inconvénient de créer un obstacle à la circulation et de nécessiter un entretien permanent. Pour y palier, on voit apparaître des réseaux en conduites enterrées à basse pression. Ces réseaux sont réalisés en conduite en matière plastique de faible épaisseur ou en amiante-ciment. Les prises sur ces conduites sont alors équipées soit de vannes papillon ou de robinets vannes classiques ou encore de vannes à clapet ou à opercule commandées par des dispositifs pneumatiques. Ces types de vannes peuvent être également automatisées.

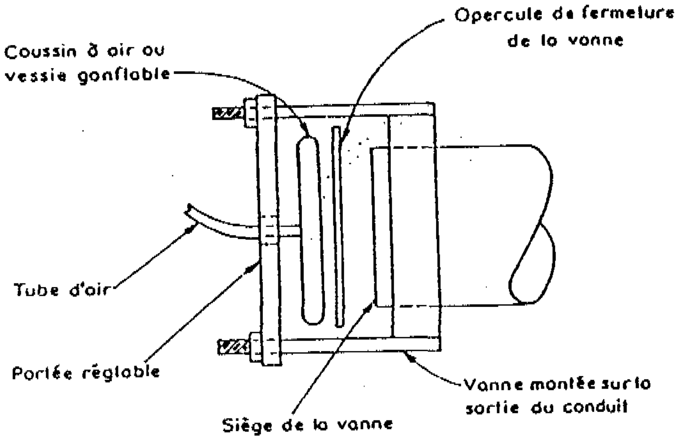


Fig.11-Vanne à opercule à coussin pneumatique

L'utilisation de tels équipements modernes associée à une bonne conduite des arrosages peut accroître considérablement l'efficience de l'irrigation. La bonne conduite des arrosages consiste à optimiser le choix débit en tête de raie, dans les planches ou dans les bassins et la durée d'arrosage *(4)*. L'utilisation de techniques d'irrigation intermittente, par vagues ou à deux débits, permet d'améliorer encore l'efficacité de l'irrigation de surface. Ces techniques consistent à humidifier la surface des raies ou des planches d'irrigation par un débit d'attaque élevé pendant un temps relativement court. On a pu ainsi constater qu'il est possible de faire passer les rendements hydrauliques de l'irrigation de surface de moins de 50% en irrigation traditionnelle à 70-80% en irrigation modernisée. Outre l'amélioration de l'efficience, on obtient des coefficients d'uniformité qui tournent également autour de 75 à 90 %. De telles performances s'approchent de celles que l'on obtient avec les techniques d'irrigation par aspersion ou de micro-irrigation.

L'irrigation par aspersion

L'irrigation par aspersion s'est rapidement développée après la seconde guerre mondiale, notamment en Europe et aux Etat-Unis. L'eau est transportée dans des réseaux de conduites sous pression puis délivrée au niveau de la parcelle par des bornes qui régulent la pression et le débit. A l'aval de la borne des conduites (porte-rampes et rampes) alimentent sous pression des asperseurs rotatifs qui répandent l'eau en pluie.

Le porte-rampes et les rampes sont constitués de tubes d'une longueur de 3, 6 ou 9 et sont faits en alliage d'aluminium, en acier galvanisé ou encore en polychlorure de vinyle. On trouve également des rampes en polyéthylène à haute densité. Les rampes ont généralement un diamètre de 50mm. L'asperseur est caractérisé par le diamètre de sa buse qui, pour une pression déterminée, définit son débit, la portée du jet et la répartition de l'eau, en un mot la pluviométrie de l'asperseur. Il existe des asperseurs équipés d'une seule buse et d'autres qui sont munis de deux buses de différent diamètre pour améliorer l'homogénéité de la répartition pluviométrique dans la surface arrosée. Les asperseurs peuvent être montés directement sur la rampe par l'intermédiaire d'une allonge rigide de 0,50m à 2 m que l'on fiche sur un Té à clapet, fixé sur une plaque stabilisatrice. On peut également monter les asperseurs sur un bi-pied ou sur un trépied de 1 à 2m50 de hauteur.

Les asperseurs les plus couramment utilisés sont des asperseurs à moyenne pression qui fonctionnent sous une pression de 2 à 5 bars, avec des débits de l'ordre de 1 à $3m^3/h$ et des portées de jet de 12 à 18m.On obtient des pluviométries de 3,5 à 6,5mm/h. Si la pression est supérieure à la pression nominale, notamment en bas de pente, on peut équiper chaque asperseur d'un régulateur de pression que l'on monte juste à l'amont de celui-ci.

La quantité d'eau qui arrive au sol le long du jet d'asperseur diminuant lorsque l'on s'éloigne de celui-ci, pour obtenir une répartition de l'eau homogène on doit disposer les asperseurs de manière à avoir un recoupement suffisant des jets. Ils sont généralement disposés en carré, rectangle ou en triangle dont les dimensions les plus courantes sont 18 x 18m, 18 x 21 m, 21x21 m, 18 x 24m..

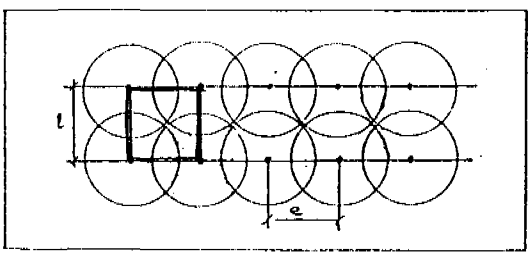


Fig.(a)- en carré : e = l
en rectangle : e < l

Fig.(b)- en triangle

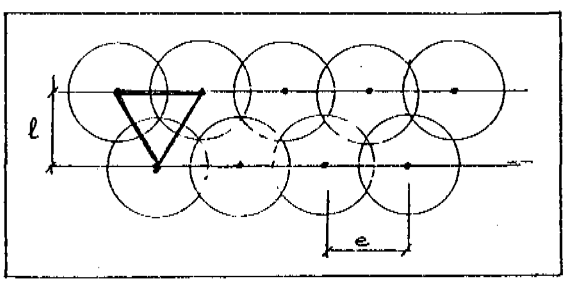


Fig.12-Disposition des asperseurs

Les premiers réseaux étaient équipés de petits asperseurs disposés le long d'une **rampe mobile** en alliage léger que l'on déplaçait à la main de poste en poste, pour irriguer l'ensemble de la parcelle. Relativement peu coûteux en investissement, ce système était très exigeant en main-d'oeuvre.

On a peu à peu évolué vers la **couverture totale** qui consiste à disposer sur la parcelle en début de campagne un quadrillage de rampes de petits diamètres, le long desquelles on déplace ensuite manuellement les asperseurs.

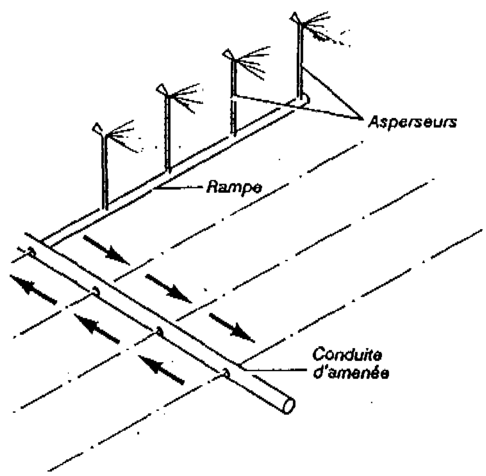


Fig.13-Irrigation par déplacement d'une rampe mobile

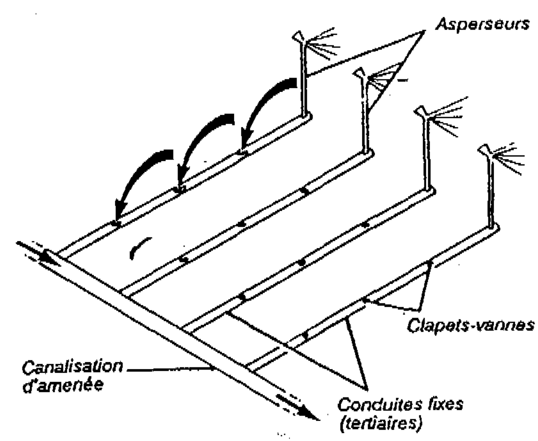


Fig.14-Couverture totale

On a finalement abouti à la **couverture intégrale** qui consiste à équiper les rampes fixes de l' ensemble des asperseurs. Une fois posé l'ensemble n'est plus déplacé pendant toute la saison d'irrigation. La mise en eau successive des postes d'arrosage est réalisée par l'ouverture ou la fermeture de petites vannes en tête de chaque rampe. Ces vannes peuvent être commandées manuellement ou à l'aide de vannes semi-automatiques comme les vannes volumétriques ou encore de manière automatique par des programmateurs d'arrosage.

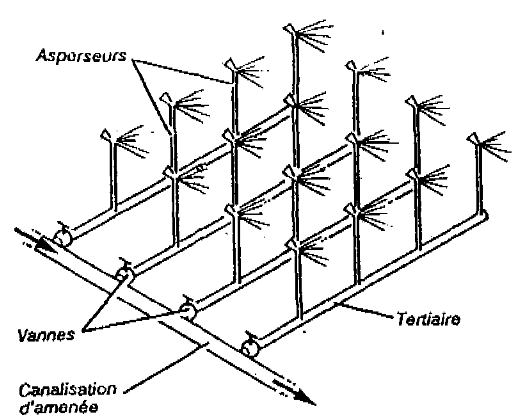


Fig.15-Couverture intégrale

La couverture intégrale présente l'avantage de supprimer les interventions manuelles pour les changements de poste, presque totalement lorsque les manoeuvres de vannes sont manuelles ou totalement si ces manoeuvres sont automatiques. Cet avantage est néanmoins obtenu au prix d'un investissement d'autant plus élevé que le système est automatisé.

Le gros intérêt de la couverture intégrale est qu'avec une bonne disposition d'asperseurs on peut obtenir une répartition bien homogène de l'eau sur l'ensemble de la surface irriguée. Les pertes d'eau sont pratiquement nulles et dans des dispositifs bien conçus, on obtient des rendements hydrauliques de l'ordre de 90 à 95 %. Ces systèmes peuvent être bien adaptés à toutes les formes de parcelle, à toutes les natures de sol quelle que soit la topographie et à toutes cultures. La couverture intégrale convient particulièrement bien aux cultures annuelles, dont la sole irriguée peut être déplacée dans l'assolement sur l'ensemble de l'exploitation.

Le problème en aspersion est l'influence du vent qui augmente très sensiblement l'hétérogénéité de répartition de l'eau dès que la vitesse du vent atteint environ 10 km/h. Au-delà de 30 km/h l'irrigation devient pratiquement impossible. On atténue l'effet du vent en rapprochant le plus possible les asperseurs et en les disposant en triangle ou en rectangle, dont la plus grande dimension est orientée dans le sens du vent.

Peu à peu, pour arroser de plus grandes surfaces, les asperseurs ont évolué vers les **canons** d'arrosage qui sont de gros asperseurs rotatifs fonctionnant sous une pression élevée de l'ordre de 5 à 8 bars, équipés de buses de 16 à 30mm. Ces canons ont un débit de 30 à 100 m^3/h et une portée du jet qui peut aller d'une vingtaine de mètres à plus de cinquante mètres. Il faut savoir que l'irrigation au canon est d'autant plus sensible au vent que la portée du jet est importante. Par ailleurs les gros canons ont une forte pluviométrie avec de grosses gouttes qui peuvent poser des problèmes de battances du sol (formation de croûte superficielle) sur des sols limoneux ou fins.

Les systèmes ont également évolué peu à peu vers des appareils mobiles ou machines d'arrosage. Les plus répandus sont les enrouleurs et les pivots.

L'enrouleur est constitué d'une bobine mue par un moteur hydraulique, sur laquelle s'enroule un tuyau flexible en polyéthylène. L'enroulement du tuyau provoque le déplacement d'un canon d'arrosage monté sur un chariot à roues fixé à l'extrémité du tuyau. L'enrouleur effectue ainsi un arrosage en bande, sans intervention. Au cours de l'arrosage, la vitesse d'enroulement est réglée automatiquement de façon à apporter la dose d'eau choisie. En fin de parcours l'enroulement s'arrête automatiquement et l'ensemble est déplacé au moyen d'un tracteur pour arroser la bande suivante.

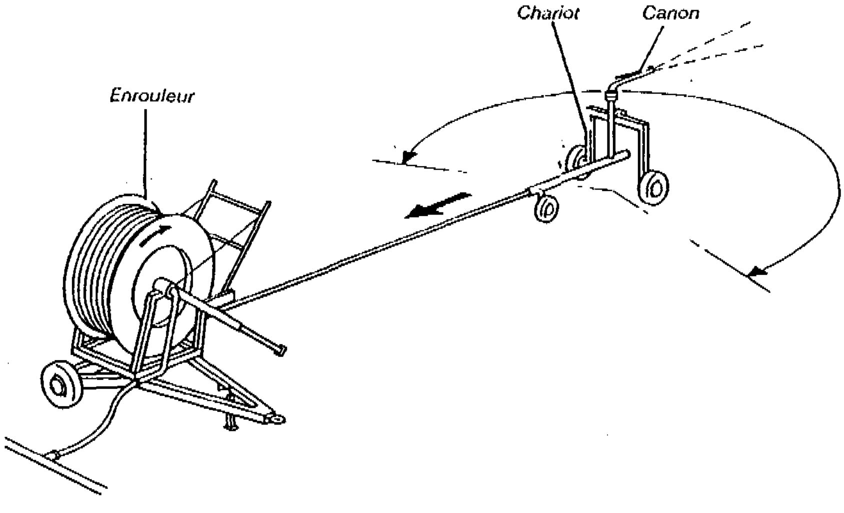


Fig.16-Enrouleur

L'enrouleur est le dispositif le plus utilisé en France pour arroser les grandes cultures annuelles. Il présente l'avantage d'une grande souplesse d'utilisation, pouvant être aisément déplacé d'une sole à l'autre. Il présente l'inconvénient du canon à savoir que la sensibilité au vent qui peut entraîner un arrosage très hétérogène. On peut y palier en remplaçant le canon par une rampe d'asperseurs montée sur roue. Le dispositif, beaucoup plus encombrant, perd alors de sa souplesse. Exigeant une pression de fonctionnement élevée (7 à 8 bars) il consomme beaucoup d'énergie.

Le pivot ou rampe pivotante est constitué d'une rampe articulée dont les travées sont portées par des tourelles auto-motrices entraînées par des moteurs électriques. La rampe peut comprendre jusqu'à une quinzaine de travées de 35 à 65m chacune. Elle est alimentée en eau par l'une de ses extrémités, par un tuyau vertical ou pivot, autour duquel elle tourne. Le pivot arrose automatiquement un cercle ou une portion de cercle dont la superficie peut atteindre 100 à 150 ha.

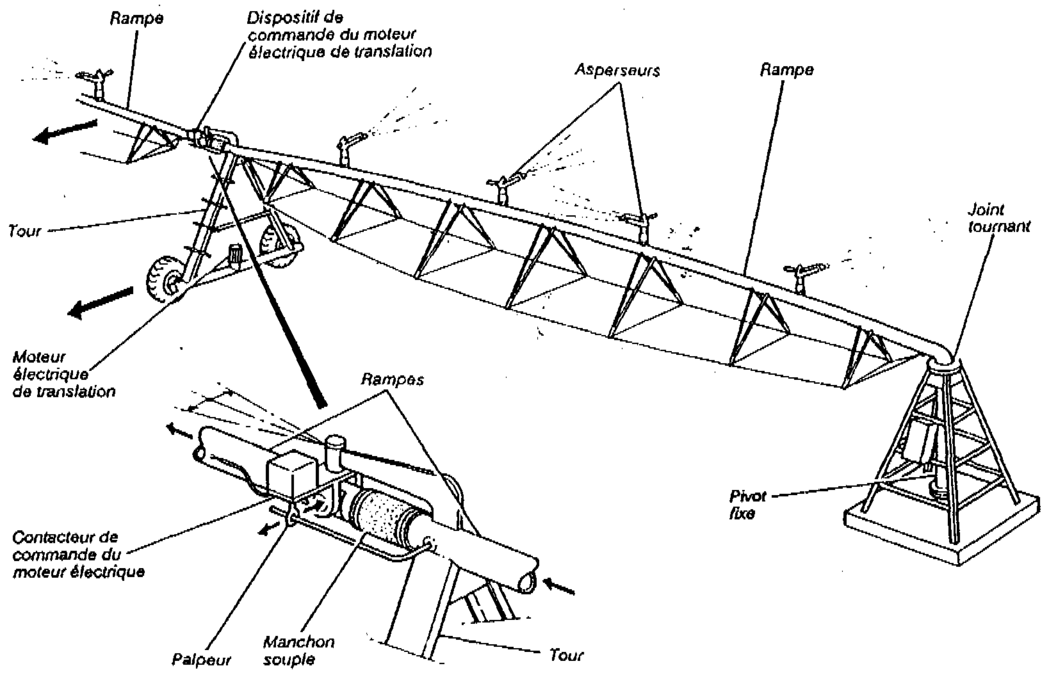


Fig.17-Pivot

Le pivot présente le gros avantage de pouvoir réaliser un arrosage très homogène et bien contrôlé, sans aucune intervention manuelle. Cela permet d'envisager son utilisation pour répandre les produits fertilisants ou de traitements phytosanitaires. Son principal inconvénient est la forme circulaire de la surface arrosée. Il convient bien pour les grandes surfaces de monoculture.

Ces dispositifs modernes présentent l'avantage d'être plus faciles d'emploi que l'irrigation de surface et d'être automatisables. Ils sont nettement plus efficients et permettent d'importantes économies d'eau : Bien utilisés, ils permettent d'atteindre des rendements hydrauliques nets voisins de 85-90%. Ces rendements peuvent néanmoins être bien inférieurs si les arroseurs sont mal disposés ou les enrouleurs mal réglés, ou encore par vent fort.

La micro-irrigation

D'abord utilisée sous serre, la micro-irrigation ou irrigation localisée fut appliquée en plein champ en Israël vers 1950 et s'est ensuite développée progressivement à partir des années 1960, notamment en Australie, aux Etats-Unis, en Afrique du Sud et en Europe. L'irrigation localisée consiste à humidifier une partie du sol dans la zone des racines des cultures en y apportant des petites doses d'eau fréquentes à faible débit. L'eau véhiculée dans des tuyaux en plastique de faible diamètre, est diffusée au voisinage des racines par des organes de distribution tels que des goutteurs, diffuseurs ou des ajutages calibrés. Ces organes fonctionnent sous une pression de l'ordre de 1 bar avec des débits de 1 à 8 l/h pour ce qui concerne les goutteurs ou les gaines perforées, 20 à 60 l/h pour ce qui concerne les diffuseurs, 35 à 100 l/h pour les ajutages calibrés *(5)*.

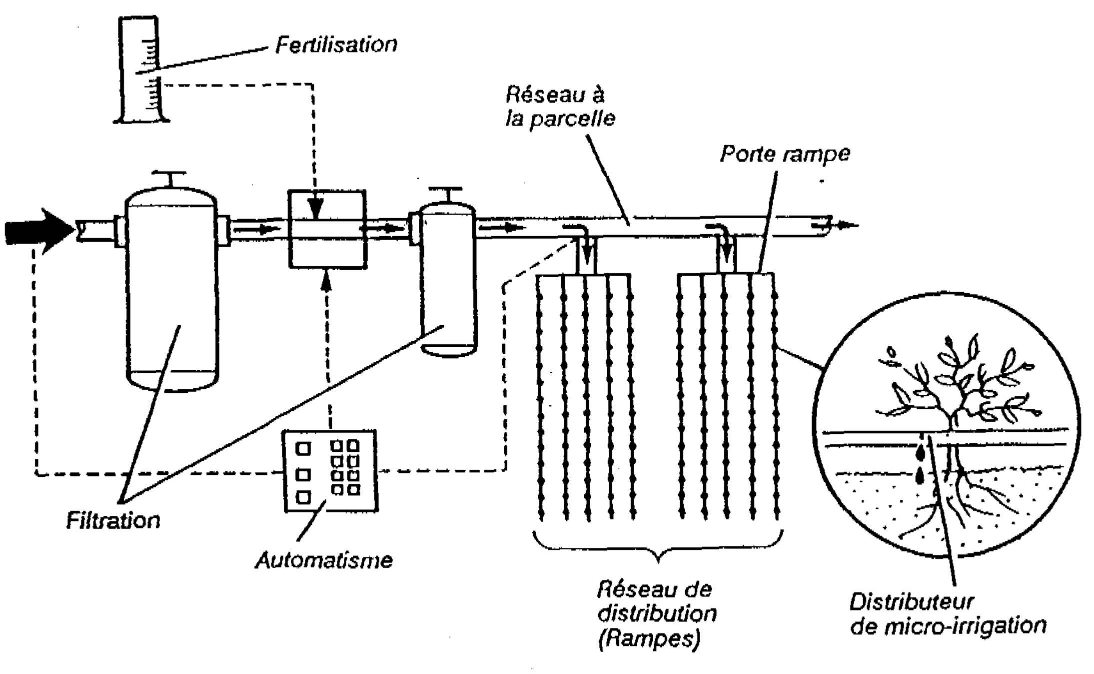


Fig.18-Schéma d'une installation de micro-irrigation

Utilisant de faibles débits avec de faibles pressions, cette technique présente l'avantage sur l'aspersion d'exiger peu d'énergie et des équipements légers. Les arrosages ne mouillent pas les feuilles, ne sont pas sensibles au vent et les pertes par évaporation sont limitées. La micro-irrigation permet un très bon contrôle des apports d'eau tant en ce qui concerne les quantités apportées que l'uniformité des apports : on peut atteindre des rendements hydrauliques de 95%, voire même plus élevés. Cela à condition toutefois que le système soit bien conçu et fonctionne bien. La conception du réseau, c'est-à-dire le choix de débits et de l'espacement des goutteurs, ainsi que la conduite de l'irrigation nécessitent une étude assez précise, qui tienne compte des caractéristiques du sol et de son aptitude à diffuser l'eau latéralement.

Les dispositifs de micro-irrigation sont sensibles au colmatage physique (particules solides), chimique (dépôts, incrustations) et biologique (développement d'organismes). Leur bon fonctionnement exige une eau de bonne qualité, ce qui nécessite en général un poste de filtration, une surveillance et un entretien du réseau efficaces.

L'apport fréquent de doses faibles impose pratiquement une automatisation du réseau. Mais celle-ci est facile tant pour l'irrigation que pour les apports d'engrais par le réseau.

La concentration des racines dans les volumes limités des bulbes humides rend les plantes sensibles à toutes défaillances qui peuvent affecter les apports d'eau.

Enfin les investissements d'un bon réseau de micro-irrigation sont élevés.

C'est un système particulièrement bien adapté aux cultures à haut revenu telles que les vergers, les vignes et le maraîchage. Sur les grandes cultures sont coût d'investissement limite son développement.

CONCLUSION

Moderniser l'irrigation ne signifie pas obligatoirement qu'il faut remplacer l'irrigation de surface par l'aspersion ou par la micro-irrigation. Des progrès, qui permettent la diminution des interventions manuelles pénibles et l'amélioration des performances des réseau, ont été réalisés dans tous les modes d'irrigation. Mais cela au prix d'équipements industriels plus ou moins automatisés, souvent coûteux et dont l'utilisation peut exiger une bonne technicité.

Certes, l'irrigation de surface ne permet pas d'atteindre les rendements hydrauliques maximaux des réseaux sous pression. Mais un système d'irrigation de surface modernisé bien utilisé peut avoir une performance bien supérieure à celle d'un réseau d'irrigation par aspersion ou de micro-irrigation qui fonctionne mal.

Le choix du mode d'irrigation et du niveau d'équipement et d'automatisation doit tenir compte non seulement de la disponibilité de la ressource en eau, mais aussi des contraintes financières, de main-d'oeuvre et de niveau de technicité de l'exploitation et de son environnement *(6)*.

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Figures

1, 2, 3, 4, 5, 6,

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12

INFORMATION SYSTEM FOR WATER RESOURCES PLANNING AND MANAGEMENT : APPLICATIONS TO IRRIGATION

LUIS SANTOS PEREIRA

PORTUGAL

INFORMATION SYSTEMS FOR WATER RESOURCES PLANNING AND MANAGEMENT: APPLICATIONS TO IRRIGATION

Luis Santos Pereira (*)

Summary

This paper reviews some aspects of information systems, mainly systems analysis in water resources planning and management. After a short overview on methodologies and techniques, several examples of their application to agricultural are presented water management. These case studies include irrigation scheduling simulation models and decision support systems (DSS) designed to help farmers optimize decisions on when and how much to irrigate, as well as planners and managers to orient decisions on allocation and deliveries according farm strategies. Case studies also cover the use of DSS for design of surface irrigation systems and for improved management of canal irrigation systems. Examples make evident the usefulness of information systems, but also the need of appropriate institutional solutions for implementation and for communication between medellers and users.

Resumé

Cette communication fait la révision de quelques aspects des systèmes d'information, en particulier l'analyse des systèmes, pour la planification et gestion des ressources en eau . Ainsi, après un aperçu sur les méthodes et techniques utilisées, sont donnés quelques exemples d'application en irrigation. Des études de cas concernent des modèles de simulation de la conduite des arrosages et des systèmes de support à la décision (DSS) pour

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appuyer les irrigants à decider sur l'opportunité et les volumes des irrigations, aussi bien que les projectistes et gestionnaires à orienter leurs décisions sur les allocations et les fournissements d'eau selon la perspective des producteurs. D'autres études de cas concernent les DSS pour le project de systèmes d'irrigation de surface et pour l'amélioration de la gestion de systèmes gravitaires collectifs. Les exemples montrent l'utilité potentiel de l'analyse de systèmes en même temps qu'ils font découvrir le besoin de solutions institutionnelles appropriées pour leur implementation pratique et, aussi, la necessité d'améliorer la communication entre les analystes et les utilisateurs.

INTRODUCTION

Information systems are methodologies aiming at supporting decisions. Two main type of information systems are used in water resources planning and management: geographical information systems (GIS) and systems analysis. Geographical information systems are powerful database systems which combine data banks, spatial data processing, thematic mapping and graphic/geometric data processors. GIS are essential support of information for decision making and are often associated with systems analysis for building decision support tools.

Systems analysis is a broad methodology of using models for solving engineering and management problems by decomposing them into inderdependent processes of different nature. Modellers represent the processes involved and theirs inter-relationships according the nature of processes - physical, economical, social, ecological - and objectives to be attained - planning, design, management, operation.

In systems analysis there are two main group of agents, the modellers and the users. Among users we may have designers, managers, operators and other decision makers. The interfaces between these two main group of agents can do not be very clear but distinction can be made in a simple manner, like discussed by Loucks (1992): modellers must accept that decisions may not be influenced by model results, while decision makers should not blame on the models if their judgement has not been the best.

Systems analysis require a strong interaction among modelers and decision makers. The statement of the problem must be clear, objectives be well defined and information maximized. To do so the users have to be involved with the conceptual development of the models and not only be the clients for a final product, while modellers can not be left alone, without any feedback about theirs outcomes.

Main advances in systems analysis methodologies come from research but no similar progress is visible on its use by decision makers despite developments in computational facilities and users friendly interfaces. Therefore the gap between research and practice may be increasing. Challenges have to be faced by both analysts and users (Loucks, 1992) and new efforts have to be done for filling the gap between research and practice. This is particularly true in irrigation and agricultural water resources planning and management.

AN OVERVIEW ON SYSTEMS ANALYSIS

Systems analysis can be applied to a very large number of problems in irrigation and agricultural water management. These comprise on-farm decisions, project operation and management, water resource planning and allocation, water quality management, environmental impacts assessment. In any case an optimal solution is searched but the optimal result can be expressed in particular forms or satisfying specific requisits. Very recent review papers by Loucks (1992), Yeh (1992), Goulter (1992), Simonovic (1992), Uber et al (1992) and Orlob (1992) give a complete information on systems analysis methods and their application in water resources.

Linear programming (LP) is one of most widely used techniques for managerial purposes in water resources (Yeh, 1992), including linearization or quasilinearization procedures when dealing with non linear equations. This optimization technique is common in agriculture when the objective function is expressed in monetarian terms. A recent example is given by Prato and Ma (1991) for evaluating impacts of agriculture on water quality. Linear programming is also common to optimize pipe distribution networks (Goulter, 1992).

Techniques derived from linear programming like dynamic programming and non linear programming are also common, with both deterministic and stochastic approaches. As for LP, they are particularly useful for water resources management, namely for water allocation purposes and for reservoir management (Simonovic, 1992). Several other formulations of mathematical optimization models have been developed in the last decade to responde to complex systems or multi-objective and multi-criteria problems. They are applied in particular to optimize water allocations and to evaluate water quality strategies and alternatives (Uber et al, 1992; Orlob, 1992; Kindler, 1992).

The use of simulation models also developed enormously to support decisions. These models cover a great variety of situations and approaches (Loucks, 1992). A simulation model can be utilized alone creating alternative solutions or scenarios which help the user to make a decision. This is typically the case for irrigation scheduling (Stockle, 1991; Pereira et al, 1992). Or the model can generate state variables which allow the best operation decisions, as it happens with canal models (Burt and Gartrell, 1991, Clemmens et al, 1991).

More recently, several models are embedded in a frame programme making it possible an holistic approach considering the interaction of different processes. This is tipically used for design and management (Ait Kadi et al, 1990, Zagona and Strzepek, 1991) of irrigation systems. The present literature is rich of similar examples in many areas interesting irrigation and agricultural water resources management. At present, decision support systems (DSS) become more widely used because they combine, in a holistic and interactive approach, simulation and/or design models, optimization models, data bases and/or geographical information systems embedded in a friendly and graphical user interface. This facilitates the use of models and should increase the interaction and communication between analysts and users (Loucks, 1992).

Exemples of DSS in irrigation and agricultural water management are growing, both for design (Bralts et al, 1990; Garcia et al, 1990) and management at farm (Hoogenboom et al, 1991; Wilmer et al, 1991) and project level (Ait Kadi et al, 1990; Zagona and Strzepek, 1991).

EXAMPLES OF APPLICATION IN IRRIGATION

Decision levels and planning scales

For irrigation and agricultural water management, three levels of decision must be considered (Pereira, 1987):

a)_ The farm level. Farmers decide on crops, cropping systems, irrigation methods and irrigation management practices. These decisions combine to define the on-farm water management. Results of the irrigation projects depend upon the appropriateness of such decisions. Nevertheless, farmers decisions and O-FWM practices are influenced by decisions and criteria from the upper levels.

b)_ The irrigation project level. Decision belongs to the operation, maintenance and management (OM&M) authorities. The OM&M decisions, in particular the delivery scheduling, affect and introduce restrictions to the on-farm water management decisions. Thus they should be oriented to provide the adequate conditions that enable the best irrigation and farming practices. Decisions should also make effective the water resources policies and the involvement of farmers in the management process.

c)_ The basin level. Decisions are related to the country or regional water resources policies and influence agriculture through water allocation and water quality criteria. Representatives of the farmers and of irrigation associations should be involved in the process of water resources policy making and for solving intersectorial conflicts.

Exemples are given bellow relative to the first two levels of decision. These examples concern case studies of research being developed. For the third level of decision, the river basin or region, it is our understanding that problems of institutional nature prevail on the technical ones (Pereira 1987; Pereira 1991). A large number of tools to support corresponding decisions are reviewed in Loucks (1992), Simonovic (1992) and Uber et al (1992), just to quote some of most recent papers.

Irrigation scheduling simulation

Large number of papers give information on simulation models which could help farmers decisions about when and how much to irrigate. The papers included in Pereira et al (1992) give a perspective on these diversity and explain a large number of models and approaches. As exemple, the model ISAREG is selected (Teixeira and Pereira 1992; Teixeira et al, 1991).

The model ISAREG performs a soil water balance for irrigation in combination with an water-yield routine. Thus irrigation scheduling is evaluated through two parameters, the relative crop evapotranspiration and the relative yield loss.

The programme has a friendly users interface, with Portuguese and English versions, which permit the users:

- to select, introduce, modify or update the data files on crops, soils and meteorological variables (evapotranspiration and effective rainfall);

- to choose the simulation options for (i) fulfilling the crop water requirements (maximal yield), (ii) applying deficit irrigation using a selected irrigation treshold, (iii) irrigating with restricted available depths and at fixed periods; (iv) optimizing the irrigation dates when water supply is limited;

- to repeat calculations with new tresholds or new assumptions for the computational procedures, thus comparing alternative irrigation strategies;

- to make new computations for alternative crops or crop systems, as well as other environmental data.

This simulation model is therefore a tool for selecting alternative strategies for irrigation management, helping the farmer to plan irrigation of several crops in more than one location. Present developments include: the development of a programme to help designing irrigation projects using simulated scenarios of crop patterns and irrigation management rules (programme PROREG); the development of programme to simulate the demand in an irrigation system aiming at improving deliveries and operation; the combination with a geographical information system to make easier the utilization of ISAREG at regional scale.

Decision support systems for irrigation management

The usefulness of DSS for irrigation management is evident: the farmer (or an irrigation system manager if the programme is designed under this perpective) can, in real time, decide and revise decisions on the timeliness and depths of irrigations.

These DSS developed first for center pivots irrigation management (Wilmes et al, 1990) but tend to be applied to diversified conditions. This is the case for an EC project[1] aiming at developing an irrigation management DSS, the HYDRA DSS. Diverse irrigation processes (sprinkling, drip/trickle and surface irrigation) are considered as well as several crops - fruit, vegetable and field crops. The system is expected to be applied by farmers at regional level, integrated or not in collective irrigation systems.

The HYDRA is composed by

- an user's interface, commanding the input and output using a friendly language;
- a knowledge processor, consisting of (i) an interpreter for converting users goals into optimization calls, (ii) a scennario generator to select the computational sequence and models to be utilized, (iii) an optimizer for solving optimization functions, and (iv) a translator which converts the mathematical optimization results into the user language;

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1 The project leader is the University of Trento and associates are CSIC-Murcia, IAM-Bari, Staring Centre-Wageningen, RES, Rothamested, ISA-Lisbon, Bonifica-Roma, HITEC, Athens.

- a models processor commanded by the knowledge processor. Several simulation models can be embedded which are called by a trigger model according the nature of problem to be solved. At present models considered are ISAREG (Teixeira & Pereira, 1992), a real time irrigation scheduling model RELREG derived from ISAREG, the soil water balance and crop growth model SWACRO (Kabat, 1992), and sub - models derived from this one, including a salinity model;

- a data processor composed by a data base management system commanding several information systems relative to agro-meteorological data, soils, crops and other spatial data like thematic geographical information systems.

Building this HYDRA DSS is a very challenging activity requiring a strong multidisciplinar approach, which justifies the involvement of institutions of several countries.

It is expected that HYDRA be accessible to farmers under different hardware configurations like personnal computers or videotex. This DSS should enable farmers to optimize planning of irrigation strategies and to decide irrigations in real time. The simulation capabilities together with the thematic and spatial database would allow managers and planners to optimize deliveries and water allocation. Uses of DSS are comparable to those of simulation models but optimization capabilities, multiple choice of models, and enlarged capacities of databases give to DSS a wider application and improved accuracy.

As for using simulation models, a problem subsist: the implementation in field practice. This require not only the models be adequately validated but that appropriate institutional arrangements be built, involving farmers and extension officers in a strong cooperation.

Design of farm surface irrigation systems

The design of surface irrigation is not anymore a task to be left to farmers, like it happen when these systems were traditional. With modern surface irrigation multiple options have to be considered simultaneously: the irrigation process (furrow, level basin or borders); the slope; the length and width of the field units; the irrigation discharge and duration of irrigations; the water supply, like a field ditch with syphons, gated pipes, surge flow equipment, cablegation or other automation devices.

A DSS can be of great interest to help farmers, designers and managers making the best decisions. Thus a DSS for designing farm surface irrigation systems must embed several models or programmes:

- a data base (GIS) including information on field forms and locations, soil hydraulic characteristics, land slopes, the water distribution system and turnout discharges, main crops, water requirements;

- a design model for furrow, border and level basin irrigation, like SIRMOD (USUF, 1989);

- a land leveling design model;

- design models for the on-farm supply systems;

- a programme for computation of the economic impacts of the design solutions;

- a programme for evaluation of alternative solutions based on investment costs, operational costs, irrigation performances and related impacts on yields.

This DSS is being developed for the Mondego area, based in field calibration now under progress. This DSS would provide the support to:

- the selection of the most appropriate surface irrigation method: furrow with continous or surge flow, border or level basin irrigation;

- the required land levelling;

- the definition of the design parameters like furrow length, slope, discharge and irrigation time and, for level basins, the discharge, the length and width of the basin, and the irrigation time;

- the choice of the water supply system, size of conduits and automation devices;

- the computation of irrigation performance parameters, mainly application efficiency and distribution uniformity;

- the investment and operational costs;

- the comparative economic advantage of the irrigation system.

Improvement of irrigation systems management

As reposted earlier, many attempts are being developed and implemented to improve deliveries, operation and management of collective irrigation systems (Ait Kadi et al, 1990; Pereira et al, 1990; Zagona and Strzepek, 1991; Gates et al, 1991). Developments are particularly important for irrigation canal systems, where response time and restrictions to delivery are much greater than in pressurized systems (optimization tools for these systems are dealt in another paper to this Workshop).

For canal systems, objectives of decision suport tools are to help managers deciding deliveries that match demand. This would improve farm irrigation conditions allowing the implementation of more flexible irrigation delivery scheduling, and providing conditions to reduce operational water losses.

Decision support tools for management of irrigation canal systems include several models and processors. Taking as example the case study described by Pereira et al (1990), it can be observed that a system has to include.

- a database concerning the canal conveyance and distribution system including turnouts, the irrigated parcels, the agro-meteorological information, the records of past years irrigation and the records of actual deliveries. A GIS would be required. Information has to be used by the different models;

- a demand model for predicting in advance the outflows at main turnouts in the system in case no restrictions are imposed to users for formulating their own demands. In alternative, if farmers demand is provided enough time in advance, the demand model aggregates the demands at turnouts;

- a delivery model which computes the demand hydrographs and helps to decide priorities of delivery where demand exceeds the capacity of the system;

- a canal simulation model which computes travel times. The hydraulic simulation helps to establish the inflow hydrograph that better satisfy the target deliveries.

Canal irrigation systems management tools can be used not only to improve deliveries but also they may be utilized with remote controlled devices to command regulation structures if remote sensed state variables are available in real time. The data base can also be used with an interface for the irrigators to formulate the demands. Also the database can be use for billing using the information on actual deliveries. More advanced configurations of the systems using optimization processors can be considered as DSS. The advantages of using any kind of these management tools are evident when compared with traditional upstream control systems, where the rigidity of operation and delivery is the basic condition for equity and reliability.

CONCLUSION

The short review above shows a diversity of methodologies and approaches on using information systems to support decisions in water resources planning and management, particularly in irrigation. Applications to on-farm and off-farm irrigation management, as weel as for design of irrigation systems, make evident the potential of such decision support tools, but also two great challenges for making full use of them: reducing the gap between research and irrigation practice and improve institutional arrangements for farmers participation.

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IRRIGATION COST RECOVERY IN DEVELOPING COUNTRIES

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IRRIGATION COST RECOVERY IN DEVELOPING COUNTRIES

M. ABU ZEID (*)

ABSTRACT

The cost of delivering irrigation water to agricultural producers in a marketing economy is customarily accomplished by private irrigation companies or districts that operate on a non-profit basis for the purpose of providing the service and the commodity at cost.

In developing countries where the economy is usually subsidized recovering the cost of water delivery is much more complicated and difficult. A key policy for cost recovery for an irrigation system should be based upon a sense of equity among the beneficiaries. Because costs for maintenance and operation lag seriously over years of operation, water is not usually delivered effectively and therefore produces inequities. Methods of assessment and collection of fees must be considered in light of country's economic and technical environment. This and other issues are discussed to assist decision/policy makers concerned with cost recovery.

INTRODUCTION AND BACKGROUND

In the last few years in Egypt there has been great interest in the issue of water pricing as a means for irrigation water management, and for saving a portion of the investments required for modernization of irrigation systems at the farm level. In spite of the fact that there are difficult technical and economic considerations concerning the subject of water pricing, The issue is still considered highly important in the political and social areas.

However, in view of the difficultly of separating the technical/economical considerations on one hand from the political/social ones on the other, it is necessary to provide political decision-makers with a sound technical basis for their decision. This is the main purpose of this paper.

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The most obvious reasons that make irrigation water pricing an issue of such importance, is that many of the countries and international agencies have focused upon this subject in their conferences and seminars, and have come to some conclusions, eg:

1) Increasing the efficiency of the already existing irrigation projects by modernization and /or improved development has become a higher priority from an economical viewpoint than initiating new projects. Undoubtedly, any improvement or modernization of the existing projects must include the need for additional investments, a large portion of which must cover the on-farm irrigation network which is the farmer's domain.

2) Frequently international donor agencies may offer grants or loans for agricultural sector development under conditions that the government establish a cost recovery system.

3) In most cases, modernization of the irrigation network necessitates increasing the allocation of operation and maintenance funds in such a way that these funds are guaranteed to be available and therefore ensures the efficient performance of the network.

4) Numerous professionals have emphasized the importance of on-farm water management in the existing projects with the aim of increasing their productivity and saving the extra water. One opinion indicates that water pricing automatically leads to improved water management. However, there is evidence to the contrary also.

The complexity of the problem is further increased by the fact that some farmers, especially in the new lands, bear the total expense of water delivery to their fields from the main canals or from conveyance and operational wells (Which is considered a part of the suggested water pricing fees), while on the other hand farmers on the old lands bear no expense for delivery.

WATER PRICING CONCEPTS

There have been different opinions and understandings concerning the terminology and concept of the Water pricing. Some suggested that the pricing should be considered as additional tax or a fee that covers part of the expenses of modernization, operation and maintenance of the irrigation network. Another concept is that the price should be based upon some value of the irrigation water per unit area, per crop or per cubic meter.

It should be noted that one or the other of these two concepts is used by many of the developing and developed countries for water pricing.

Irrespective of the value set for the irrigation water fee, it is very important to establish a procedure that governs the farmer-government interrelationship in terms of estimating and collecting the fees and ensure that they are directed toward the improvement and maintenance of the irrigation system.

Specialists have handled this matter controversially based upon the different economic policies and concepts used in each individual study case. Nevertheless, in order to put into motion any drastic changes or the establishment of any fee for irrigation water, there should e a strong political subsidy, particularly in countries like Egypt where irrigated agriculture is an important economic sector.

It is also essential to have the same governing principles of irrigation water pricing for both old and new lands. It should be made clearly evident to the farmers that these water fees are not an additional tax or scheme for charging them more money; but rather, a service charge for improving the irrigation network and increasing its efficiency, which will lead toward increased agricultural productivity, a benefit primarily for the farmer and of course to the national economy in the long term.

The Water Research Center of Egypt has recently conducted two valuable studies in water pricing in cooperation with Cairo University. The first of these studies was aimed at determining the costs of irrigation water conveyance from the High Aswan Dam to the different delivery application sites, taking into-consideration the expenses due to transfer, distribution, operation and maintenance of irrigation network. The second study focused on an assessment of the agricultural return (benefit) from $1000m^3$ of water when used in irrigating different crops in various areas.

The results at this stage have general implications, however, a considerable amount of additional data is still required if precise values are to be used in establishing a water pricing policy. Yet, no matter what the values might be-which exceeds the scope of this paper it is only one fact of the numerous criteria that should be considered before affixing any new policy on cost recovery or water pricing.

It should be pointed out that irrigation water pricing may have a very harmful impact on farmers under poor economic conditions. It may lead to total abandonment of their incentive for high productivity or to a tendency to cultivate only for subsistence. Therefore, a proper balance between the advantages and disadvantages is of utmost necessity before decisions are made.

INVESTMENTS REQUIRED FOR IRRIGATION IMPROVEMENT PROJECTS

The Government of Egypt is presently implementing a National Irrigation Improvement Program in various regions with a total area of about half a million Acre. The required costs for development were estimated on the average to be $ 300/Acre,of which $ 100 were allocated for private irrigation networks.

At present time even though some of those projects are partly funded, it is usually difficult to justify them economically, at least according to the conventional economic criteria. In such cases, governments tend to subsidize the projects for several reasons; ie, decreasing population growth in critical areas, increasing the population in certain sensitive geographical regions, or saving water. It is noteworthy that the subsidy may occur as a transfer of resources from one group of society to another to improve a certain imbalance. Such subsides should be avoided whenever possible.

On the other hand, it is difficult to determine all beneficiaries that gain from irrigation modernization projects even if the improvements are restricted to the on-farm improvements. Consequently, part of the costs should be recovered from the most direct beneficiaries, and the balance should be recovered as a general water fee.

Another reason that governments may justify a subsidy, especially in the initial stage of project execution for national irrigation improvement projects, is that in most cases these projects are typically designed in a highly complex and very expensive manner. It may take considerable time before they finally become cost-effective. In addition, delays in scheduling of project execution may lead to additional unnecessary costs, and it would be unreasonable to charge farmers for such delay for additional projects costs.

Many specialists believe that, if irrigation water requirements and quotes were determined, all irrigation problems would be solved, and any modification in the irrigation rates should be preceded by a detailed analysis of the problem that affect irrigation efficiencies, the solution of which should be given priority consideration. It is certain that the sound management of the irrigation system as a whole requires additional financial resources.

WATER PRICING VERSUS IRRIGATION EFFICIENCIES.

The relationship between the cost of goods and its market value is well known in economics. Water is no exception to this law, and yet it may become invalid under two conditions: If the price of water becomes too high or if water is sold on a unit quantity basis. However, those two conditions are the exception rather than the rule. In most cases irrigation rates do not generally have any impact on irrigation efficiencies. Thus, if the farmer suffers from water shortage, he will try to use whatever quantity he can obtain by any means available to him. Consequently, it does not seem reasonable to set a pricing policy for water by attempting to force him to use it efficiently. However, water pricing in this particular case may actually lead to the use of less water. But if that is socially acceptable, then the question arises concerning how to beneficially use the water.

Concerning the measurement of water quantity as a basis for pricing, it has been found that the cost of installation, operation and maintenance of the measuring devices themselves (counters or other) are rather high, which in turn increases the price of water.

In most cases, the cost of water represent 10 -20% of the production costs for the majority of crops. As for the vegetable crops, they may be as low as 5%. Thus, one might expect that water pricing would have a great effect on the farmer's preference for certain crops over others. In order that such costs would have a tangible impact on the production, they should be increased (double or more); a trend which is now favored in most countries. In such a case, the farmer will find ways to avoid cultivating the high water-consuming crops. It is certain that the production costs have doubled within the last ten years, whereas the increase in productivity has not kept pace, a fact which should not be overlooked if a satisfactory income is to be obtained by the farmer.

And since irrigation water pricing is the basis for ensuring proper operation and maintenance, it is necessary to review and adjust all operation and maintenance practices before considering a policy. This should take place in the framework of acceptable management concepts, which is different from one country to another according to their different social and economic conditions. Other alternatives for lowering the operation and maintenance costs are to transfer some of the responsibilities to the water users themselves, or to design and operate the networks in such a way as to ensure their high efficiency and cost-effectiveness. All this should take place within the environment of a very efficient management system.

In the case of assigning the management of part of the irrigation network to the farmers, the costs of operation and maintenance may probably be greatly reduced and particularly cases of unlined canals or watercourses (mesqas). An additional advantage is the farmers' feeling of commitment due to their participation in operation and maintenance.

The farmers' responsibility of managing part of the network necessitates the precise determination of their duties and rights. A worth while consideration is to have them participate in decision-making, valuation and collection of fees, and scheduling the required training and organizational assistance for their service. Official instructions and procedures may be necessary to regulate such matters.

In the design of different irrigation projects, it has been observed that the improvement and modernization process of irrigation networks have noticeably increased within the last twenty years without consideration of the factors that reduce operation and maintenance costs. Consequently, many projects now represent a heavy financial burden on both the governments and farmers without finding practical solutions for this situation. Therefore, it is utmost importance to give more attention during the design stages of these projects to reducing their operation and maintenance costs to a minimum.

Moreover, instead of allocating a definite percentage of the gross budget to the operation and maintenance requirements, a detailed budget breakdown for operation and maintenance should be developed in harmony with available actual social, physical and organizational conditions. this step will encourage the use of local materials and will help obtain data from responsible authorities concerning operation and maintenance during the design stage.

WATER PRICING

In case of establishing these fees, they should be estimated as a percentage of the "Traditional user's capability for payment" derived form irrigation (i.e the net increase in his income as a result of irrigation), in order that the user might have a reasonable motivation for continuing irrigation and cultivation. As for the new projects, extraordinarily high fees should be avoided in the project developmental stages, where the payment capability is much less at the beginning than at the end of those stages. Thus, changes in the production rates and farmer's income in those regions should be closely observed.

In recent studies, specialists, have recommended that water pricing occur on a compound basis : The first is a unit area fee (constant fee) and the second is an additional fee per water unit (variable fee).

SUMMARY AND CONCLUSIONS

Developing countries are found to have over 75% of the World's irrigated lands. In order to meet the growing food demands in these countries, agricultural output must be expanded. It is apparent that irrigation efficiency of irrigated agricultural lands must be improved if future world food needs are to be met. Improved irrigation efficiency means more water for horizontal expansion of agricultural lands, since under most agricultural systems, water is the limiting factor and not land. A crucial issue in improving irrigation system efficiency is the equitable distribution of the irrigation water among users.

A better equitable distribution and increased efficiency in conveyance of irrigation water and on-farm irrigation is costly. These costs compete with other budgetary needs in the public sector and they increase the pressure for recovering some or all of these costs from the beneficiaries.

In many instances, multilateral and bilateral donors assisting in rehabilitating and improving the efficiency of irrigation systems have brought pressure to bear upon host governments to discontinue the subsidy of operation and maintenance of the system and have encouraged the government to focus more upon farmers as a source of revenue or cost sharing in the operation and maintenance. They have pressed also for more farmer involvement in management and planning.

Local government decision makers are under pressure to implement cost sharing schemes for irrigation expansion. This paper cautions decision makers in making decisions without extensive study and background information. Conflicts already exists between government and the private sector in agriculture. Decisions based upon insufficient information and background may produce a negative impact, the opposite to that desired of increased productivity. Policy/decision making must better understand the characteristics and motivation of the human components of the irrigation system.

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PUBLIC PARTECIPATION IN IRRIGATION AND DRAINAGE PROGRAMMES

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FAO

PUBLIC PARTICIPATION IN IRRIGATION AND DRAINAGE PROGRAMMES

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I. Introduction

Irrigation and drainage programmes are for the general benefit of the public. In the eyes of many, the people running the systems day to day are seen as the major beneficiaries but the water is a common good belonging to the people and in many locations is limited. Therefore, all citizens have an important interest in the efficient use of a resource which all share. Often water resources organizations are accused of thinking in terms of the best engineering solution without adequate attention to social and environmental goals or objectives.

Public participation is needed at the planning, project concept, design, implementation and operation stages. This paper examines the subject from first the standpoint of planning and then managing irrigation and drainage systems. It then discusses the FAO International Action Programme - Water and Sustainable Agricultural Development (IAP-WASAD) which is intended to assist the countries in preparing their programme for addressing these important issues.

II. FAO'S Plan of Action for People's Participation

Over the past few decades many governments, development agencies and non-government organizations have recognized that the "top-down" approach characteristic

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of traditional development strategies has largely failed to reach and benefit the poor. In their search for alternative approaches, they all have come to recognize the importance of people's participation as a principal mechanism for promoting rural development.

FAO's experience has shown that through participatory programmes and activities it is possible to mobilize local knowledge and resources for self-reliant development and, in the process reduce the cost to governments of providing development assistance. People's participation is also recognized as an essential element in strategies for sustainable agriculture, since the rural environment can only be protected with the active collaboration of local population.

In 1989, following requests from Member Governments, the FAO's Committee on Agriculture (COAG) and the Council examined the issue of people's participation and its activities in rural development. They recommended that the concept of participatory development be integrated into all development policies and programmes of FAO and also suggested that FAO develop a Plan of Action for People's Participation.

Accordingly, FAO developed a Plan (FAO, 1991 a) which was adopted by the 25th Session of the FAO Conference in 1991. The overall aim of the Plan is to ensure active participation of people in the achievement of sustainable rural development. While it is recognized that other factors relating to social, economic/financial and technical aspects do play an important role in achieving this objective, the active participation of voluntary, self-reliant organizations of their own choice is equally important.

The Plan, while fully recognizing and respecting the sovereignty of Member Governments, proposes that action be taken in the following seven areas:

* Promotion of greater public awareness of the role of people's participation and peoples's organizations in agricultural and rural development;

* Creation of favourable legal and policy framework for people's participation;

* Strengthening internal capacities of the rural people's organizations at local and national levels;

* Decentralization of government decision-making;

* Promotion of increased dialogue and technical collaboration between governments, development agencies and people's organizations;

* Introduction of appropriate operational procedures and methods to facilitate wider participation;

* Monitoring and evaluation of people's participation.

It must be recognized that the objective of active participation by the people in the development process can be achieved only through consistent and concerted efforts over a long period. The implementation of the Plan of Action will therefore call for the commitment by Member Governments to both long-term policies and adequate resources. FAO can, and will need to play an important role in the implementation of the Plan and to provide technical and financial support to interested countries in this task at their request. The Plan envisages FAO acting as a catalyst and an advocate to encourage and assist governments and people's organizations in promoting participatory activities.

III.What is Public Participation?

Public participation means different things to people. The dictionary defines public - "Of, concerning, or affecting the community or the people: the public good. Connected with or acting on behalf of the people, community, or government, rather than private matters or interests." It defines participation - "Taking part or sharing, joining with others." Thus public participation means the involvement of the people, even those not farming, in decisions related to irrigation and drainage.

For purposes of this discussion public participation includes being informed about the activity before the decision is made regarding the project; being given an opportunity to be heard; having an influence on the decision; and agreeing to the decision. Of course not all will likely agree to the final decision and that is not always essential (Creighton 1986). At the planning or project identification stage the "players" are often different than at the operational stage.

The tendency is to think in terms of farmer participation but to ignore the public at large. Serious consideration is being given in many countries to the transfer of the operation and maintenance of water delivery systems to farmers groups. An FAO sponsored expert consultation held in Indonesia in 1984 which examined Participatory Experiences in Irrigation Water Management went further, even encouraging farmer involvement in the planning, design and construction of the system as well (FAO, 1984).

IV.Public Participation in Planning Irrigation and Drainage Systems

The environmental movement in developed countries has caused increased attention to public participation in major projects. In some countries public hearings are required at various stages of project planning to insure an aware public which is being given a voice in how public money is being spent.

An aware public is important at all stages of projects. Community participation will significantly contribute to enforcement during implementation but the process begins during the planning stage. There are many examples of polluters doing a better cleaning up the environment when it was made known where the dangerous emissions were originating and who was causing the problem which was endangering the public.

In a recent World Bank report it was pointed out that for large water investments, governments must encourage stakeholder participation and work toward getting a national consensus. The people with environmental concerns and also secondary economic impacts should be heard. Of course, this will cause some delays during the approval process but will likely prevent costly delays later.

Although the importance of farmer involvement at all stages of irrigation project formulation and development is known, the government organization does not always take the time to insure that it is done. The FAO Consultation on Irrigation in Africa (FAO, 1986), concluded "farmers' involvement in all stages of irrigation development and management, and devolution of management responsibilities to farmer-water users' associations are indispensable to achieve successful development."

Through the implementation of pilot swamp development schemes in Benin, FAO has developed and tested a participatory methodology, in which local communities are considered as full partners and make the major decisions in a negotiation process with local authorities (FAO, 1986). The communities, organized into associations, are responsible for scheme planning, operation and even marketing of products. The project prepares several alternatives for consideration of the association which makes the decision. The inputs to be provided by various partners are negotiated and a development contract is signed. Monitoring and evaluation of the process is provided by members of the association to insure that there is two way communication to improve the techniques of working with people.

In Burkina Faso FAO uses a similar approach to rural development (FAO, 1987). The project team works with villagers to assess the situation and identify development problems. Priorities are defined together and alternative courses of action considered. The choice of development activities which will be performed is the basis of a contract between the village and the project. After completion of the project activity an assessment of results is carried out by the team and villagers.

Bagadion (1986) reported that lack of participation of the farmers during project planning and construction usually results in location of canals and structures which do not correspond with their perceived needs and thus non use those facilities. Problems which often occur when participation is lacking include inequitable distribution of water, wastage of water at the farm level, and poor maintenance of the system. He further reported that government irrigation agencies tend to resist the idea of farmer participation because of anticipated delays. Projects in the Philippines indicate that properly planned and implemented farmers' participation, while difficult at first, facilitates many aspects of implementation and does not need to delay the project. It is often necessary to provide training and reorientation for the government people working with farmer groups.

In the Philippines, an Irrigation Community Organizer (ICO) was introduced into the village to assist the farmers. The ICO helped the community to identify their problems and seek solutions to resolve them. This grass-roots approach was well received as the planning and implementing of solutions was that which the villagers saw as their solution for which they felt ownership and responsibility for its success. The farmers would participate in all phases of development and rehabilitation. A formal Irrigation Association (IA) would be created to continue operation and maintenance after the National Irrigation Administration (NIA) withdrew. A formal contract is involved between NIA and the IA. The key to the program is the involvement and gaining confidence of the leaders of the village and the people.

Non-governmental Organizations (NGO's) are another group which strongly support participation on the part of the rural community. NGOs encourage self reliance in rural communities. This grass-roots approach has been well received by those they attempt to serve. The FAO reports a number of examples of cooperation among members of the community in various countries and types of projects (FAO, 1989).

Although there are many success stories of participation, problems have been encountered. In Africa, for example there have been problems in moving from popular participation to a workable arrangement for project implementation. In practice, social organization and custom may discourage participation; government staff may be antagonistic or a ruling elite may see it as seditious; and contractual relationships, land tenure or gender roles may divide the community.

The tendency is to go with pilot exercises to refine the process prior to a large investment. A rural sociologist has often been essential to determine appropriate arrangements for participation.

V.PUBLIC PARTICIPATION IN MANAGING IRRIGATION SYSTEMS

While public participation in a general sense is particularly important at the planning stage since at that time the public opinion can change the course of the project but once the project is operational its role becomes less important and the participation of the direct beneficiaries, namely the farmers, emerges as a key to the success of the project.

The history of irrigation development testifies to the fact that most of the ancient systems were developed by group of farmers anxious to use a valuable resource: water. Farmers participation in the management of the system, once completed was a natural consequence. However, at some stage of this process, the magnitude of the effort to store and distribute the resource was beyond the capacity of the private groups and the governments started to take up the responsibility of building the systems. Here the dilemma of farmers participation starts. Several options are open to the governments : (1) for government officials continue to manage the systems after their completion; (2) to turn system over to the farmers to manage the system; and (3) to manage the system jointly, meaning that some part of the physical system (generally the larger canals) are managed by the civil servants while the smaller ones are the farmers responsibility.

Most governments have favoured the first option, particularly in the developing world, but this is precisely the one that is less conducive to the participation of the beneficiaries. The literature on management of irrigation systems is full of cases where the performance of such systems have been much below expectations and recurrent reason for it is the scarce level of involvement of the beneficiaries. This is often evidenced by the low financial contributions to meet the expenditures of the system which lead to a chain of negative consequences : poor maintenance, unreliable water distribution, lack of confidence in the project staff, etc..

On the other hand if one analyses the systems that were developed by the farmers and are managed by them the picture turns very positive and there is quite a number of success stories related to them. Examples of such systems are reported in South Korea Taiwan (China), Nepal, India, Indonesia, Spain, Italy, USA, Argentina and many others.

The conclusion that emerges from the above is that there is high correlation between farmers participation in the management of irrigation systems and their sustainability. Consequently many countries have embarked in recent years in programmes that tend to reduce the government role in the management of irrigation systems and expand that of the farmers by transferring part, or the whole, responsibility for managing the physical systems. Unfortunately, this is a recent phenomenon and there is little documentation about the processes and the results obtained (Vermillion, 1991).

Programmes of transferring the responsibility of management to the farmers are often introduced to reduce government expenditures as part of major reforms to the economy. There is the expectation that most of the costs related to the operation and maintenance of the systems will be borne by the beneficiaries and therefore considerable savings will be made as a result of these changes, for example savings, from the salaries of the officials that worked in the institutions responsible for operation and maintenance. There is also the assumption that a more direct involvement of the beneficiaries will result in greater accountability of those directly responsible for the day to day management task. There is the hope that better services will be provided and that this will lead to increased crop productivity and sustainability of the systems.

Governments have followed two different strategies to hand over irrigation systems to farmers. Some have favoured a rather quick establishment of water user's associations (WUA) and a rapid transfer of responsibilities to them. This approach has been followed in some few countries but with little success. Most of the countries are in favour of a phased handing over accompanied with training programmes for the leaders of the water users organizations. Both approaches have their pros and cons but the general believe is that a phased programme has better chances for success and provides more opportunities to change course if required.

Although these transfer programmes have mostly been initiated in recent years, already some lessons are being learned and there some issues that need to be tackled from the beginning in a decisive way:

- A transfer programme needs a very strong political support at the highest political level of the country. The public institutions that are responsible for the management of irrigation systems are likely to resist to these changes and only decisions at high political level can overcome such resistance. Furthermore changes to the water laws are often required and there should be political will for such changes.

- Farmers must understand what the transfer programme means: their roles and responsibilities, how to organize, clear rules and regulations for the operation of the system, financial implications etc.. To convey all this information to large number of farmers is not a simple task. A major effort in communication is required that needs careful planning and resources allocation.

- Transfer programmes imply that one or several government institutions will see its staff drastically reduced or will have to assume different responsibilities. In either case a plan is required and important financial resources may be needed for the payment of indemnizations and accrued benefits. Consultations with the concerned staff are of great importance in these situations.

- Farmers are not likely to accept the transfer of irrigation systems that have been poorly maintained and are in need of major rehabilitation. Therefore it is wise to undertake the rehabilitation works prior to the transfer programme. In such cases farmers must commit themselves to keep the system as received and this may imply substantial financial contributions through the water fees.

- Training of the farmers and the technical staff that will have the responsibility for the management of the system is also an important consideration. Government must take some initiative in this mater and bear some of the costs. Without this support farmers will experiment considerable difficulties in managing the systems during the initial years.

- The ownership of the physical systems is an area of conflict. Government take different stands in this mater. Some prefer to remain the owners of the systems and pass them to the farmers in a sort of indefinite lease and therefore the investment cost are not recovered. Others favour the transfer of the ownership and would require the payback of the investment costs or a part of them. Also if there are problems with the land ownership (like when some of the farmers land is public) they must be solved prior to the transfer since such problems are likely to affect the cohesion of the WUA.

- WUA must be legalized and their rights, obligations and attributions must be clearly spelled out and integrated in the water codes or regulations of the country.

- While many governments are favouring the transfer of irrigation systems there are high reservations about transferring the dams or the structures that store the water. The concern is that in many instances water is used for several purposes and only governments - as representatives of the general public - can manage the resource for the benefit of all possible users. There are however exceptions, and some countries (USA, Spain) have transferred even for main structures to the WUAs or to the private sector and they are being properly managed.

The above observations illustrate that the transfer of irrigation systems is not a simple affair and a number of aspects have to be well thought and planned carefully. This is why many governments are approaching the problem in a step by step manner and transferring only the minor canals (tertiary and below) and depending on the results obtained the responsibility for managing larger canals will be added.

Some countries have a definitive policy that irrigation systems must be managed by the farmers and there are some good examples of this policy in the Mediterranean basin. In such cases, it is of utmost importance that farmers are involved since the planing stage of the irrigation system in all aspects that may have consequences in its future management. During the construction phase efforts should be made to promote the establishment of the WUAs and help them to understand the technical aspects of the management of the system and take an increased responsibility in it. This tutoring period may be short (one or two years) or require longer period if farmers have less experience in irrigation and the associations have little cohesion.

Interactions between the irrigation systems and the surrounding environment

Irrigation systems generate intensive agriculture and tend to become social and physical environment with different characteristics than the surrounding rainfed areas. Often the irrigation areas attract people from the nearby as well as remote areas on expectation of finding work and a better livelihood which unfortunately only becomes true for some few. This is often the result of faulty information publicized through the media and generating expectations that cannot be fulfilled. The general public must be informed of what is happening in their area but overoptimistic statements about the potential that can be generated may create more problems than expected.

Another important aspect is that irrigation systems are mostly developed where a rural habitat already exist and rarely the needs of these villagers are taken into consideration. A small part of the irrigation water can be used to improve the quality of life of the concerned people and generate positive effects. For instance, with proper water treatment the water supplies of the villages can be improved, or some recreational areas established, or the drainage of the village facilitated. On the other hand the interaction of those villages and towns with the irrigation systems sometimes cause pollution problems in canals resulting in serious problems in their maintenance or to the crops grown. There is certainly the need for a dialogue between the beneficiaries of the irrigation systems and the rural environment that is influenced by them. Information about each other needs is the first requirement but also institutional mechanisms are required to operationalize the solutions.

VI.IAP-WASAD

The role of the public in promoting sustainable development is widely accepted. The FAO's strategy document on Sustainable Agriculture and Rural Development (SARD, 1991) emphasizes the active involvement of rural communities, collectively and individually, in all phases of rural development. Promotion of a "bottom-up" approach by developing more decision-making authority and responsibility down to the local level, providing incentives and enhancing the status and management capacity of local communities, including that of women were stressed in the FAO's SARD strategy. A conceptual framework of the FAO's SARD strategy is illustrated in Figure 1.

One of the four basic principles for sustainable water management adopted by the International Conference on Water and the Environment (ICWE, 1992) was on public participation. This principle states that water development and management should be based on a participatory approach involving users, planners and policy-makers at all levels. The conference recommended that decisions will need to be taken at the lowest appropriate level, with full public consultation and involvement of the users in the planning and implementation of water projects.

The importance of public participation for sustainable development is amply reflected in the FAO's International Action Programme on Water and Sustainable Agricultural Development (IAP-WASAD), FAO (1990). The objective of the IAP-WASAD is to assist developing countries in planning, developing and managing water resources on an integrated basis to meet the present and future needs for agricultural production.

IAP-WASAD emphasizes the importance of involvement of the farming community and the private sector for sustainable water use in agriculture. The following recommendations of the IAP-WASAD are relevant in this regard:

* ensure participatory approaches in water programmes by involving all members of the community, farming as well as non-farming members of the community;

* enhance the capability of farmers in the implementation, operation and maintenance of water programmes; and

* increase local capability for integrated water resources planning and management, with special emphasis on linking public technical agencies to rural development institutions and local community organizations.

VII.Lessons from IAP-WASAD Country Missions

FAO in collaboration with relevant UN Organizations and bilateral donor governments carried out six country and lake-basin missions (Egypt, Indonesia, Lake Chad Basin, Mexico, Tanzania and Turkey) under the framework of the IAP-WASAD. The objectives of these missions were to identify issues relating to water management for sustainable agricultural development and formulate costed and targeted national or basin action programmes.

The following could be deduced with regard to public participation (FAO 1991 b, c, d, e and FAO 1992) in irrigation policies, planning, development and management from these missions:

(a) In all countries, national irrigation planning is a "top-down" exercise, with little public participation in the decision making process. National agricultural and irrigation development policies are developed by the relevant government ministries in accordance with social and economic development goals. If public participated in shaping such policies, it has only been indirect; ie through the political process, as the government constitutes elected members, who are representatives of the people.

(b) In water management at project level, the participation of beneficiaries is evident in all countries, but in varying degrees. Management of water beyond the tertiary level is often left to farmers, who may manage water collectively through water users' groups or may function individually.

In Egypt, in the Sakia area and gravity fed areas of Fayoum, informal water users' groups were managing water at the farm level for hundreds of years. While other areas have had little or no experience with formal or informal water users' groups. Egypt has now formulated legal framework for the establishment of WUA's under the Egyptian Irrigation and Drainage Law which states:

" the mesqa (tertiary canals) hydrological unit is private by virtue of being located on private property. The WUA is legally a private organization. As private formal associations, WUAs will be involved in planning, operating, maintaining and monitoring their own mesqa."

In Mexico, the government is actively pursuing the transfer of 2.0 million ha of irrigation districts to WUAs. In the first phase, hydraulic structures up to secondary canals are transferred and it will be followed by a total transfer of the system.

In Indonesia, village irrigation systems covering an area of about 850 000 ha are managed by farmers. There is a move to hand over the responsibility of operating and managing tertiary systems of large and formal irrigation projects to the farmers, but creation of formal WUAs or similar farmer groups is still in experimental stage.

In Turkey, WUAs are functional in a few selected irrigation schemes. The government encourages the formation of such groups in all irrigation projects and proposes to establish legislation for the creation of WUAs and provide incentives for them.

It has become evident from the country missions that peoples' participation is more evident in soil and water conservation and watershed management activities as compared to irrigation and drainage activities. In fact, many governments promote community and peoples participation in such activities as the latter have not been successful when operated by government agencies.

In Turkey, a World Bank funded watershed rehabilitation project is being planned for implementation. There was broad agreement with participatory approach, whereby the local population and the government agencies will work together to identify problems and plan and implement solutions through integrated activities on a micro-catchment basis. The following two initial activities amply demonstrate the participatory approaches to be adopted by the project:

- An initial contact and confirmation of local interest in soil and water conservation activities;

- Using a "farmer centered-problem census, problem solving" approach sessions with local population to elicit the real and perceived problems of individual households; and

- Evaluation and implementation of the community's proposed solutions to the problems.

The IAP-WASAD has included in its national action programmes technical assistance to promote peoples' participation in all possible water management activities:

In Egypt, Indonesia, Mexico and Turkey, assistance is proposed to: strengthen legislation for WUAs; provide direct assistance to the creation and functioning of WUA's ; and train participating farmers on organizational and management skills.

In Mexico, a technical assistance programme is proposed to support the transfer of operation and maintenance activities to irrigation districts and modernize irrigation infrastructure and operation and maintenance techniques.

In Indonesia, direct support to farmer groups is proposed for operation and maintenance of irrigation systems beyond tertiary level, crop diversification, and soil and water conservation in rainfed agricultural areas.

In Tanzania, the need to promote the role of women in irrigation and agricultural activities is emphasized. The Action Programme states the following in this regard: "women's productivity needs to be improved, both in the production of food as well as in her other household chores. For agriculture, this requires improved technologies that increase output and the productivity of labour through for example, better land preparation, irrigation and weed control techniques "

VIII.Conclusion and Recommendations

Public participation and involvement in decisions which impact their lives is considered essential by many governments today. Water resources are used by all people but many governments distribute responsibility for planning and managing its use among many bodies of organization. In the United States, at present, there are at least 13 congressional committees, eight cabinet level departments, six independent agencies, and two White House offices with responsibilities related to water resources issues. Similar situations exist in other national governments. Coordination is often very difficult under the circumstances which exist. Sometimes the same water is being assigned or programmed for different uses by a "responsible" organization. Conflicts exist and the public should be given a voice in resolution of the conflict.

Recent changes in governments and increased concern about the environment have caused the public to express greater interest in having their views heard by decision makers. The June United Nations Conference on the Environment and Development held in Rio has focused considerable attention to the need for a sharing of responsibility for the wise use of limited resources.

FAO has developed a Plan of Action for People's Participation, which could serve as a framework for public participation in all rural activities including those related to Irrigation and Drainage programme.

FAO's experience has shown that farmers involvement in all stages of irrigation development and management and devolution of management responsibilities to farmer water users' associations are indispensable to achieve sustainable development. A number of national government and non-government organizations have taken bold steps to induce public participation in irrigation and drainage programmes and may have plans to follow.

Country and lake-basin programming missions carried out under the framework of FAO's International Action Programme on Water and Sustainable Agricultural Development indicate that, the concept of transferring the responsibility of managing tertiary units of irrigation and drainage systems to farmer groups is accepted by the governments in principle. Transfer of responsibility will have to be well planned and executed. A phased programme that will enable the establishment of required policy and legislative changes; the training of farmers and strengthening of farmer organizations; and transferring operation and administration oriented government agencies to perform advisory and monitoring functions needs time and requires resources.

Public participation is the key to sustainable development. As we march towards the 21st Century, public participation is likely to grow. It is incumbent for all of us to promote this change into a dynamic and constructive process in which people take initiatives and take action stimulated by their own thinking and deliberation.

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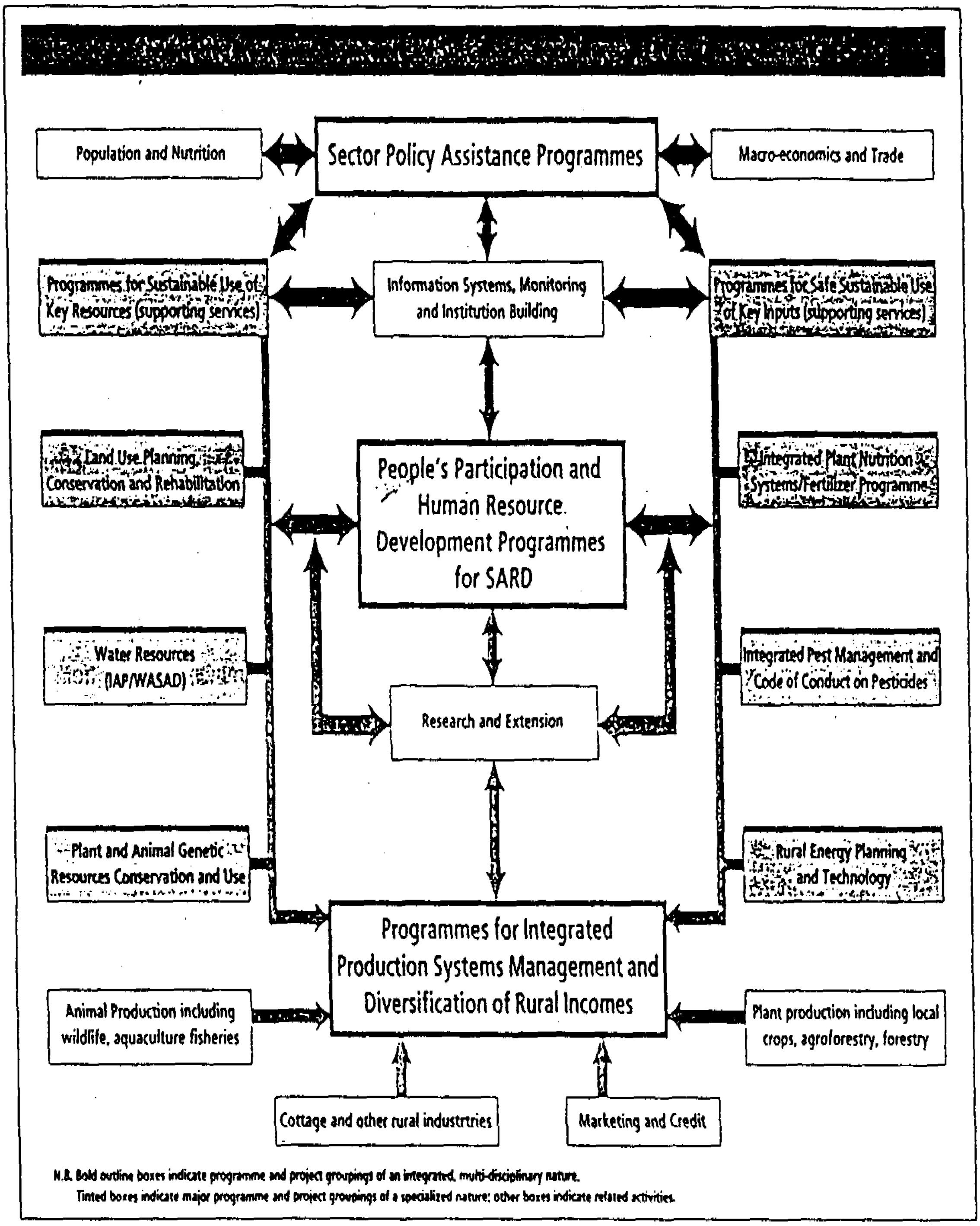
Population and Nutrition
Sector Policy Assistance Programmes
Macro-economics and Trade
Programmes for Sustainable Use of Key Resources (supporting services)
Information Systems, Monitoring and Institution Building
Programmes for Safe Sustainable Use of Key Inputs (supporting services)
Land Use Planning, Conservation and Rehabilitation
People's Participation and Human Resource Development Programmes for SARD
Integrated Plant Nutrition Systems/Fertilizer Programme
Water Resources (IAP/WASAD)
Research and Extension
Integrated Pest Management and Code of Conduct on Pesticides
Plant and Animal Genetic Resources Conservation and Use
Rural Energy Planning and Technology
Programmes for Integrated Production Systems Management and Diversification of Rural Incomes
Animal Production including wildlife, aquaculture fisheries
Plant production including local crops, agroforestry, forestry
Cottage and other rural industrtries
Marketing and Credit
N.B. Bold outline boxes indicate programme and project groupings of an integrated, multi-disciplinary nature.
Tinted boxes indicate major programme and project groupings of a specialized nature; other boxes indicate related activities.

Figure 1.

15

WATER LEGISLATION IN THE MEDITERRANEAN COUNTRIES

GUY LE MOIGNE

WORLD BANK

WATER LEGISLATION IN THE MEDITERRANEAN COUNTRIES

G. LE MOIGNE (*)

I. INTRODUCTION TO WATER LEGISLATION

Since all human activities, economic, social, cultural and even religious, use water, legal and institutional aspects related to water are everywhere and have always been quite important.

Sound understanding comes out from a keen study of the diversified legal and institutional arrangements which have been experienced all around the world. Observation must not be limited to a few recent years of comparison; we also need to know the performance of alternative solutions over many years of changing conditions. For one test of good water legislation and institutions is their ability to adapt successfully over time. Legal and institutional variations are an opportunity to learn from it in order to derive some predictions of how new adaptations might perform in other geographical or historical contexts.

Observations, experience as well as scientific theory can help to suggest legal and institutional frameworks which will suit different specific conditions.

But the only real test, of course, will ever be to try very carefully!

A. The Hydrological Cycle

Most of human economic and social require water. For health and life itself, water is a vital need for everyone, everywhere. That is the reason why early human settlements began and can any time develop where surface or ground water is more or less regularly available.

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Since the end of the 17th century, the natural circulation of water has been interpreted in scientific terms by the British and the French as the hydrological cycle within river basins bounded by watersheds.

Through its own territory, water may restlessly change its volume of flow and its quality substantially. These features have two main consequences:

- First, the availability of water is subject to uncertainty through variations of quantity and quality, which can be natural or man-made.
- Secondly, through these variations, the different uses of water intervene in the natural river basin regime and have direct or indirect effects--called externalities-- on each other over long distances and sometimes during a long period of time for ground water.

Where effects are strongly local and short term, they are like other problems that have to be dealt within a community. Through their legislation and institutions which reflects their own identity, communities try to come to terms with what they perceive as their water environment and feel as their responsibility. But the long distance and/or the long-term quantity or quality effects are often difficult to handle because they cross various institutional boundaries and different periods of time.

Because in the hydrological cycle water resources regimes are forever moving and varying under the influence of interrelated natural and human actions, there can be no ownership of flowing surface or ground water: water has to managed as a genuinely common asset. Public institutions necessarily have a role in the management of water resources which cannot be avoided or abandoned, that of the custodian, organizer, and referee of limited rights for particular purposes by legislature and administrative processes, often subject still to restraints in the courts of the constitution. The quantity and quality management of water resources has long been and will continue to be, in all communities, a matter of public governance.

B. Water Legislation

In all countries, water legislation draws on old standing traditions, local customs and rules of conduct. Water legislation is not an end in itself: it is one of the various instruments of giving effect to the water policies which it should reflect. Accordingly, legislation which is not preceded by, or does not explicitly involve, the adoption of certain policies, is unlikely to be effective. The policies may be adopted before the legislation and may even originate with another governmental body. To these two factors, namely, "policies" and "legislation", there should be added a third one: a water development plant for each country including, if necessary, specific planning for some river basins or ground water aquifers.

In all countries water legislation has been passed on a piece meal basis to deal with certain hazards, community conflicts or specific uses through the following stages:

a) legislation oriented towards certain hazards deriving from the existence of use of water or water run-off (regulations on flood control, natural run-off of rain-water, construction of wells, ...);
b) legislation oriented towards particular uses of water (laws on the supply of potable water, irrigation, river navigation, energy, industry, fish breeding, ...);
c) legislation oriented towards multiple uses of water and conservation of water as a resource, such legislation being concerned primarily with water and the coordination of its uses and secondarily with the particular uses themselves;
d) legislation oriented towards the joint management of various natural resources, which takes into account and regulates the interdependence of water and other natural resources (soils, forest, etc. ...);
e) legislation oriented towards the environment and dealing with water and other natural resources;

Most Mediterranean countries are at stage (b) moving towards stage (c).

As far as functional or intersectoral integration is concerned, stress must be laid on the need to harmonize water legislation with the legislation in other closely related or overlapping sectors of activity ad with a country's overall policy.

The wide range of branches of knowledge that are involved as regards the topics dealt with, is attributable to the very nature of water legislation and institutions and to the effectiveness of their role as instruments in the implementation of water policy. While the drafting of laws is a task for legal experts, the drafting of water laws is a task for experts with a specialized knowledge in various subjects working with the aid of specialists in related disciplines, for example, hydrologists, hydro-geologists, meteorologists, engineers, economists, administrators, sociologists and the like. This inter-disciplinary character of water legislation and institutions is widely recognized. Therefore, there is a critical world shortage of not only legal experts but also economists and administrators possessing the kind of education, training and experience referred to.

Although water resource management cannot be the responsibility of only governments, national governments must define and implement a legal and institutional frameworks balanced to meet the contradictory objectives of flexibility on one hand and simplicity and stability on the other. This framework must be flexible enough to adapt to diversified geographical and climatic features as well as to changing economic and social uses, yet both simple enough to be easily understood and effectively implemented and stable enough to be reliable and long-lasting.

II. WATER LEGISLATION IN THE MEDITERRANEAN COUNTRIES

Before entering upon the study of the various legal water laws in Mediterranean countries, it is necessary to have a general view of the customs and practices governing land-ownership, water ownership and use in various regions, always taking into account the effect on the evolution thereof of the legal doctrines and rites prevailing in each area. These established customs and uses form the basis of water legislation which, although complex because of their cautious and detailed provisions, have been respected even during the most anarchistc period of troubled life in arid zones.

As regards local customs, the geography has exerted a profound influence upon all aspects of human activity connected with the search for, and the distribution of water. In the final analysis, all water policies attempt to balance resources and requirements. One point should be borne in mind: in general, the scarcer the water, the more complicated and elaborate the regulations are. Where water is plentiful, control is relaxed and a strict distribution patten is no longer followed.

Although religious precepts have maintained their influence, practical needs have profoundly affected the various rules and regulations concerning the ownership and use of water in arid zones on the basis of local geographic features.

A. Principles Governing Main Earlier or Original Legal Systems.

Four legal families have to be considered: ancient China, the Hebrew and Moslem worlds, Roman law and its derivatives, common and civil law.

A.1 The first regime in time which appears to be of special relevance is the Chinese. Chinese civilization emerged around the Yellow River, and represents the largest and most ancient irrigation civilization in the world.

Chinese water law has been concerned mainly with surface water; some basis philosophical and legal principles underlying it are a useful source of inspiration. Two concepts emerge in China's complex legal history: the high price placed on flexibility, and that placed on equity. Flexibility is at the heart of Chinese legal through, based on belief in a close interconnection between the human social order and the natural cosmic order. Harmony and unity, which were felt to prevail throughout all creation, were considered to be in close relationship with all aspects of human behavior. Social order was based not on laws but on rites, rules of conduct, or customs, which prescribed behavior in harmony with the natural order of things. Whenever private interests conflicted, it was the duty of everyone to find, as far as possible, a solution which would take into account the interests of all parties and avoid creating a winner and a loser.

Recourse to justice would be made only after all possibilities of conciliation or transaction at the family, village or guild level had failed. It was important not to act in such a way as to have the other party lose face, so that the door would be left open for the possibility of re-establishing harmony and order between the parties, which has been shaken by legal proceedings.

A.2 Another ancient civilization, the Hebraic, is an important guide in water legal regime probably because it grew up in a semi-arid environment where water is scarce. The basic principles of early Jewish law are contained in the Bible and other Talmudic texts. Legal doctrines and opinions are contained in the *Talmud*, a code written between the IV and the III Century B.C., which includes a few references to water which are the development of the basic principles contained in the *Torah*, or revelation of biblical texts. The existence of public wells and the right for every traveller to use them is recognized. It is possible that the rules for protected areas (the Moslem *harim*) applied to rivers and wells. Domestic and irrigation water was subject to an order of priorities. In the case of several irrigators receiving water form a common water resource, the one closest to the conduit filled his cistern first, and the other irrigators did so in turn. The laws of Babylon, which influenced the *Talmud*, consider the criterion of the ease with which the respective owner may use the water. The order of priority and the importance given to the position of the user in terms of proximity and ease of access to the common water resource are pertinent to the present study.

A.3 Due to special regional geoclimatic conditions, Moslem law is one of the legal regimes which has dealt the most with water. Many legal principles in Moslem law are similar to those in Talmudic law. According to Moslem water law water is considered to be a public good and cannot be individually appropriated. For example, wells belong either to an entire tribe or to an individual whose ancestors dug it; however, appropriation of a well does not give ownership rights to the water itself but it only gives exclusive or priority rights of use.

According to the tradition of the Prophet, there is an absolute right of thirst and even the owner of a well cannot abuse the water. The use of water is subject to a strict order of priority. Stock watering in a desert area is high in the order. In Moslem water law the notion of alternative source for water supply has an important bearing.

Moslem law establishes a close relation between surface and ground water and land use through the concept of *harim* or 'forbidden area': For example, in order to prevent new wells from depleting the aquifer, all schools have adopted the principle that the ownership of wells entails ownership of a certain amount of adjacent land - the *harim*, in fact. These fundamentals of Moslem water law entail established customs and uses which have been respected even during the most anarchistc periods. Customs governing water ownership are dominate by the fact that in deserts water constitutes the main object of real property. As water becomes scarcer, the land proportionately becomes an accessory to it, contrary to the case in European legislation.

Codified Moslem law in the Mejelle Code (Ottoman Civil Code) is the basic source of law in Moslem countries. According to the Mejelle Code, ground water belongs to the community; the definition of water as a non-saleable, publicly-owned commodity applies to water in wells dug by unknown persons.

As everywhere modern trends in water law in Moslem countries aim at institutionalizing the concept of community of interest. This concept constitutes the traditional basis not only of Moslem but also of many present-day traditional societies with regard to both customary and codified water law. In Iran, The *Water Nationalization Act* specifies control measures to prevent the depletion of aquifers. The utilization of ground water by wells or *ghanats* is subject to government authorization and holders of ground water use permits are required to report the amount of water used. In Jordan, the Natural Resources Authority is responsible for the control, exploration and exploitation of ground water. In Algeria, Morocco and Tunisia surface and ground water resources are part of the public domain in their code des eaux.

From the Moslem experience, the following points are worth consideration: water is a highly regulated resource; control of the community (tribe, village, state) is far-reaching; attention is paid to the protection of water and water works; water uses are always ranked according to a precise order of priority; the notion of alternative source is well developed; a close relation is established between water and land use; the role of customs and traditions is of paramount importance. Moslem law regards all countries where a majority of Moslems live as one land. It is the abode of Islam (dar al-islam). There is no record in Islamic history of any international water dispute prior to this century, so that Moslem law has little or no provision concerning such disputes. No-Moslem countries are regarded as the abode of war (dar-al-harb). However, where water is concerned, Islamic law speaks of man and mankind, and not of Moslems. Water rights therefore extend to all human beings.

A.4 Roman Law is very important in the Mediterranean countries because its influence has dominated most of the area during the early past centuries. The importance of Roman law is also that it is the origin of the two major legal systems which have spread all over the world: the Common Law and the Civil Code systems, and as such became the cradle of early principles of water legal regimes. Under these systems, ground water is either considered a part of the land and hence can be appropriated by the owner of the land, or as a commodity susceptible to ownership. In Common Law countries, a distinction is usually made between under ground streams which were treated in the same way as surface water which were never subject to private ownership, and other forms of ground water which are susceptible to exclusive ownership rights to the benefit of the landlord of the overlying land.

Roman law, as applied to water resources and to ground water in particular was bound to favor, at the international level, the development of the sovereign rights of states over their resources. It is logical that states, having full control of territory and land, would affirm full sovereignty over underlying resources. Such a principle would have produced many disputes in private law if both the courts in Common Law countries and the legislative bodies in Civil Code countries had not refined it in order to temper the principle of ownership or exclusive rights of use. Although surface water use rights are, under the riparian doctrine, limited by the theory of natural flow and the notion of reasonable use, these limitations do not affect the exclusive right of the landowner over ground water beneath his land nor on the flowing ground water once it has been extracted.

Under the French Civil Code, the right of ownership that a landlord enjoyed over springs located on his land was defined very early. A landowner could fully use the spring water of his land, but in doing so he might not harmfully affect the lands of his neighbors. The basic law of 1898 on the legal regime of water resources limited this ownership right whenever the spring waters were vital to the population of a nearby community.

Under the Spanish Civil Code of 1889, all ground water resources accrued to the regime of the land above them. They were private if underlying private lands, and public under public lands (article 408). Water brought to the surface by artesian wells or galleries became the property of whoever developed it. This regime influenced ground water law in Latin-America and still is in force in many countries.

Virtually all of these basic, traditional, legal regimes have either been amended by court decisions and new legislative developments or abandoned. In the former case the evolution has produced many hybrid regimes. In the latter case they have been replaced by modern legislation and new institutional arrangements; for example, new comprehensive codifications, were passed in Algeria (1973), Tunisia (1975), Spain (1985).

III. MODERN LEGAL REGIMES FOR EFFECTIVE WATER RESOURCES MANAGEMENT

Under the impulse of economic and social development, increasing needs for water and the introduction of modern abstraction methods, the uncontrolled use of water and especially ground water, has compelled states to introduce new modern water legislation and regulation in order to replace private litigation, especially about ground water uses, and to improve water resources management, coping with water quantity and water quality issues.

Two main legislative methods exist in this respect:

One method, which has been followed by countries with a non-consolidated water legislation, has consisted in the promulgation of ground water laws aiming at solving this new problem as a unique and isolated one. Cyprus, France, and Turkey may be cited as examples. These legislations have tended toward the limitation of exclusive private ownership rights in favour of a form of central administrative control over ground-water uses, thereby creating a formal separation between ownership (nuda proprietas) and use rights. In certain cases, private-ownership rights have been suppressed altogether by the transfer of water resource from the private patrimonium to the community, or by its incorporation into the Public Domain (nationalization). In other cases only geographical limitations to the use of ground-water could be introduced because of vested interest.

The second and most recent method was preside over the promulgation of consolidated water resources laws which, either by vesting the over-all water resource in the community as in France, or by incorporating it into the Public domain as in Algeria, Tunisia, Spain, Israel for instance, have institutionalized central administrative control over water resources conservation development and use.

Irrespective of the legal technique used and whatever the political motivation, these tendencies are present in all modern systems of law.

Modern legal regimes of water resources have led to increased public control over water through the permit system. This is a basic feature of modern regimes, another being the declaration of special zones where the use of ground-water is subject to strict controls.

Thus, the permit system and the declaration of special zones have now spread over almost all parts of the world. The need for concessions are permits to use water resources is becoming the most frequent and with regard to ground water has gradually superseded the more traditional systems inspired by Roman Law. The need for modern water legislation or regulation is now felt everywhere and in most Mediterranean countries where the modern system has not yet been introduced, consideration is being given to the adoption of the permit system. In France any installation intended for extracting surface or ground-water for non-domestic purposes is subject to the supervision of the administration. Prior authorization for exploration is needed within the water resources protection districts of Italy. The same applies in Spain for private ground-water extraction (on public lands a concession is required). Special legislation applies in the Canary Islands, where all extraction requires authorization. In Turkey, almost all ground-water exploration operations require a permit. Once ground-water has been found, its use is authorized immediately, but is limited to beneficial use criteria. But there is not yet a permit system for surface water.

Israeli water legislation, the first to modernize concepts and criteria for water management has integrated ground and surface waters under the same legal system: ground-water exploration, abstraction and use is subject to the general requirements which apply to surface water, namely the obligation of obtaining administrative authorization (drilling license, water use permit and recharge license).

The permit system is also found in modern African legislation. The National Water Resources Commission Order of Ethiopia, for instance, holds broad powers which allow the imposition of any necessary licensing procedures.

The introduction of the permit system is a highly significant element for the present study. It shows the importance now attached to water resources management. It will gradually given states adopting this system a more exact picture of surface and ground-water use patterns. This is very important in one bears in mind that sound cooperation in the field of water resource management requires more exact technical data. National criteria for permits could also provide a model for the criteria to be followed at the international level for water resources management between states. Although the concept of equitable use remains fundamental in many modern legal systems, the weight assigned to the various criteria used to define what is equitable have changed considerably over time. To determine what is 'equitable', the importance to be given to the land ownership, or to the seniority of existing water use rights, or to the type of use, is gradually yielding to the criteria of reasonable and beneficial use and in some instances to the optimum use criteria, at least in areas where the water supply/demand relationship is delicate. This of course leaves considerable room for speculation as to what is a 'reasonable', 'beneficial' or an 'optimum' use but it affords greater justification for the attempt to propose new solutions for conflicting claims on the water, and in promoting co-operation between the parties concerned.

IV. MODERN TRENDS IN WATER LEGISLATION IN THE MEDITERRANEAN COUNTRIES

As we paid above, the Mejelle Code regulated the use of water in all countries belonging to the Ottoman Empire, that is until 1911 in Libya and until 1922 in Somalia, Saudi Arabia, Jordan, Iraq, Syria, Lebanon and Turkey.

Turkey became a secular republic and , in 1926, promulgated a new Civil Code.

Some territories were placed under French or British mandate (Syria, Lebanon, Iraq, Trans-Jordan and Palestine); although the Mejelle Code continued and still continues, at least partially, to govern the use of water in these countries, special laws were promulgated to develop further a centralized water control. These, while recognizing the provisions of the Mejelle Code, the principles of the Shari'a and local customs, declared water to be State property and introduced a government permit as a prerequisite to every new water use (except for drinking and animal watering purposes). This legislation also created commissions for the registration of existing and new water rights.

Most of these territories later became independent. In some of them (Jordan, Iraq, etc.) new laws on water issued in addition to the provisions of the Mejelle Code still in force and to the laws enacted by the Trusteeship powers. These laws also provided for public ownership of all waters and for existing water rights to be surveyed and registered special committees set up for this purpose.

Other territories (Saudi Arabia, Yemen and Oman) became independent Moslem States. These countries, notably Saudi Arabia, declared the provisions of the Mejelle Code to be no longer in force and reestablished the sacred principles of the Shari'a. In this group of countries no new water law was enacted to modify the traditional principles of Moslem Customary Law.

Still in another group of states, the codification process followed a different pattern:

- Afghanistan, already independent before the fall of the Ottoman Empire, appears to have no written basic water law. However, there do exist special rules and regulations for water uses aside from local customs.

- Iran, with a long independent past, strated in the early 1900's, under the stress of technology and with a view to developing its agriculture, to promulgate a whole series of laws concerning water.

- Egypt practically ceased to be part of the Ottoman Empire in 1830, although theoretically it remained under Turkish sovereignty until 1922. Since time immemorial, Egypt has developed rules on the use of water. At the end of the 19th century, it codified numerous water regulations and brought the whole matter under municipal law. Here, too, all waters belong to the State and their distribution and use are controlled in great detail by an administrative organization responsible for regulating strict rotation use patterns.

In the majority of States which have since acquired independence, waters are still governed by the laws enacted during the colonial era. In this group of countries all waters as well belong to the State and any use thereof requires a government authorization or, in some States, the distribution of water and the rotation use patterns are controlled by a central administration.

However, a majority of States had come and remained under colonial dominion (essentially French North, West and Equatorial Africa and British East Africa). There, water legislation, although occasionally respectful of local traditions and customs, was largely imported or adapted from the metropolis and super-imposed over Moslem Customary Law. Basically, the public and private ownership doctrine of French continental Law and the riparian use right doctrine of the Common Law of England have since left their imprint which is still strong today.

The accession of these States to independence, technological development and increased demand for water have given a new impetus to the codification of water legislation. A comprehensive water act has been promulgated in Iran in 1968. Similar developments have reached various stages of progress in Afghanistan, Indonesia, Jordan, Libya, Saudi Arabia, Syria and Yemen. In these and in other countries (Bangladesh, Egypt, Iraq, Lebanon, Pakistan and Tunisia), central water administrations have been created and entrusted with the overall control of water use.

Current tendencies are to treat water, legally as well, as one natural resource which constitutes an essential component of the National Wealth and to vest the control of its conservation, development and use with the central government for the benefit of the whole community. Such a tendency is necessarily based on a strengthened principle of Public Interest to which private water ownership rights, where they exist or where they happen to be substitued for private water use rights, constitute a basic constraint.

It therefore appears that modern tendencies in water legislation aim at institutionalizing, in one form or another, the concept of community of interest which concept, in fact, constitutes the traditional basis of ancient customs and rules of conduct.

Like in Hydrology, water legal regimes make a cycle over time!

16

A CASE STUDY ON THE CONTRADICTIONS BETWEEN THE EXPECTATIONS AND THE ACTUAL RESULTS OF WATER RESOURCES PLANNING: LOWER SEYHAN IRRIGATION PROJECT OF ADANA - TURKEY

O. TEKINEL

TURKEY

A CASE STUDY ON THE CONTRADICTIONS BETWEEN THE EXPECTATIONS AND THE ACTUAL RESULTS OF WATER RESOURCES PLANNING: LOWER SEYHAN IRRIGATION PROJECT OF ADANA- TURKEY

Osman Tekinel (*)

INTRODUCTION

It is well known that soil is the leading factor in agricultural production. Water, on the other hand, is the most important factor in increasing production, or in getting the highest possible level of yield under existing agricultural conditions. It is an important factor to help with other production inputs, and also to stabilize production in any climate.

It is natural to have enormous investments in these developments, since careful use of soil and water resources is important in increasing agricultural production.

There has been a subtantial development and improvement in the agricultural sector since the foundation of the Republic of Turkey in 1923, both in terms of expansion of arable land and increase in agricultural productivity.

During this period, agricultural land has increased from 11.7 million hectares up to 28.5 million hectares and this reflects an improvement of 2.5 times in the total area of arable land. On the other land, the population of the country has reached 60 millions, from 10.5 millions in the early 1920's, which also reflects an increase of approximately 6 times. Furthermore, the ratio of productivity and net income, per hectare, has gone up 2-10 times and 10-20 times, respectively, depending on the variety of agricultural products. All these developments have made Turkey one of the 7 or 8 countries in the world which are self-sufficient in food and fibre production.

It can be concluded that 36.5% of the total land in Turkey is suitable for agriculture while 25.9% is forest. At the same time 32% of total irrigable area is under irrigation, whereas 68% is not yet irrigated, and 16% of available water resources is used for irrigation and for other purposes, while 84% is not used.

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Realization of high-yielding, persistent and successful irrigated farming requires detailed soil surveys, selection of alternate land utilization patterns and maintenance of the suitable patterns in every stage of the irrigation projects, skilled soil management, accurate size determination of the projects area, precise determination of water supply according to encountered land utilization patterns and size of the area, efficient application of irrigation water, efficient and durable drainage, effective extension services, and the other necessary technical amendments.

Irrigation has an essential role in agricultural production in Turkey. Crop yields have increased to large amounts with irrigation.

The place of exportation of agricultural products in total export income has increased from 1.2 billion dollars in 1980 to 2,2 billion dollars in 1990. In the same period, the total exports, have increased from 2,2 billion dollars to 14.0 billion dollars.

Since 1937 many irrigation projects have been undertaken in Turkey. The Lower Seyhan Irrigation system (ASO) is the one of the first projects established during the time of the republic. Fifty five years later, the most significant project is the South-East Anatolia Project (GAP). Its construction was begun within the last ten years.

This study has been prepared for two purposes, one of it is to give an overview "On the Contradictions Between the Expectations and the Actual Results of Water Resources Planning": It is a case study on Lower Seyhan Irrigation Project of Adana, Turkey.

The second aim of the study it to give a detailed information on one of the world largest irrigation projects, namely, Southeastern Anatolia project (GAP) and its importance for Turkish agriculture.

Materialization of a high yielding agricultural system will involve solutions to existing problems related to the choice and use of technology, inputs, economic incentives, and institutional restructuring.

Experiences gained from the Lower Seyhan Irrigation Project must be used in the South-East Anatolia Projects to obtain the maximum profit expected from GAP. The schematic presentation of locations where ASO and GAP were established is shown in figure 1.

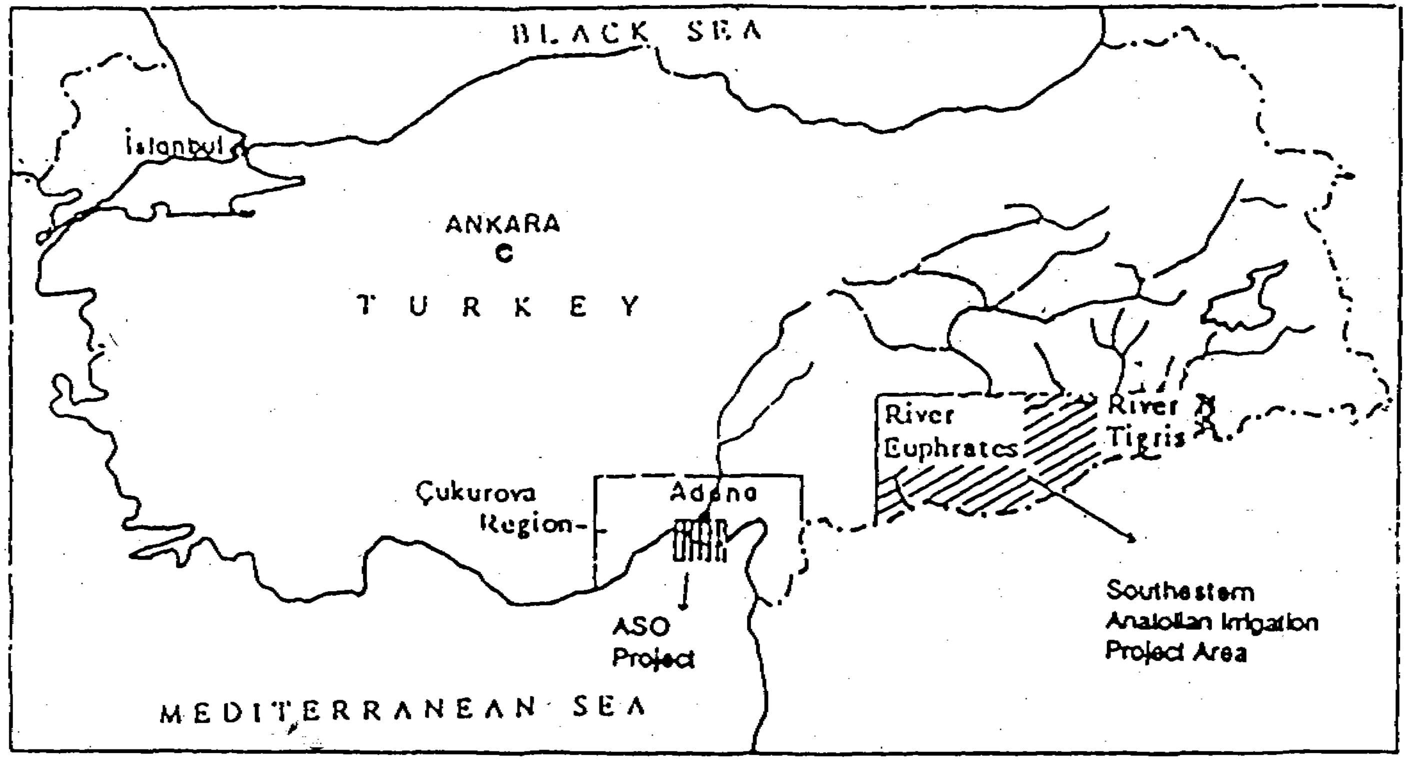

Fig. 1. LOCATION MAP.

—Lower Seyhan Irrigation Project Area (180.000 Hectars)

—South eastern Anatolia Irrigation Project Area (1.650.000 Hecters)

LOWER SEYHAN IRRIGATION PROJECT

The Seyhan plain is the largest and the most important deltaic plain area in Southern Anatolia. It is bounded by southern foothills of the Tarsus mountains on the north, the Mediterranean sea on the south, the Ceyhan river on the east, and the Berdan river on the west. The whole area of the Seyhan Plain is about 210.000 ha., of which 181.300 ha. are irrigable. The Seyhan River cuts in a southwesterly direction through the Seyhan Plain, dividing it into two subplains: the Tarsus Plain of 85.000 ha. to the west of the river, and the Yüregir plain of 125.000 ha. to the east (Figure 2).

A typical Mediterranean climate prevails in the project area. The summer is hot and dry and the winter is warm and rainy, with a high humidity throughout the year.

Due to the favourable geographic, climatic, soil, and topographic conditions, the Tarsus and Yüregir Plain have attracted many well known civilizations throughout centuries. The region was one of the most important areas of Roman and Byzantine Empires and to this day it has remained as the most valuable agricultural region of Turkey. The major agricultural activity in the plains has been the raising of livestock on extensive range lands for the last few centuries. As a result of changing living conditions and habits of local farmers, the cattle raising on range lands diminished rapidly during the last 40 years and was replaced by mainly cotton and cereals, and to the less extent by vegetable and citrus growing.

The development of water resources, mechanization of farming methods, land reclamation practices, extension services and the others have brought about dramatic changes in the agricultural development of the Plains. Average annual yield of cotton was about 50-75 kg per decare in the recent past, but today the yield has reached well over 400 kg per decare in better lands. The same trend of increased yield has also been observed for all other crops of the region.

Although all other factors contributed in increasing yields, the development of water resources alone has had the biggest share in achieving this increase. The water resource development works of the Plains have included the flood protection, the Seyhan Multi-purpose Project, and the Seyhan Plain Irrigation Works.

Suitable soil, climate, and topographic conditions, joined by the rich water resources **in the plain (the Seyhan river has an estimated capacity of 6x109 m^3/year) make it possible to cultivate various plants throughout the year.**

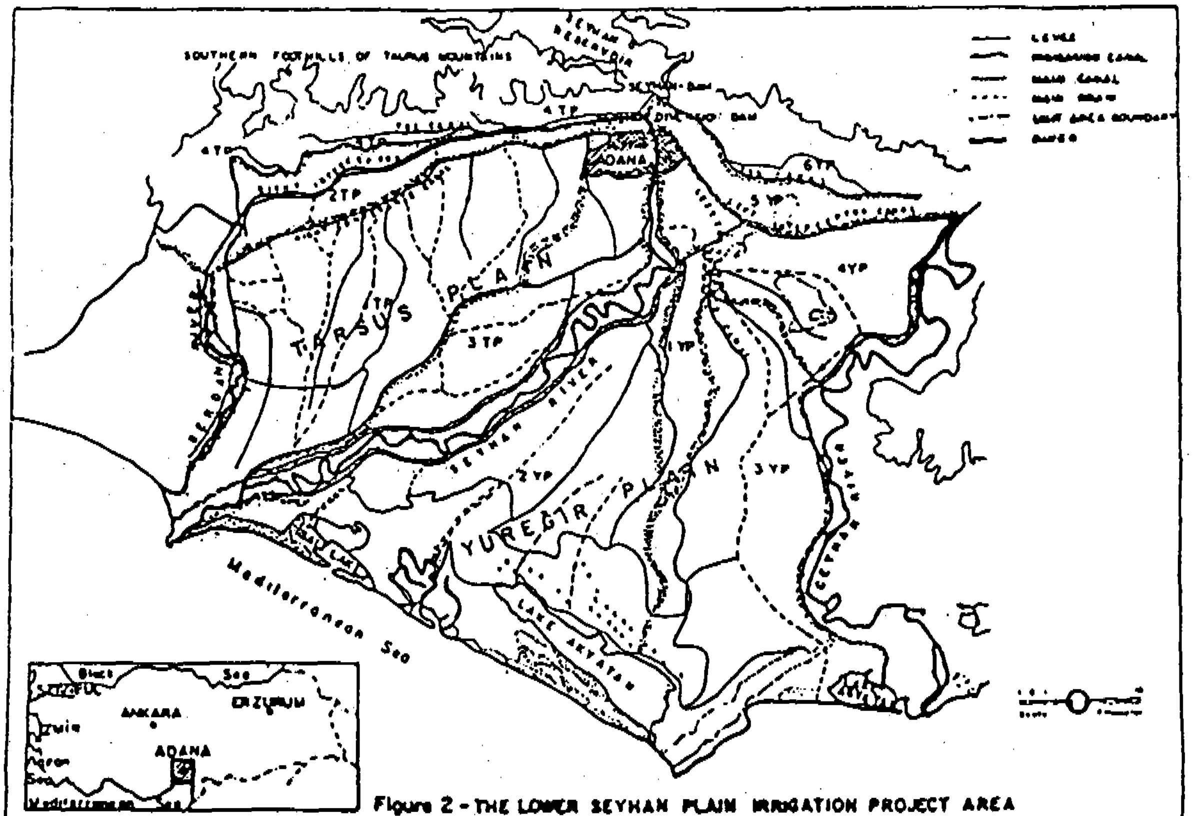

Figure 2 - THE LOWER SEYHAN PLAIN IRRIGATION PROJECT AREA

Table 1. indicates the change of sown area of the irrigated crops and the first crop pattern of the project.

Irrigation works of the Seyhan Plain have been planned to be completed in three stages. The works of the first stage have been completed. The second stage works were completed in 1978. Stage three was officially supposed to be started in 1978.

The input of the agricultural production of the Seyhan Plain to the national production has increased sharply with agricultural development in the recent years. The input was negligible in the late 1930s, but today it is estimated that the agricultural production value of the plain excluding animal production, has reached around 500 million dollars annually. Increase of agricultural production has also had the biggest share in the creation of agricultural industry in the region. Since the 1960s, the region has turned into one of the most important food and soft drink, textile and agricultural machinery production centers of Turkey. The Adana Chamber of Commerce reports that there were more than 180 agriculture-based industrial establishments in 1986. This industry provides jobs for about 40.000 workes and adds to Turkish economy approximately 1 billion dollars in production value annually.

Agricultural production increase and the industry have had great impact on improving the social and economic levels of the people living in the region. Along with this development, Adana which was a small city in the past became a modern city with a population of 1.000.000. As a result of this fast development, University of Çukurova was established in 1972 in order to fulfill the ever-increasing educational and research needs of the region.

Although the Lower Seyhan Project has contributed a lot to the region, it can not be said that the project itself is a perfect one. Today there are serious problems regarding the project. Various anticipated problems of the completed parts of the project are given and discussed in the following sections.

Irrigation

Due to high rate of evaporation and insufficient amount of precipitation during the growing season, a larger portion of plant water requirement should be artificially fulfilled by irrigation for optimum growth. For this reason, irrigation application practices take place

Table 1. The Change of the Sown Area of the Irrigation Crops with Years (%)

Years	Whaet	Alfa	Soybean	Melon	Cotton	Maize	Pedy	Youngtre	Citrus	Vegetabl	Other
According to Project	13	20	-	-	35	-	5	-	8	15	4
1964					94.0		1	2	1		2.0
1966				0.1	97.4		2.4	0.1	0.1		0.1
1967				0.1	94.8		4.6	0.1	0.2	0.1	0.3
1968	0.2			0.1	96.4		1.7	0.8	0.5	0.1	0.3
1969	1.2			0.2	91.6		5.5	0.3	0.7	1.0	0.5
1970				0.6	88.7	1.1	4.9	1.2	1.0	0.4	2.0
1971				0.4	97.1	0.1	0.4	0.3	1.3	0.2	0.2
1982	7.0			0.3	90.0		0.8	0.9	0.9	0.2	0.2
1973	6.3			0.8	90.0	0.1	0.4	0.4	0.9	0.3	0.7
1974	0.6			0.6	96.5	0.1	0.4	0.4	1.0	0.3	0.1
1975				2.0	84.0	3.0	5.0	1.0	1.0	1.0	3.0
1976				4.0	81.0	3.0	4.0	1.0	3.0	1.0	2.0
1977				5.0	92.0			1.0	1.0		1.0
1978				9.0	81.0	1.0	4.0	1.0	2.0	1.0	1.0
1979	1.0			6.0	66.0	15.0	7.0	2.0	2.0	1.0	
1980				8.0	82.0	2.0	2.0	3.0	1.0		2.0
1981	1.0		1.0	10.0	77.0	1.0	3.0	4.0	2.0	1.0	
1982	16.0		6.0	12.0	48.0	5.0	4.0	6.0	2.0	1.0	
1983	0.8		8.4	10.4	62.4	1.6	2.7	7.1	4.1	0.7	0.2
1984	0.7		9.6	6.5	68.4	2.0	2.4	5.3	3.4	0.9	0.2
1985	2.6		16.6	8.5	51.6	8.7	4.8	2.1	2.4	1.0	2.1
1986	11.5		12.7	5.8	41.3	16.9	0.5	3.6	4.2	1.3	22.3
1987	1.0		19.0	9.0	37.0	20.0	1.0	3.0	6.0	2.0	3.0
1988	1.0		8.0	10.0	51.0	18.0	-	3.0	6.0	1.0	2.0
1989	16.09		9.0	6.0	35.0	23.0	1.0	3.0	4.0	1.0	15.0

in the plain from May to October. Water diverted from the Seyhan reservoir is classified as C2-S1, which is considered fairly good for irrigation.

During the planning stages of the Lower Seyhan Project, land utilization pattern was proposed as 35 per cent cotton, 15 per cent wheat, 12 per cent citrus, 8 per cent vegetables, 20 per cent forage crops and 10 per cent rice. However, proposed optimum land utilization pattern has not been realized up to this day. Although, cotton cultivated area changes from one year to another, generally, the cultivated area varies from 75-90 per cent of the total land. Another major crop of the region is wheat. Under the present land utilization pattern, majority of land is only single cropped. Additionally, marketing conveniences and high cash values attract farmers to cultivate the land with the same crop every year preventing them to follow up a rotation.

Furrow and flood irrigation methods have been traditionally practised on the most part of irrigated areas of the region. As it is a universally known fact that when dry farming switched to irrigated farming, majority of farmers apply more than enough water to the soil with the common misbelief that more water would result in higher yields. The same misconception on water consumption has also been observed among farmers of the region. For instance, Seyhan dam which provides water for the Lower Seyhan Plain irrigation project is designed to supply water for the irrigation of 181,300 ha of land. The allocated water for irrigation in the dam is totally used at the end of each irrigation season despite the fact that only 120,200 ha of land is being irrigated in the plain today. This fact obviously reflects unnecessary utilization of water by the farmers and thus creates severe salinity and drainage problems on some parts of the project area.

Another reason for over-irrigation problem is related with the present land utilization pattern. The capacity of Seyhan Dam was designed according to the proposed land utilization pattern in which cotton was planned for 35 per cent of the total area. Today cotton cultivation is on 35 to 90 per cent of the land, and farmer's habit to over-irrigate cotton has resulted in unexpectedly high water consumption. This over-consumption naturally lays the foundation of readily available water supply for southern farmers to use water from drainage channels which also convey industrial wastes. This misuse of drainage water has created salinity and toxic element problems in some sections.

The existing irrigation system has been designed to provide measuring devices at the heads of all main and most of the secondary and tertiary canals. However, turnouts and measuring devices are not provided for individual farms. Somehow these are excluded though they are essential for adequate distribution, equal division of water among users, and to control water application. Non-existence of these control structures provokes farmers to over consumption of irrigation water. Presently, farmers obtain water directly from canalets with syphons at their will. In addition, water cost is billed to farmers according to crop type and size of the irrigated area. This, along with low cost of water, leads to excess consumption of irrigation water.

Despite the enormous investments made toward the realization of the project, it has been observed that farmers of some sections have switched back from profitable, irrigated farming to less profitable dry farming in recent years. (Table 2). For example, irrigation facilities were brought to 57322 ha. of land, of which 90,9 per cent was actually irrigated in 1968; on the other hand, irrigation facilities were extended to 110480 ha. of land, but actually irrigated area dropped to 66.4 per cent in 1978. This unexpected situation might be attributed to government price policy, high labor cost, problems involving pesticides and insecticides, fertilizer and seeds, insufficient credits, and lack of rotation. At the end of 1989, irrigation facilities were about 137, 039 ha., but actually irrigated area was about only 120,200 ha. at the same year.

Drainage

The most essential problem of the irrigation of the plain is to maintain proper drainage of irrigated lands. The relative flatness of the major portion of the plain, the high winter rainfall, the excessive irrigation water application and seepage from irrigation water conveyance channels cause high ground-water table levels the year round. This situation has been creating serious drainage problems for optimum crop production.

State Hydraulic Works have set up an intensive ground-water observation network consisting of 1600 observation wells in order to follow up ground-water fluctuations in the project area.

Table 2. Proposed Usage of Irrigated Lands, and Actually Irrigated Area.

Years	Proposed Land Utilization(ha)	Actually Irrigated Area(ha)	Irrigation Rate %
1964	18030	18727	103.9
1965	25200	26516	105.2
1966	41512	40145	96.7
1967	51200	46776	91.4
1968	57322	52129	90.9
1969	58400	50104	85.8
1970	58400	36929	63.2
1971	58400	53041	90.8
1972	58400	58199	99.7
1973	62400	66965	107.3
1974	83550	82517	98.8
1975	95527	66650	69.8
1976	98547	45022	45.7
1977	104102	86937	83.5
1978	110480	73399	66.4
1979	110480	78573	71.1
1980	103000	84670	82.2
1981	103000	85934	83.4
1982	103000	92575	89.9
1983	115000	71919	62.5
1984	119000	95756	80.5
1985	125300	114134	91.1
1986	133431	116198	87.8
1987	132300	97979	74.1
1988	132300	102032	77.1
1989	137039	120200	87.7

The ground-water table levels have been regularly recorded at monthly intervals, and water samples from each well have been taken from time to time, to determine the chemical quality of ground water. The change of surface area having the highest critical levels of ground water from 1975 to 1989 is given in Table 3.

Table 3. Land Distribution According to the Levels of Ground Water in Plain

	The highest critical level equivalent (m)						
Years	0-1	% of Total Land	1-2	2-3	3-4	4	Total (ha)
1975-76	34530	45	33100	6950	1320	175	76075
1976-77	38617	43	46834	3846	923	545	90765
1977-78	47648	51	41727	3520	55	-	92950
1979-80	42300	50	41800	2200	400	-	88700
1881-82	53957	57	37051	2133	450	550	94141
1982-83	51459	55	38520	3673	489	-	94141
1983-84	53351	57	38308	2431	51	-	94141
1984-85	53506	54	42867	2651	549	-	99573
1985-86	46749	46	49370	4959	463	-	101541
1986-87	63294	62	34137	3583	527	-	101541
1987-88	57261	56	39731	4429	120	-	101541
1988-89	57784	57	39900	3642	215	-	101541

The ground-water level reaches its critical peak value in two different periods within a single year. One of these peaks is seen in the months of January and February, in which heavy winter rainfall takes place. The other occurs in the months of intensive irrigation, which are July and August. Most parts of the plain have a very flat and low topography, and the soil has very low diffusibility; therefore, especially when the winter rains are above the normal levels, the ground water reaches above the soil and interrupts the agricultural activities, sometimes until the end of April.

In table 4, we see land distribution in the Seyhan Plain according to the salt levels of ground water.

It can be seen in table 4 that the area with 2000 micromhos/cm salt content of ground water has increased from 22 200 ha. in 1975/76 to 30.884 ha. in 1988/89.

Though irrigation works in the plain were started in 1950s, construction of drainage system was not progressed parallel to the irrigation systems. The construction of tile drainage systems had begun in 1966 after serious drainage problems surfaced in the project area. This delay has caused sharp decreases in yield in some sections and consequently has resulted in considerable loss of income of the farmers.

Management and Maintenance

One of the reasons for excess water application in the plain could be said to come from the inadequate number of technical personnel, who could maintain controlled water distribution.

Another problem related with management is farmers' unwillingness to irrigate at night. Farmers traditionally have practiced only daytime irrigation. As a result of this practice, water in the irrigation channels is directly dumped into drainways during night hours and approximately one-third of released water from the dam is lost.

Additionally, the spacings of tertiary irrigation channels being 500-600 m, along with some farmers' refusal to respect neighbors' water rights of way, have been causing management problems in some sections of the project area.

Other problems associated with irrigation in the plain are the use of the very fertile first-class agricultural lands for urban and industrial misplacements, and insufficient extension service.

Table 4. The Change of Surface Area According to the Salt Content of Ground Water (ha)

	salt level of ground water (micromhos/cm)					
Years	0-1000	1000-2000	2000-5000	5000-10000	10000<	Total Land (Ha)
1975-76	26925	22200	15995	5960	5265	76975
1976-77	28567	30039	20568	10623	948	90765
1977-78	38391	32373	13634	7271	1281	92950
1979-80	35300	23440	22100	5600	2360	88700
1971-82	28241	26482	24017	10586	4813	94141
1982-83	31671	33035	19498	6417	3520	94141
1983-84	28703	34655	23839	4628	2316	94141
1984-85	41501	33121	16883	5987	2081	99573
1985-86	47304	37396	9536	5051	2254	101541
1986-87	48484	32959	13504	5038	1563	101541
1987-88	60712	23202	12606	3172	1849	101541
1988-89	55876	30884	12841	1502	438	101541

CONCLUSION

Favorable climatic, soil and water resource conditions of the Seyhan Plain permit year around cropping of wide variety of plants. It is no doubt that the described water resources development works of the plain have brought enormous changes in the economy of the region. However, these works alone have not been able to bring solutions to the deficiencies associated with the development.

Today's irrigation practices provide substantial production increase as compared to dry farming. However, attention is not given to the necessary steps which are essential for prolonged productivity. Yield increase in the initial years of irrigated farming is an unexpected event for farmers who were accustomed to get whatever natural fluctuations of weather would permit. From this point on they would not make any special effort to increase the yields further.

Recent developments in agriculture have increased the yield of irrigated farming in considerable amounts. Unfortunately this side of irrigated farming has not been considered as important as engineering aspects of conveyance and distribution of water in Turkey. Historical development of irrigated farming has shown that success of the projects depends on giving equal importance to both engineering and agronomic aspects, realization degree of the objectives proposed in the planning stages, extension, and close coordination of related agencies working on the project.

In view of the realities discussed above and evaluation of the experience gained from planning and application stages of the Lower Seyhan Project, it can be concluded that this project and others similar to this would be the most profitable if the following measures are taken into consideration.

1. Construction of irrigation and drainage systems should be started and carried on simultaneously.
2. An administrably and finacially independent extension service organization should be formed at the planning stage of project. Extension service should begin its

activities immediately without waiting the application stage of the project. Additionally, technical personnel of the service should be in close ties with Research Organizations and Universities, and opportunities should be provided to its members for frequent on-job training programs.

3. In order to obtain optimum economic and technical usage, alternate land utilization patterns, which would be suitable to local conditions and to the capacity of water supply, should be selected instead of classical preference of one. Proposed patterns should be realized voluntarily otherwise necessary legislative actions should be taken.

4. Detailed alternate feasibility studies should be conducted before selecting the irrigation methods for the project area.

5. Necessary measures should be taken to maintain the original form of land leveling on places where levelling is essential for uniform application of irrigation water through surface irrigation methods. For this purpose, farmers have to be trained about proper ways of tillage and rotary tiller.

6. Measuring devices and structures should be installed on every required place and water cost should be collected from farmers on the basis of consumed water.

7. On large irrigation projects, where huge sums of money are invested for irrigation facilities, actual irrigated area should be kept as high as possible. If declining trend of actual irrigated area is seen immediate actions should be taken to overcome reasons of reduction.

8. Land consolidation works reduce overall project cost by at least 15 per cent on areas where irrigation is to be introduced. Hence, land consolidation works should be executed either voluntarily or legislatively.

9. Drainage criteria should be determinated by considering regional conditions. Especially, precaution has to be taken in respect of hydrogeologically complex deltaic plains.

10. In order to determine possible chemical and physical changes along the soil profile, detailed soil surveys should be conducted some time after irrigation facilities enter into service. If data necessitate, practised irrigation method should be altered.

11. Legislative actions should be taken to prohibit placements of urbanity and industry on fertile agricultural lands during the planning stage of project. Placements should be carried on according to land use maps based on soil surveys.

12. Number of technical personnel and size of machinery park in the first stages of project should be updated according to the needs of the advanced stages. A maintenance unit should be established for tile drainage system in addition to establishing of drain maintenance teams.

13. Close cooperation should be maintained among responsible agencies for optimum service.

Some of the above mentioned measures were taken into consideration in the planning and application stages of the Lower Seyhan Project but unfortunately no special efforts have been made toward realization of them. Even, Required attention has not been given to majority of the measures up to this day. It is a reality that the project has not contributed up to its real potential yet despite the fact that large amounts of money have been invested. Optimum benefit from the project would be obtained if and only if the proposed measures are considered as vital as engineering works.

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RESSOURCES EN EAU, IRRIGATION ET PRODUCTION ALIMENTAIRE PRESENTATION SOMMAIRE DU CAS DE L'ALGERIE

M. A. MECHEBBEK

ALGERIE

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M.A.MECHEBBEK (*)

INTRODUCTION

Irrigation et production alimentaire

Dans nos conditions de climat nord-africain et de milieu naturel marqué, une production agricole soutenue exige un apport d'eau complémentaire à celui qui provient des précipitations.

L'irrigation, sous nos latitudes, lorsqu'elle est menée de manière rationnelle et cohérente, engendre de multiples effets positifs concrets, qu'on peut résumer de la façon suivante:

* elle permet de régulariser et de stabiliser la production par la correction de la sécheresse agricole,

* elle introduit un coefficient d'intensification sur une superficie donnée, en permettant d'allonger la durée d'occupation de la parcelle et d'introduire ainsi des cultures supplémentaires sur une même surface, pendant la même période de référence,

* elle amène à remplacer des cultures "rustiques" par des spéculations de plus grande valeur,

* elle multiplie les rendements d'une même production, toutes autres conditions étant égales,

* enfin, la disponibilité de ressources en eau permet de multiplier les surfaces irriguées à travers le territoire et démultiplie ainsi les quatre effets précédents.

Le facteur EAU dans l'agriculture, dans nos conditions, peut avoir des effets insoupçonnés par la démultiplication de la production, par les effets d'entraînement sur toute la "machine" de la production agricole et sur l'ensemble de l'économie du pays.

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Dans le Monde -

Les superficies consacrées à l'irrigation sont passées de 95 millions d'hectares en 1950 à 250 millions d'hectares en 1986.

Parmi les leçons tirées des expériences, il est désormais considéré comme évident que les agriculteurs doivent être associés de plus près que dans le passé aux projets surtout que ceux-ci coûteront de plus en plus cher et nécessiteront plus de "machinerie"...

Dans les conditions favorables, les coûts d'équipement à l'hectare sont de 4000 à 5000 dollars; en Afrique ils varient de 10 000 à 20 000 dollars.

On s'achemine, au niveau international, vers une phase de consolidation où la priorité est désormais donnée:

- à la FORMATION des agriculteurs et des techniciens

- à l'amélioration de la GESTION

- à la protection de la qualité des eaux et des sols.

L'Irrigation en Algérie -

Notre pays n'est pas bien placé parmi les pays appréciés selon l'attention qu'ils accordent à l'agriculture irriguée et suivant les résultats obtenus.

Douze hectares irrigués pour 1000 habitants et ce ratio ne cesse de baisser.

(moitié de celui du Maroc, le tiers de celui de la Tunisie, le cinquième de celui de l'Inde...)

Des traditions d'irrigation existent chez nous: les foggaras, les ceds, djeboubs, les puits à balanciers...

La colonisation a usé de l'arme de l'eau au point que les services coloniaux s'appelaient " Service de la colonisation et de l'hydraulique "!

Le potentiel actuel est constitué, en grande partie par les périmètres réalisés, depuis 1850, 1870 mais surtout à partir de 1930-40 jusqu'à l'indépendance.

En 1962, l'infrastructure constituait près de 100 000 ha de réseaux qui ne permettait cependant qu'une irrigation en extensif de l'ordre de 50 000 ha par an.

De ce point de vue, il n'y a eu aucune évolution, puisque c'est le même chiffre que l'on retrouve pour les surfaces irriguées en grande hydraulique, actuellement; les superficies nouvellement aménagées venant compenser les "pertes" du système Habra-Sig, du Moyen et Bas Chélif.

Malgré tout cela, l'agriculture irriguée algérienne qui compte pour environ 300000 ha, donc environ 10 % des surfaces travaillées,produit globalement 40 % de la production agricole nationale.

Le décuplement des surfaces irriguée en grande hydraulique et le triplement des surfaces totales sont possibles en vingt ans.

Pour cela, le rythme de livraison en grands périmètres doit être quintuplé, sans tenir compte du sous-programme Sud, auquel une attention particulière doit être consacrée.

Les données de l'année 1988 montrent que, sauf pour les légumes frais, le taux de couverture de la demande alimentaire actuelle par la production nationale varie de 0 (huiles et sucre), 0,10 (fourrages), 0,15 (légumes secs), 0,22 (céréales) à 0,75 pour les pommes de terre...

La croissance de la population va grever encore plus ces taux et aggraver ainsi la dépendance alimentaire de notre pays.

La multiplication de la population par un facteur 1,6 en 20 ans entraînera une multiplication des besoins par 2 pour la plupart des denrées et par 3 pour les viandes et oeufs.

Il s'agit ainsi d'optimiser l'utilisation des "avantages comparatifs" nombreux dont l'espace, le soleil, les ressources en sols et eaux même relativement limitées en quantité ou qualité...

1. Besoins alimentaires

La population de l'Algérie est de **25 Millions d'habitants** en 1990.

Production et demande agricole apparaissent comme suit :

Produits	Demande	Production Agricole	% de couv.
Céréales	4593	1035	22,5
Pommes t.	963	745	**77,4**
Légumes f.	1705	2212	***129,7***
Légumes s.	206	34	**16,5**
Fruits	1458	764	**52,4**
Betteraves	4167	0	**0**
Fourrages	1220	122	**10,0**
Oléagineux	384	19	**5,0**

(en milliers de tonnes et MUF pour les fourrages)

La situation est ainsi caractérisée par un déficit quasi général, sauf pour les légumes frais.

Si nous considérons un modéle de consommation théorique moyen comme hypothèse pour l'horizon 2010 :

Céréales	150	kg/hab/j
Pomme de terre	50	
Légumes frais	85	
Légumes secs	9	
Fruits	70	
Sucre	20	
Viandes	34	
Oeufs	8.5	
Lait et dérivés	100	
Matiéres grasses	16.5	
Poisson	3.8	
Valeur energétique	2772	cal/hab/j
Valeur nutritionnelle	83	g prot./hab/j
Proteines animales	29.2	%
Calories "céréalieres"	53	%

les besoins se trouvent alors multipliés par 2 en 20 ans pour toutes les denrées, sauf pour les céréales (1,4) et les viandes-oeufs (3), la population étant elle multipliée par 1,6.

2. Ressources en Eau et Demande en eau d'irrigation:

Globalement, elles sont évaluées comprises entre 16,4 et 19,1 Milliards de mètres cubes répartis en:

- 12,4 Milliards de m^3 d'écoulements superficiels
- 1,8 Milliards de m^3 pour les ressources en eaux souterraines dans la zone Nord du pays
- 2,15 à 4,9 Milliards de m^3 pour les ressources en eaux souterraines du Sahara

A l'horizon 2010, un taux de récupération de 5 % des eaux consommées par les populations et l'industrie peut être envisagé.

Le total potentiellement disponible en incluant les eaux recyclées serait de l'ordre de 17,6 à 20,4 milliards de métres cubes par an, les ressources obtenues par dessalement étant négligées.

2.1 Possibilités de mobilisation

Ressources en eau superficielle:

L'inventaire des sites réalisé à ce jour, permet d'évaluer la valeur mobilisable à 5,7 Milliards de metres cubes soit 46 % des potentialités.

Ressources en eau souterraine:

A ce jour, les potentialités sont déja exploitées, à raison de 90 % pour le Nord et 10 % pour le Sud.

Les ressources mobilisables sont ainsi estimées globalement à 12,4 Milliards de mètres cubes répartis entre 5,7 pour les eaux superficielles et 6,7 pour les eaux souterraines.

2.2 Demande en eau potable et industrielle

Les besoins en eau potable et industrielle, à l'horizon 2010 sont estimés, pour une population de 42,7 Millions d'habitants dont 28 Millions en zones urbaines, à 2,9 Milliards de métres cubes par an.

2.3 Potentiel en terres agricoles

1.350.000 hectares sont considérés comme irrigables et 350.000 hectares susceptibles de l'être après des investissements assez importants.

2.4 Disponibilité en eau agricole

Aprés satisfaction des besoins en eau urbaine et industrielle les ressources mobilisables qui restent disponibles pour l'irrigation sont de **4,6 Milliards de m^3 pour le Nord**_et **4,7 Milliard de métres cubes pour le Sud**_soit un total de 9,3 Milliards de métres cubes par an globalement.

Alors que les besoins en eau agricole sont estimés à 8,9 Milliards de métres cubes pour le Nord_et 2,9 Milliards de m^3 pour le Sud_**soit un total de 11,8 Milliards de métres cubes.**

Un déficit est donc observé .

2.5 Possibilités d'irrigation et productions agricoles

Compte tenu des ressources en eau mobilisée ou en cours de mobilisation et des possibilités technico-économiques de transferts, **il est possible d'équiper,en première approximation 983.000 hectares** répartis comme suit:

- Grande hydraulique (Nord)	**476.000 ha**
- Sud	277.000 ha
- PMH	230.000 ha

ce qui entraînerait l'accroissement des superficies actuellement équipées pour les porter de 316.000 ha à **983.000 ha à l'horizon 2005** ce qui donnerait encore près d'**un million d'hectares irrigués à l'horizon 2010**.

Ainsi, malgré l'accroissement de la population de 25 à 40 Millions d'habitants entre 1987 et 2010, le développement des productions agricoles par un programme d'équipement de périmètres irrigués, pourrait **réduire le déficit de la balance exportation / importation des produits alimentaires de 7 à 4 Milliards de DA (valeur 1988), soit près de 50%**.

On sera cependant conduit à n'équiper qu'une partie des potentialités irrigables.

Compte tenu des aptitudes des sols, et sur la base des données disponibles au Ministère de l'Agriculture:

Les grands périmètres irrigués seraient spécialisés pour les fruits, fourrages, pomme de terre, betterave à sucre.

La PMH produirait légumes frais, pommes de terre, fourrages...

Le Sud contribuerait essentiellement pour les céréales.

L'agriculture en sec produirait les céréales, fourrages, légumes secs, cultures industrielles (oléagineux, tabac, parfums...)

2.6 Demande en eau agricole correspondante :

- Grande hydraulique	3.3 Milliards de m^3		
- Sud	4.7	-	-
- PMH	1.3	-	-
Total	**9.3**	**-**	**-**

avec des dotations moyennes : m^3 / ha / an

GH	6500
PMH	5000
SUD	15000

Les besoins pour la grande hydraulique et le Sud seront satisfaits comme suit:

Ressources en eau affectées à l'irrigation (Hm^3/an)

	superficielle	**souterraine**	**recyclée**	**Total**
Grande Hydraulique	2.65	0.5	0.15	3.3
Sud	-	**4.7**	-	**4.7**
PMH		non ventilés	-	1.3
Total	-			9.3

Des programmes de réutilisation des eaux usées épurées dans l'irrigation seront à l'évidence, nécessaires.

Certaines cultures peuvent à cette faveur connaître un développement: cas des cultures à "consommation indirecte", qui nécessitent un traitement avant de pouvoir être mises à la portée des consommateurs ("barrières multiples" de sécurité mises entre les eaux "à risques" et le marché...).

Des régions resteront déficitaires: Oranie, Medjerda-Mellègue, Aurès, Hodna-Plaines Sétifiennes ..., elles devraient se lancer dans les techniques de récupération des eaux pour améliorer le bilan de l'utilisation des sols et permettre ainsi de dépasser à long terme les 50 % de sols aptes équipés pour l'irrigation.

3. Les Périmètres existants

Les grands périmètres d'irrigation existants sont classés en deux catégories:

- Les périmètres anciens hérités de la colonisation avec une irrigation traditionnelle gravitaire (canaux et séguias)

-Les périmètres récents: réalisés aprés l'indépendance où domine une technique moderne d'irrigation: l'aspersion; ils représentent environ 40.000 hectares .

Les premiers connaissent les difficultés dûes à la vétusté des réseaux; les deux souffrent de la concurrence pour l'eau des autres usages: eau potable et eau industrielle .

Huit périmètres ont été réalisés entre 1937 (HAMIZ) et 1958 (SIG). Ils sont donc largement amortis. Ils couvraient une superficie d'environ 100.000 hectares.

La plupart (six) sont réhabilités (Haut Chélif, Ksob) ou en voie de l'être (Bas Chélif, Mina, Moyen Chélif, Hamiz) .

Deux (Habra et Sig) nécessitent une intervention urgente.

4. Les Rénovations ou Réalisations en cours:

Des travaux sont actuellement en cours pour:

- la réhabilitation (renouvellement à l'identique) ou la renovation (renouvellement avec une autre étude et d'autres normes) des périmétres anciens existants sur près de 20.000 hectares.

- la réalisation ou l'extension sur de nouveaux périmétres

(environ 50.000 hectares)

5. Les Etudes:

Le portefeuille *études en cours* est de plus de **170.000 Hectares** .

Ces etudes devraient logiquement s'achever dans les prochaines années.La plus grande partie est confiée à des associations Bureau d'Etudes Nationaux / Grands Bureaux d'Etudes internationaux spécialisés .

Le programme ultérieur en préparation qui sera entamé en **1993/94** prévoit **48.000 ha** de plus.

Le programme prévisionnel **1995/99** contient encore près de **135.000 ha** de plus .

6. La Petite et Moyenne Hydraulique :

Les aménagements de petite et moyenne irrigation sont constitués de périmètres de tailles trés variables dont l'alimentation en eau est diversifiée: puits, forages, pompages dans les oueds et dérivations au fil de l'eau, retenues collinaires, épandages de crue, etc...

** Les Superficies*

La petite et moyenne hydraulique représente en moyenne 238 000 ha de terres irriguées :

- 108.000 ha répartis sur 874 petits périmétres de taille de 10 ha et plus (taille moyenne 100 ha) .
- 130.000 ha en irrigation dispersée suivant des ilôts inférieurs à 10 ha .

** L' utilisation agricole*

Les cultures maraîchères et l'arboriculture occupent 60% des superficies irriguées de la PMH , les grandes cultures représentant 15% .

La PMH est une affaire avant tout locale et à l'échelle des producteurs agricoles eux-mêmes soutenus par les institutions et services de la région.

Elle constitue, actuellement les 5/6 du patrimoine irrigué.

A terme, en 2010, elle en représentera encore 25 %.

7. Mise en valeur des régions sahariennes

Le Sahara recelle des potentialités spécifiques qui, prises comme des ressources valorisables sur le long terme, peuvent contribuer, de manière essentielle à la réduction du déficit alimentaire actuel.

Les interventions doivent s'opérer d'une maniére particulière en recherchant constamment l'adaptation, y compris pour la maintenance des infrastructures.

La population vivant dans ces zones est passée de 1,4 à 2 millions d'habitants entre 1977 et 1987; il est estimé qu'elle atteindra 3,2 millions en l'an 2000.

Le peuplement y croit donc plus vite que celui du pays entier.

La ressource en eau considérable constituée par le "gisement" du continental intercalaire et du complexe terminal est pratiquement non renouvelable, impliquant qu'un scénario prudent mais optimal soit mis en pratique pour son exploitation, avec l'exigence d'ailleurs, d'une coopération avec nos voisins...

Les populations de la région ont appliqué un système adapté pour capter et utiliser cette ressource avec les foggaras et les puits à balanciers.

Des projets modernes sont menés depuis les années soixante-dix: Abadla irriguée par le barrage de l'oued Guir, Gassi Touil, les tentatives de réhabilitation des oasis de Zelfana, Oued Rhir, Touat Gourara et enfin les actions récentes de mise en valaur privées.

Les superficies irriguées étaient estimées à 53 000 ha (source Statistiques agricoles) pour la campagne 1988 .

Le scénario qui semble se dégager permettrait d'équiper globalement environ 300000 ha, répartis comme suit:

- gravitaire traditionnel : 100 000 ha
- aspersion classique : 40 000 ha
- irrigation localisée : 20 000 ha
- pivots : 140 000 ha

Le Sud pourrait ainsi contribuer à raison du tiers environ des superficies équipées et irriguées, pour presque 80 % de la production de céréales en irrigué, 15 % de la production totale et 10 % des besoins de l'année 2010 .

Tout cela nécessiterait cependant l'exploitation de près de 5 milliards de m^3 d'eau, soit environ 150 m^3 par seconde, à raison de 15 000 m^3 par hectare.

Un rythme de mise en service de 10 000 à 20 000 ha par an permettrait de réaliser le sous-programme Sud en 15 à 30 années.

La période 1990-2005 ou 2020 serait donc celle d'une mise en valeur prudente, réfléchie, concertée et intégrée, calée sur des projets-pilotes, évaluant, en permanence, les conséquences des actions engagées et les risques encourrus.

Les recherches expérimentales menées en vraie grandeur devraient porter sur:

* les niveaux optimaux d'exploitation, compte tenu:

- de la baisse de l'artésianisme et des augmentations de coûts provoqués sur l'investissement et sur le fonctionnement,

- des problèmes de qualité, minéralisation et température de l'eau...

* les techniques et matériels d'irrigation adaptés,

* les espèces et systèmes de culture,techniques agricoles...

8. Agriculture, qualité de l'eau et pollution:

L'eau indispensable aux besoins des plantes doit obéir à certaines normes de qualité minimale.

L'excès d'éléments indésirables peut être nuisible:

- *aux cultures,* d'où baisse des rendements et même risque d'intoxication du consommateur,

- *aux sols,* risque d'appauvrissement, d'où baisse des rendements, mais aussi risque de contamination des cultures, des nappes souterraines...

- *aux nappes d'eau souterraine,* risque de contamination des consommateurs d'eau

- *aux consommateurs,* qui peuvent ingérer directement des polluants fixés aux feuilles, fruits ...

Les eaux utilisées en irrigation, en Algérie, sont, en général, de qualité assez moyenne et elles sont minéralisées...

Le développement de l'Agriculture, entraîne, lui même, des dégradations fâcheuses de la qualité de l'eau pour les autres usages (pollution des nappes d'eau douce, utilisées pour la boisson humaine par les nitrates); ce sujet est à l'ordre du jour de toutes les instances internationales concernées.

A son tour l'usage de l'eau par les populations agglomérées entraîne une pollution biologique, mais aussi, de plus en plus physico-chimique des réserves utilisées pour tous les usages.

Il est indispensable de monter un véritable programme d'économie de l'eau au niveau des industries, incluant les procédés peu consommateurs, reçyclage, récupération, traitement à l'amont, épuration des rejets à l'aval...

La réutilisation des eaux usées épurées dans l'agriculture

Elle devient une nécessité impérieuse, tout au moins,au stade de la planification, de la recherche, de l'expérimentation et du lancement de projets pilotes.

L'Algérie est sur ce sujet en retard par rapport à ses voisins méditerranéens qui ont compris les multiples avantages de cette technique et travaillent pour contrôler ses inconvénients.

Un programme concret devrait être lancé autour de l'ouvrage de Baraki, qui pourrait couvrir l'irrigation de vingt milliers d'hectares de la Mitidja.

Sur les Hautes plaines des techniques naturelles peuvent être mises en oeuvre aux alentours des villes et villages; ces techniques sont basées sur l'utilisation de l'espace disponible, des conditions climatiques favorables et du temps de séjour dans des étangs artificiels .

9. Les hommes, la formation

Un programme de développement hydro-agricole a besoin de profils diversifiés: ingénieurs de conception en aménagement hydroagricole - physiciens du sol - hydrauliciens - les sous-spécialités de génie civil ou d'électricité et mécanique diverses - mais aussi économistes et financiers spécialisés dans la gestion des programmes d'investissement - juristes - spécialistes en organisation etc...

A terme ce sont 250 ingénieurs et cadres qui doivent exercer dans la gestion et l'exploitation et 200 dans les services d'équipement.

10. Les coûts:

On peut retenir une valeur de **250 000 dinars par hectare,équivalents à 10 000 dollars par hectare**, avec une part devises de l'ordre de la moitié, pour les aménagements récents, en cours de réalisation, ou de lancement.

(pour le réaménagement , 6000 $ / ha)

Ces chiffres ne tiennent pas compte de la mobilisation, ils incluent l'adduction (qui est différente du transfert, lié à la mobilisation), tous les réseaux hydrauliques et connexes et excluent les équipements et réseaux à la parcelle, dits équipements "mobiles"...

Le projet-type tel qu'il est réalisé actuellement est basé sur l'aspersion, qui nécessite une charge minimale et donc, le plus souvent du pompage, donc de l'énergie.

Le "projet-type moyen" conçu pour des assolements maraîchage-fourrage à écartements 12x12 ou 12x18 représentatifs nécessite, en plus, 70 ou 80 ml de tuyauteries et 3 à 6 asperseurs par hectare, ce qui correspond à 1200 $ / ha , pris en charge par l'exploitant.

Enfin, ces projets nécessitent une puissance installée de 1,5 KVA par hectare en moyenne, avec une fourchette allant de 0,5 à 2.

Ces éléments permettent d'approcher les volumes d'investissements à engager, de crédits à prévoir pour financer le matériel d'aspersion et l'énergie à mobiliser; les dépenses "d'accompagnement" indispensables à la viabilité tels les investissements agricoles, "à la ferme", les infrastructures diverses financées en concours définitifs par l'Etat ou par des crédits ordinaires ou spécifiques sont à considérer par ailleurs.

Les approches de coûts ont une valeur purement indicative, en ce moment, chez nous; des efforts doivent être accomplis pour une maîtrise des coûts dans le sens d'une baisse et d'un rapprochement des moyennes internationales (ordre de grandeur 6000 à 8000 dollars par hectare).

Les 300 000 ha à équiper en plus, en sus des "en cours" de 1990 nécessiteraient ainsi **3 milliards de US $** . Les 45 000 ha à rénover **270 millions $**. 360 millions $ seront nécessaires pour l'équipement à la parcelle.

Une puissance installée supplémentaire de l'ordre de **500 MVA** sera indispensable, correspondant à 600 millions $.

Ce sont ainsi, au total environ 4 milliards de US $ qu'il faut consacrer à l'ensemble du programme, sur une quinzaine d'années, dont la moitié en devises directes; c'est encore l'équivalent de 250 millions de dollars par an .

Des différentes hypothèses élaborées résulte un rythme moyen d'équipement de 25000 ha par an, approximativement et en tenant compte des travaux déja engagés.

Participation de l'agriculteur usager -

Différentes formules sont possibles pour faire participer l'usager aux investissements,étant entendu qu'il devrait payer intégralement pour les frais de fonctionnement et d'exploitation des organismes de gestion.

Sa participation peut revêtir différentes formes:

- l'Etat peut lui faire endosser une part raisonnable de l'amortissement,

- l'Etat peut décider de financer seulement les ouvrages de tête et principaux, laissant le soin aux agriculteurs, soit de financer les réseaux secondaires et tertaires, soit de les réaliser eux-mêmes.

La participation des producteurs peut se faire directement ou par l'intermédiaire de l'organe de gestion, avec ou sans un système coopératif ou syndical...

La rentabilité de l'ensemble du programme ne peut s'approcher avec précision que par un modèle macroécocnomique complexe.

Une approche rapide et sommaire montre que l'investissement global par hectare:

- **10.000 $** infrastructure hydroagricole, arrondis à 300.000 DA **pour tenir compte de l'investissement "Energie" (30.000 DA / KVA ?...)**
- 10.000 $ mobilisation de la ressource eau et energie

Ce sont donc 20.000 dollars que l'hectare équipé doit "rendre" à l'économie sur une certaine période.

Un revenu à l'hectare de 1000 à 2000 $ par an rentabiliserait donc les dépenses en une dizaine ou une vingtaine d'années.

Un revenu de moitié entraînerait un amortissement en une cinquantaine d'années au maximum, ce qui correspond à la durée de vie d'un périmètre irrigué.

Une autre manière consiste à considérer que les 250 millions de dollars dépensés annuellement en devises fortes pendant 15 ans rapporteront ensuite 400 millions de dollars qui seront économisés sur les importations alimentaires actuelles .

Tous les efforts de maîtrise des coûts et de la gestion ne peuvent qu'améliorer ce bilan sommaire.

11. Conclusion

- L'existence d'une demande alimentaire qu'il faut satisfaire, même en partie,
- l'existence de ressources et de conditions climatiques et générales globalement favorables, même en partie,
- l'existence d'un "marché", "porteur", inducteur d'aval en amont d'activités multiformes...,

conduisent naturellement à l'élaboration d'un programme à même, de constituer l'*axe directeur du développement économique régional*; ce programme pour être une réussite doit veiller particulièrement aux "points critiques", de même qu'il doit s'intégrer dans une approche globale, considérant toute la problématique agricole.

Les points considérés comme *critiques* concernent les sous-programmes:

* moyens de conception que l'on peut relier étroitement au développement des ressources humaines,

* inputs nécessaires et moyens de réalisation, où une "vision industrielle", est nécessaire,

* outils de programmation, administration, suivi et gestion qui posent des problèmes d'organisation et de réglementation, au sens large...

* participation active et réelle des mondes de l'agriculture et de l'économie...

Les axes d'un programme d'actions multiformes intégrées comprendraient:

- l'approfondissement des connaissances du potentiel "ressources eau" par l'affinement des schémas directeurs régionaux; ces schémas directeurs doivent intégrer fortement la préoccupation de la recherche d'aménagements "économiques", au sens de l'investissement et de la gestion,

- l'effort d'amélioration et de rationnalisation de la gestion des périmètres en exploitation, incluant leur rénovation si nécessaire...

- la multiplication du rythme d'équipement de nouvelles surfaces par un facteur de cinq, aboutissant à terme à l'utilisation optimale des potentialités connues...

- la consolidation de l'organisation des outils de suivi du programme...

- un sous-programme de formation (cadres + agriculteurs), de perfectionnement, de vulgarisation et de recherche,

- un sous-programme d'incitations "moyens de conception et de réalisation"...

Le rôle et l'association des services et élus locaux, des producteurs eux-mêmes ainsi que la manière de leur faire prendre en charge leur part, doivent être pensés et précisés.

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PROSPECTIVES EN MATIERE DE FORMATION ET DE RECHERCHE SUR LA GESTION DES RESSOURCES EN EAU EN MEDITERRANEE

M. LASRAM

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PROSPECTIVES EN MATIERE DE FORMATION ET DE RECHERCHE SUR LA GESTION DES RESSOURCES EN EAU EN MEDITERRANEE

M. LASRAM
Secrétaire Général du CIHEAM

Résumé

L'eau constitue un facteur important contribuant à réaliser les objectifs de la sécurité alimentaire. Malgré la rareté de cette ressource dans la plupart des pays de la région méditerranéenne, l'eau continue à être gérée souvent de manière peu rationnelle.

Une gestion rationnelle des ressources en eau nécessite forcément une approche pluridisciplinaire à la base de laquelle il convient de former des profils adéquats et de mettre en place des programmes de recherche répondant aux besoins du pays et visant une meilleure valorisation de l'eau.

La coopération régionale et internationale a un grand rôle à jouer pour renforcer les capacités nationales et favoriser l'échange des connaissances et des expériences.

Le CIHEAM-IAM de Bari qui oeuvre dans ce sens depuis une trentaine d'années dans la région méditerranéenne devra renforcer sa coopération avec les institutions nationales spécialisées en Méditerranée pour mieux répondre aux besoins du développement de l'agriculture irriguée dans les pays membres.

Abstract

Water is a significant factor which contributes to the achievement of the objectives of food-supply security. In spite of the scarcity of this resource in most countries of the Mediterranean region, water supplies are still managed in an often not very rational way.

A rational management of water supplies necessarily entails a multidisciplinary approach at the foundation of which it is advisable to frame adequate proficiencies and to implement research programmes which would meet the requirements of the country and aim at a better valorization of water.

Regional and international cooperation has an important role to play in order to strengthen national competencies and to promote the exchange of knowledge and experiences.

The CIHEAM/BARI.MAI, which has been striving in that direction for about thirty years in the Mediterranean region, shall have to strengthen its cooperation in order to meet better the requirements of the development of irrigated agriculture in member countries.

INTRODUCTION

L'eau revêt une importance capitale dans la région méditerranéenne, particulièrement dans le secteur de l'agriculture où elle constitue, notamment dans les zones semi-arides et arides, le facteur limitant principal pour l'extension et l'intensification des cultures. L'irrigation constitue ainsi un moyen pour accroître et stabiliser la production de certains produits de base (sécurité alimentaire) et pour développer certaines cultures d'exportation (fruits et primeurs).

Malgré la rareté de cette ressource, de nombreux pays de la région ont déployé des efforts considérables pour mobiliser les eaux de ruissellement et les eaux des nappes superficielles et profondes. Cependant, la demande en eau est sans cesse croissante du fait de la poussée démographique, notamment dans les pays du Sud, et en raison des impératifs de développement de l'agriculture, de l'urbanisation, du tourisme et de l'industrie. Ainsi, en dépit d'un taux de mobilisation des ressources en eau souvent élevé, atteignant 95 % en Egypte, 83 % à Chypre, 68 % en Tunisie, 41 % en Algérie et en Espagne et 38 % au Maroc, les quantités d'eau disponibles à l'utilisation demeurent insuffisantes pour répondre aux besoins dans plusieurs pays du Sud où la consommation moyenne annuelle par habitant se situe aux environs de 200 m^3 , alors que les pays européens consomment en moyenne 800 m^3 par an, par habitant et les U.S.A. 5000 m^3.

On constate néanmoins que, malgré sa rareté dans de nombreux pays du Sud, l'eau est utilisée de manière peu rationnelle. Le gaspillage de certains secteurs d'activité, le faible taux d'utilisation et d'intensification dans les périmètres agricoles irrigués, ne permettent pas de valoriser au mieux les ressources hydrauliques déjà mobilisées.

Le rôle de la formation et de la recherche dans le domaine de la mobilisation et de la gestion de l'eau demeure le point de départ de la mise en oeuvre d'une politique hydraulique nationale adéquate.

Plusieurs pays ont mis en place des cycles d'enseignement, à différents niveaux, pour la formation des ingénieurs et techniciens nécessaires à la mise en oeuvre de leurs politiques hydrauliques et à l'encadrement des zones irriguées.

En même temps, de nombreuses institutions de recherche sur l'eau ont été créées dans de nombreux pays et des programmes de recherche visant une utilisation efficiente de l'eau ont été lancés.

Devant la similitude des problèmes posés par la mobilisation et la gestion de l'eau dans les pays de la région méditerranéenne, et vu la diversité des profils nécessaires et des programmes de recherche, une coopération régionale et internationale ne peut être que bénéfique pour favoriser les échanges d'expériences et combler les insuffisances par la recherche d'une complémentarité dans le domaine de la formation et de la recherche sur l'eau et l'irrigation.

LA MULTIPLICITE DES PROBLEMES ET LA NECESSITE D'UNE APPROCHE PLURIDISCIPLINAIRE.

La mobilisation des ressources en eau et leur gestion nécessite la formation d'une multitude de profils d'ingénieurs hydrauliciens, hydrologues, agronomes, physiologistes, socio-économistes, etc.

De nombreuses technologies ont été produites par la recherche, mais leur transfert et leur adoption dans différents pays ont souvent posé des problèmes en raison des conditions naturelles ou socio-économiques pouvant varier d'un pays à l'autre et même d'une région à l'autre dans le même pays. C'est pourquoi chaque pays doit développer une recherche appliquée permettant d'adapter des technologies développées ailleurs et même de créer des innovations répondant à des situations spécifiques régionales ou locales.

D'une manière générale, l'agriculture irriguée dans la région méditerranéenne se caractérise par :

- des performances bien inférieures aux objectifs fixés lors de la conception et de la mise en place des projets d'irrigation,
- une politique du prix de vente de l'eau entraînant peu de motivation pour une meilleure valorisation de cette ressource,
- une gestion et une maintenance inadéquates des infrastructures,
- une plus grande attention sur les quantités d'eau que sur les aspects de qualité,
- une priorité plus grande donnée aux projets de grande hydraulique par rapport à la petite hydraulique qui s'avère pourtant plus efficace dans beaucoup de situations,
- une faible attention prêtée aux aspects de la sauvegarde de l'environnement et de la pollution des nappes.

La solution de la plupart de ces problèmes nécessite une approche pluri-disciplinaire qui fait malheureusement souvent défaut. A cet effet, il convient tout d'abord d'assurer une formation spécialisée de futurs cadres nationaux pour l'ensemble de la "filière eau" et de favoriser par la suite la formation d'équipes pluridisciplinaires que ce soit au niveau de l'administration ou celui de la recherche et du développement.

LES PRIORITES POUR LA FORMATION ET LA RECHERCHE DANS LE DOMAINE DES RESSOURCES EN EAU.

La formation et la recherche constituent la première étape nécessaire à la mise en place des programmes nationaux de développement de l'hydraulique et de l'irrigation.

La formation des ingénieurs dans le domaine de l'eau est souvent assurée, dans les pays en développement, par des écoles spécialisées ou des universités. Dans ces cas, si la partie hydraulique de la formation est suffisamment couverte, il n'en est pas ainsi de la partie agronomique, des domaines appliqués à l'agriculture et encore moins des aspects socio-économiques. De ce fait, il apparaît difficile de constituer des équipes nationales comprenant toutes les disciplines requises pour une approche globale et intégrée.

L'absence de formation continue dans la plupart des systèmes éducationnels dans les pays du Sud et la présence sur le terrain d'ingénieurs isolés chargés de la gestion d'un périmètre irrigué ne favorisent guère la mise à jour des connaissances et la constitution d'équipes multidisciplinaires.

Il y a donc un besoin évident de formation de base appropriée dans certains domaines techniques appliqués et en socio-économie pour le secteur de l'eau, ainsi qu'une nécessité de recyclages périodiques des ingénieurs formés pour leur donner accès aux nouvelles connaissances.

Cette formation de base, à tous les niveaux, ciblée selon les besoins, ainsi que la mise à jour périodique des connaissances par la formation constituent la base de toute action de développement des capacités humaines et de consolidation des institutions nationales de recherche et de développement.

Pour la recherche, les programmes en cours dans les institutions nationales des pays du Sud n'obéissent pas toujours à une démarche de programmation basée sur le diagnostic des problèmes rencontrés, sur une consultation élargie auprès de tous les partenaires et sur l'établissement d'une hiérarchie des priorités. Par ailleurs, la part des crédits accordés aux programmes de recherche sur l'eau est en deçà du rapport que représente ce secteur dans sa contribution à la production agricole nationale.

Les priorités de la recherche sur l'irrigation devraient concerner en premier lieu :

- la modernisation des systèmes d'irrigation dans un objectif d'économie de l'eau,
- une meilleure valorisation de l'eau par un bon choix des cultures et des techniques agricoles appliquées,
- les aspects relatifs à la qualité de l'eau et à la salinisation des sols,
- la recherche sur les eaux usées et les ressources en eau non conventionnelles,
- l'amélioration des méthodes de gestion et de maintenance des infrastructures.

De nombreuses recherches ont été conduites sur ces thèmes dans le monde. Les pays qui n'ont pas suffisamment développé leurs capacités de recherche devraient dans un premier temps accéder à ces travaux pour adapter certains résultats à leurs conditions locales par des recherches appliquées et des testages sur les exploitations des agriculteurs pratiquant l'irrigation.

La circulation de l'information et de la documentation, les échanges de chercheurs et de techniciens entre les pays et la confrontation d'expériences et de résultats revêtent une importance capitale pour dynamiser les programmes de recherche et en activer les résultats. A cet effet, la coopération régionale et internationale est à encourager.

LE ROLE DE LA COOPERATION REGIONALE ET INTERNATIONALE

Les institutions régionales et internationales de formation et de recherche peuvent jouer un grand rôle pour développer les capacités nationales, échanger les connaissances et les expériences et dynamiser les structures de recherche en les faisant bénéficier notamment des acquis disponibles.

De nombreuses institutions oeuvrant dans le domaine de la gestion des ressources en eau existent dans le monde et développent diverses activités de coopération. Par ailleurs, plusieurs institutions nationales spécialisées dans les problèmes de l'eau ont atteint des capacités et des niveaux d'expertise leur permettant de jouer un rôle dans une coopération régionale. Il importe, dans un premier temps, de recenser l'ensemble de ces institutions, en précisant le domaine d'activité et de compétence de chacune, et de diffuser ces informations à toutes les structures concernées.

Nous nous limiterons ici à présenter l'Institut Agronomique Méditerranéen de Bari qui fait partie des structures du CIHEAM, et qui oeuvre depuis trente ans dans le domaine de l'eau et de l'irrigation au niveau de la région méditerranéenne.

L'IAM de Bari est l'un des quatre Instituts du CIHEAM opérant actuellement dans la région méditerranéenne. Depuis sa création, cet Institut a eu comme première vocation de travailler sur les problèmes d'irrigation qui revêtent, en zone méditerranéenne, une importance capitale.

Le domaine d'activité principal de l'Institut est la formation spécialisée post-universitaire qui consiste en un cycle de formation dispensé en deux ans et aboutissant à un diplôme de Master du CIHEAM. Le programme de formation concerne essentiellement les techniques d'irrigation, la planification et la gestion des ressources en eau.

La première année de formation comporte des compléments de cours de base (14 unités) et de cours approfondis (48 unités) ainsi qu'un projet comptant pour 12 unités.

Les cours de base traitent d'informatique, de techniques de laboratoire, de statistiques appliquées et de rappels de principes en hydraulique et en économie.

Les enseignements spécialisés couvrent les quatre domaines suivants :

. relations sol-eau-plante,
. méthodes d'irrigation et de drainage,
. systèmes et schémas d'irrigation,
. aspects socio-économiques.

Le projet concerne le plus souvent un travail personnel sur un projet d'irrigation avec une simulation d'une étude de cas.

La seconde année de formation, pour les étudiants admis à la suivre, comporte 40 unités de valeur réparties comme suit :

. 14 unités de cours
. 6 unités de séminaires
. 20 unités pour un mémoire de recherche.

Le programme Master comporte quatre sections de spécialisation :

. utilisation des ressources en eau non conventionnelles,
. utilisation rationnelle de l'eau dans les systèmes agro-environnementaux,
. systèmes d'irrigation,
. aspects socio-économiques liés à l'irrigation.

L'Institut accepte annuellement une quarantaine de candidats, en majorité originaires des pays du Sud et de l'Est de la Méditerranée pour suivre le cycle irrigation.

L'objet principal de cette formation est de donner à des ingénieurs, ayant déjà reçu une formation agronomique générale, les connaissances complémentaires de base, théoriques et pratiques, leur permettant de mieux comprendre les différents aspects de l'irrigation et d'intervenir de manière efficace dans les programmes de terrain développés dans leurs pays. Ce type de formation répond bien à un besoin de plusieurs pays de la région et occupe un créneau de formation se situant entre les planificateurs et les spécialistes du secteur de l'eau.

En outre, l'existence de stagiaires originaires de plusieurs pays et la participation à la formation de nombreux spécialistes de la région méditerranéenne, de l'Europe et d'autres pays du monde favorisent l'échange d'information et des connaissances et stimulent l'établissement de liens de travail et de coopération durables.

A côté de la formation longe, l'IAM de Bari dispense quelques cours spécialisés de brève durée (trois semaines en général) s'adressant plus particulièrement à des professionnels, techniciens et chercheurs, et ayant pour objectif la mise à jour des connaissances sur les méthodologies de travail et les techniques relatives à différents domaines intéressant la gestion de l'eau.

Le deuxième domaine d'activité de l'IAM de Bari concerne la recherche qui est développée à travers les travaux de mémoire des étudiants de deuxième année et les projets de recherche financés en partie par des ressources bilatérales ou par la CEE.

Les thèmes couverts par les programmes de recherche concernent principalement :

. l'utilisation et la gestion des eaux salées,
. l'utilisation des eaux usées,
. l'irrigation de complément,
. la modélisation éco-physiologique et l'optimisation de l'irrigation,
. la conception et la gestion des systèmes d'irrigation,
. les systèmes d'information et les schémas de projets d'irrigation.
. les analyses économiques des projets d'irrigation.

Certains thèmes font l'objet de réseaux coopératifs de recherche rassemblant des spécialistes de plusieurs pays méditerranéens.

Enfin, le troisième domaine d'activité de l'Institut concerne l'organisation de rencontres scientifiques et de séminaires de réflexion sur les différents aspects de la gestion des ressources en eau et de l'irrigation.

Ainsi, les activités de l'IAM de Bari en matière de formation et de recherche sur la gestion des ressources en eau et sur l'irrigation répondent à la nécessité d'une approche intégrée intéressant spécifiquement les milieux agro-écologiques et socio-économiques méditerranéens.

PROSPECTIVES POUR LE RENFORCEMENT DE LA COOPERATION INTERNATIONALE

La première action à envisager pour le renforcement de la coopération est de procéder à un inventaire complet de toutes les institutions internationales, régionales et nationales intervenant dans la région méditerranéenne dans le domaine de l'eau, avec une description précise de leur domaine de compétence et d'activité.

L'IAM de Bari pourra continuer à jouer un rôle de dynamisation de la coopération en matière de formation de recherche sur l'eau entre les pays méditerranéens.

Pour la formation, il pourra poursuivre à dispenser un cycle long "irrigation" en procédant à son évaluation périodique en vue de l'adapter continuellement aux besoins des pays. Une plus large participation de spécialistes du Sud dans l'enseignement et l'évaluation permettrait de développer la coopération avec les institutions de ces pays et de mieux assurer une complémentarité des actions de formation.

Une plus grande attention devrait être donnée aux cycles courts de formation continue spécialisée qui fait défaut dans la plupart des systèmes nationaux.

L'IAM de Bari pourrait aider à la conception et au montage de tels cycles dans certains pays de la région en ciblant les thèmes sur les demandes formulées par ces pays.

Pour la recherche, l'IAM de Bari devra viser en premier lieu :

. le renforcement des capacités nationales dans les pays du Sud et de l'Est par la formation à la recherche, un appui méthodologique et l'établissement de liens de coopération entre équipes travaillant sur le même thème,

. le recentrage des activités de recherche sur les priorités des pays de la région, notamment ceux en développement, en mettant en place des projets pilotes intégrés tels que celui qui a été réalisé dans la région du Fayoum en Egypte sur la recherche d'une approche intégrée pour la réutilisation des eaux de drainage pour l'irrigation,

. l'orientation des thèmes de recherche pour les étudiants de deuxième année sur des préoccupations de leurs pays respectifs, ce qui ne peut que renforcer la coopération avec ces pays,

. l'établissement d'un système efficace d'information permettant la circulation des données et des références méthodologiques et le maintien d'un contact durable entre les chercheurs de la région.

CONCLUSION

La pression de la demande en eau et la rareté de cette ressource imposent aux pays de la région méditerranéenne la mise en oeuvre de stratégies visant une gestion rationnelle et une meilleure valorisation des ressources en eau.

L'Institut Agronomique Méditerranéen de Bari par ses activités de formation et de recherche peut continuer à jouer dans ces domaines, un rôle important d'échange et de coopération entre les pays de la région.

A cet effet, il devra :

. veiller à adapter sa formation post-universitaire de manière complémentaire à celle assurée par les systèmes nationaux,

. associer de manière effective les enseignants/chercheurs des pays du Sud et de l'Est à ses activités,

développer davantage de cycles courts de formation spécialisée s'adressant à la formation continue de professionnels,

. orienter les thèmes de recherche sur les besoins des pays de la région,

. assurer une diffusion large de l'information auprès de la communauté scientifique méditerranéenne.

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CLOSING SESSION

GENERAL DISCUSSION, RECOMMENDATIONS AND CONCLUSIONS

WORKSHOP ON

Water Resources: Development and Management in Mediterranean countries

CLOSING SESSION
General Discussion, Recommendations and conclusions

Towards the preparation of the CIHEAM conference on Agricultural Policies in Mediterranean Countries, on the occasion of the 30th anniversary of the establishment of CIHEAM Bari Institute has sponsored to organise a workshop on water resources development and management in the Mediterranean countries' in Adana-Turkey- University of Çukurova Faculty of Agriculture (3-9 September, 1992).

The objectives of the workshop are:

- To present a general overview on water resources, irrigation and water management in the Mediterranean countries;

- To identify potentialities, constraints in water resources and management;

- To explore possibilities of cooperation, exchange and transfer of experience towards solving priority problems;

- To set a research and human resource development agenda for CIHEAM;

- To explore means and ways of establishing an information network among Mediterranean countries.

Conventional and unconventional water resources, water resources planning and management, water resources and irrigation practices and demands, water resources use and water resources economic, institutional and legislation aspects, water quality and environmental impacts are the major technical issues treated by the workshop.

INTRODUCTION

There is no doubt that the majority of the countries of the Mediterranean region, with erratic rainfall patterns, efficient control and management of water use has to be an essential requirement for this continued development. Without proper water management, self sufficiency in food and energy will continue to be a mirage for most of these countries. Scarcity of water and reliability of its supply are major constraints for agricultural and development in those countries, many of all available sources of water which can be economically used have already been developed or are currently in the process of development. In some countries, such as Egypt or Jordan, no new major sources of water can be further developed.

In the Mediterranean countries, the major challenge facing water planners and managers in the 1990's is that while physical availability of water is fixed, its demand will continue to increase steadly in the foreseable future. Accordingly, the problem is how to balance demand and supply of water under those difficult conditions and to satisfy environmental requirements. In addition, the issue of potential climatic change due to global warming and what its impacts could be on natural resources including water, are basically unknown factors at present. This is a part of a broader challenge to water planners and managers: to anticipate impacts of climate on the full range of water management and strategies.

Scarcity and misuse of fresh water pose a serious and growing threat to sustainable development and protection of the environment in the Mediterranean countries.

Human health and welfare, food security and ecosystems on which they depend, are all at risk unless water and land resources are managed more effectively.

Major Issues of the Workshop

- Recognise the importance of water resources planning and management: A left need more comprehensive and long term approach under water scarcity conditions.

- The development for new approaches and methodologies in support of strategic planning in order to increase resilience and sustain our resource base.

- Development strategies which include the improvement of the performance of irrigated agricuture, wise water management, strong conservation methods and institutional adjustements.

- Lack of environmental impact assessments studies of water resources and irrigated projects.

- Lack of basis data and information activities: coordination, research; technical assistance, education and training.

- National, Regional and international cooperation.

RECOMMENDATIONS

Planning

- Integrated planning as a tool for national development have to achieve social goals: equity, efficiency and environmental quality starting from: physical environment, economic criteria, and social and legal decision-making processes.

- national water policy for the majority of the Mediterranean countries should be updated. The framework of the policy should be based on the Internationalships of the following three system:

The natural water resource system (The supply side);
The human activities system (The demand side).

The water resource management system (The harmonizing of supply and demand).

- Under water scarcity conditions long term strategies and practical implementation programmes for the development of agricultural water use should be analyzed and introduced.

- General planning and contingency planning in water scarce conditions has to be improved introducing new and adequate techniques for assessment and decision making.

- Strategies which increase resilience and sustain our resources base such as: improvement of agricultural practice, water management, strong conservation measures and institutional changes have to be analysed and implemented.

MANAGEMENT

- Water resources management should be implemented in an organized manner integrating on one hand the development and its water demands, and on the other one, the natural characteristics and the capacity of the area including the water resources.

- Simplified and implementable environmental impact assessment studies have to be used in the water resources management as a standard procedure in order to be able to assess and avoid the conflicts between development and nature.

- Effective management should link land development and water uses in the integral approach across the whole of catchement area or ground water aquifers.

Information

- Possible cooperation among regional experts and institutions have to be analysed and proper mechanisms for transfer technology and knowledge have to be established.

- it is necessary to analyse activities of the regional institutions, suggest cooperation and harmonize on going and future activities so that existing knowledge and capacity can be used in the most productive way.

- Strengthening capabilities to collect, store and process water-related data,.

- Information activities in the region should be improved to be able to overcome complexity and conflicts in water resources management.

- Formal and informal network of expert and regional organization have to be established trying to find a new way for working together.

Educational Training and Research

In the majority of the Mediterranean countries water scarcity and drought conditions are the main constraints for development. Those items should be included in training and research programmes.

Recycling of reclaimed waste water and its reuse in agriculture has a great future potential as new water source for irrigation, in the Mediterranean region, this topic should be one of priorities in research and training activities of CIHEAM.

Establishing and strengthening research and development programmes appropriate to the needs of countries so as to increase understanding of the fundamental processes involved in the water resources management, including the interactions between water, land and the atmosphere, and to support water resources assessment and hydrological forecasting activities.

Promoting the development of new technology for water resources assessment in scarce and drought conditions.

Transferring appropriate technology to users.

Environment and legislation

Establishment of appropriate legislation, enforcement and economic mechanisms for water resources protection and conservation at the national level with international co-operation to promote water conservation and recycling, pollution prevention and control, and environmentally-sound agricultural practices;

Development and application of water quality, reuse water quality and water supply criteria for ecosystems and health protection to be implemented at national and regional levels.

Increasing the co-operation between climatological and hydrological communities in developing predictions of climate change for individual seasons and for specific regions;

Water has an economic value and should be considered in the management in water resources as an economic good.

Water pricing on socio economic bases is essential.

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SEANCE DE CLOTURE

DISCUSSION GENERALES,
RECOMMENDATIONS ET CONCLUSIONS

ATELIER SUR

Développement et gestion des ressources en eau dans les Pays Méditerranéens

Séance de clôture

Discussions Générales, Recommandations et Conclusions

En vue de la préparation du colloque du CIHEAM sur les Politiques Agricoles dans les Pays Méditerranéens, à l'occasion du 30ème anniversaire de la création du CIHEAM, l'Institut de Bari a patronné l'organisation d'un atelier sur "Développement et gestion des ressources en eau dans les Pays Méditerranéens" à la Faculté d'Agronomie de l'Université de Cukurova - Adana, Turkey (3 - 9 septembre 1992).

Les objectifs de l'atelier sont les suivants:

- Présenter un aperçu général sur les ressources en eau et la gestion des eaux de l'irrigation dans les Pays Méditerranéens;
- Identifier les potentialités, les contraintes des ressources en eau et de gestion;
- Examiner les possibilités de coopération, échange et transfert d'expérience pour la solution des problèmes de priorité;
- Etablir un ordre du jour pour le CIHEAM visant au développement des ressources humaines et de la recherche;
- Examiner les moyens et les modalités pour la mise en place d'un réseau d'information entre les pays méditerranéens.

Les principaux thèmes techniques qui font l'objet de cet atelier sont: ressources en eau conventionnelles et non conventionnelles, gestion et planification des ressources en eau, besoins et pratiques d'irrigation, utilisation et économie des ressources en eau, aspects législatifs et institutionnels, qualité des eaux et impacts sur l'environnement.

INTRODUCTION

Sans aucun doute, pour la plupart des pays de la région Méditerranéenne, caractérisés par une distribution irrégulières des pluies, la gestion et le contrôle efficace de l'utilisation de l'eau est une nécessité fondamentale pour le développement. En l'absence d'une gestion adéquate des eaux, l'auto-suffisance alimentaire et d'énergie de la plupart de ces pays ne pourra rester qu'un mirage. La pénurie d'eau et la continuité de l'offre, sont les contraintes principales au développement agricole de ces pays; une grande partie des ressources en eau disponibles susceptibles d'être économiquement exploitées ont été déjà mobilisées ou le processus de mobilisation est en cours. Dans certains pays, tel que l'Egypte ou la Jordanie, il n'y a plus de nouvelles ressources susceptibles d'être mobilisées.

Dans les Pays méditerranéens, le défi majeur que les cadres responsables et les planificateurs doivent relever aux années 1990 est une demande croissante des besoins en eau face à une disponibilité physique fixe. Par conséquent, il s'agit de rechercher un équilibre entre la demande et l'offre de l'eau dans ces conditions critiques tout en respectant l'environnement. En outre, le problème des changements climatiques potentiels résultant du rechauffement de la planète et les impacts de ceci sur les ressources naturelles, y-compris l'eau, sont des facteurs pratiquement inconnus à l'heure actuelle. Tout cela rentre dans le plus grand défi lancé aux planificateurs et aux cadres: prévoir les impacts du climat sur la gestion et les stratégies des ressources en eau.

La pénurie et le mauvais emploi de l'eau douce posent une menace grave et croissante pour le développement durable et la sauvegarde de l'environnement dans les pays méditerranéens.

La santé et le bien-être de l'homme, l'approvisionnement alimentaire et les écosystèmes desquels ils dépendent, sont tous en danger à moins que les ressources en terre et en eau ne soient gérées d'une manière rationnelle.

Thèmes principaux de l'atelier

- Prendre conscience de l'importance de la gestion et la planification des ressources en eau: une exigence saisie pour une approche plus globale et à long terme en conditions de pénurie d'eau.

- Mettre au point de nouvelles approches et méthodologies de support à la planification stratégique aux fins d'une meilleure élasticité et soutien de notre base de ressources.

- Développer des stratégies s'étendant de l'amélioration de la performance de l'agriculture en régime irrigué, à une gestion rationnelle des eaux, aux méthodes efficaces de conservation et aux adaptations institutionnelles.

- Le manque d'études d'évaluation de l'impact environnemental des ressources en eau, et de projets d'irrigation.

- Le manque de données de base et d'activités d'information: coordination, recherche, service de vulgarisation, instruction et formation.

- Coopération nationale, régionale et internationale.

RECOMMANDATIONS

Planification

- La planification intégrée en tant qu'instrument pour le développement national doit poursuivre des buts sociaux: équités, efficience et qualité de l'environnement à partir de: l'environnement physique, les critères économiques, les processus de décisions sociales et juridiques.

- Nécessité de la mise à jour de la politique nationale des eaux dans la plupart des pays méditerranéens. L'encadrement de la politique devrait être basé sur les relations mutuelles entre les trois systèmes suivants:

Le système des ressources en eau naturelles (l'offre)

Le système des activités humaines (la demande)

Le système de la gestion des ressources en eau (l'harmonisation de l'offre et de la demande).

- En condition de pénurie d'eau il faut analyser et formuler des stratégies et des programmes de réalisation pratique visant au développement de l'eau pour l'agriculture.

- Il faut améliorer la planification générale et contingente dans les conditions de pénurie d'eau en introduisant des techniques nouvelles et plus adéquates pour l'évaluation des risques et la prise des décisions.

- Nécessité d'analyser et réaliser des stratégies permettant une meilleure élasticité et qui soutiennent la base des ressources telles que: l'amélioration des pratiques agricoles, une gestion rationnelle des eaux, des mesures efficaces de conservation et des changements institutionnels.

Gestion

- La gestion des ressources en eau devrait être réalisée d'une manière intégrée: d'une part le développement et ses besoins en eau, et de l'autre les caractéristiques naturelles et la capacité de la région où les ressources en eau sont localisées.

- Il faut réaliser des études d'évaluation de l'impact environnemental simplifées et faciles à appliquer pour la gestion des ressources en eau en tant que procédure standardisée afin d'aboutir é l'évaluation et éviter les conflits entre le Développement et la nature.

- Une gestion rationnelle devrait lier le développement des terres et l'emploi de l'eau dans une approche intégrale portant sur tout le bassin versant ou les couches aquifères souterraines.

Information

Nécessité d'analyser les possibilités de coopération entre les experts régionaux et les institutions et rechercher les mécanismes appropriés pour le transfert des technologies et des connaissances.

- Il faut analyser les activités des institutions régionales, favoriser la coopération et harmoniser les activités en cours et futures aux fins d'un emploi optimal des connaissances et des capacités existantes.

- Renforcement des capacités de collecte, mémorisation et traitement des données sur l'eau.

- Améliorer les activités d'information dans la région afin d'être en mesure de faire face à la complexité et aux conflits liés à la gestion des ressources en eau.

- Etablir un réseau formel et informatique d'organisations d'experts et régionales en recherchant les meilleures conditions pour un travail commun.

Instruction, Formation et Recherche

Dans la plupart des Pays Méditerranéens la pénurie d'eau et les conditions de sécheresse sont les contraints principales au développement. Ces thèmes devraient être partie des programmes de formation et de recherche.

Le recyclage des eaux usées et leur réutilisation en agriculture a des potentialités futures remarquables en tant que nouvelle ressources d'eau pour l'irrigation dans la région méditerranéenne; ce thème devrait avoir la priorité dans la liste des activités de recherche et de formation du CIHEAM.

Organisation de cours de formation pratiques pour améliorer les performances des services de vulgarisation dans la diffusion des technologies et améliorer les capacités des agriculteurs surtout au niveau de petits producteurs.

Etablissement et renforcement des programmes de recherche et développement appropriés aux besoins des pays, de sorte à augmenter la compréhension des processus fondamentaux de la gestion des ressources en eau, y-compris les interactions entre l'eau, la terre et l'atmosphère, et soutenir l'évaluation des ressources en eau et les activités de prévision hydrologique.

Promotion et développement de nouvelles technologies pour l'évaluation des ressources en eau en conditions de pénurie et sécheresse.

Transfert et technologies appropriées aux usagers.

Environnement et Législation

Etablissement et consolidation d'une législation appropriée, de mécanismes économiques pour la tutelle des ressources en eau et la conservation au niveau national avec la coopération internationale afin de promouvoir la conservation et le recyclage de l'eau, la prévention et le contrôle de la pollution, et les pratiques agricoles respectant l'environnement.

Développement et application de critères de qualité de l'eau, qualité de l'au de recyclage et approvisionnement en eau pour la sauvegarde des ecosystèmes et de la santé de l'homme à poursuivre au niveau national et régional.

Augmenter la coopération entre les scientifiques de climatologie et hydrologie pour la prévision des changements climatiques au niveau saisonnier ou pour des régions spécifiques.

L'eau a une valeur économique. Elle devrait être considérée un bien économique dans la gestion des ressources en eau.

La tarification de l''eau basée sur les aspects socio-économiques est un point fondamental.

CIHEAM

Centre International de Hautes Etudes Agronomiques Méditerranéennes
International Centre for Advanced Mediterranean Agronomic Studies

Cahiers Options Méditerranéennes

Cahiers OM est une nouvelle série du titre *Options Méditerranéennes* destinée à recueillir des documents de travail, des textes d'analyse et d'étude réalisés dans le cadre des activités du CIHEAM

Cahiers OM *is a new series of the Options Méditerranéennes title destined to bring together working papers, study and analysis texts realized in the context of CIHEAM activities*

ATIONAL CENTRE FOR ADVANCED MEDITERRANEAN AGRONOMI UDIE

Etat de l'agriculture en Méditerranée

Le CIHEAM contribue, depuis trente ans, au renforcement de la formation et de la recherche agricole dans les pays du Bassin méditerranéen.

Au cours de ces trois dernières décennies, la situation de l'agriculture et de l'alimentation dans la région méditerranéenne a connu des changements importants. La plupart des pays du Sud connaissent une forte démographie et un déficit alimentaire de plus en plus accru, entraînant une surexploitation des ressources naturelles, alors que les pays du Nord sont confrontés à de sérieux problèmes d'environnement, en raison de l'abandon des terres.

Les pays du Bassin méditerranéen ont besoin, plus que jamais, de renforcer leur coopération pour définir les systèmes de formation et de recherche agricoles dont ils ont besoin pour relever les défis de la sécurité alimentaire et du développement agricole durable.

En vue de recentrer ses activités sur les besoins des pays membres, le CIHEAM s'est engagé avec un appui de la CCE (DG1) dans une réflexion globale dont la première étape est une série d'ateliers de réfexion ayant pour objectifs de faire l'état des lieux et de dégager des priorités en matière de formation et de recherche agricoles.

Le volume 1 de la nouvelle série *Cahiers Options Méditerranéennes* comportera cinq numéros présentant les travaux de ces ateliers sur les thèmes suivants : ressources en eau, ressources en sols, forêts et environnement, politiques agricoles et alimentaires, et recherche agronomique et sécurité alimentaire.

The Situation of Agriculture in Mediterranean Countries

For the last thirty years, the CIHEAM has regularly contributed to reinforcing agricultural training and research in the countries of the Mediterranean Basin.

In the course of these last three decades, the food and agricultural situation in the Mediterranean region has undergone important changes. Most of the countries of the South are experiencing a sharp rise in demography and an ever-increasing food deficit, causing overexploitation of natural resources, while the countries of the North are facing serious environmental problems due to land abandonment.

More than ever, the countries of the Mediterranean Basin need to strengthen their cooperation in order to define systems of agricultural training and research necessary to meeting the challenges of food security and durable agricultural development.

With the view of refocusing its activities concerning the needs of member countries, the CIHEAM, with the support of the ECC (DG1), has committed itself to an overall rethinking process whose first step is a series of workshops aimed at determining the state of affairs and accordingly identifying priorities in the area of agricultural training and research.

Volume 1 in the new series Cahiers Options Méditerrannéenes will include five numbers presenting the results of these workshops on the following themes: water resources, soil resources, forest and environment, agricultural and food policies, and agricultural research and food security.

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