Water resources in the OSS

(Observatory of the Sahara and the Sahel)

countries

Evaluation, use and management

International Hydrological Programme

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Foreword

Since the beginning of man, societies have been dependent on water. Their livelihood has always depended on their ability to manage and share this rare resource. This is particularly true in the Sahara and Sahel where water has become an essential possession which is an integral part of the history of the countries and of the lives of men.

This vital and symbolic resource deeply affects the collective memory of societies in these arid and semi-arid zones of Africa.

Groundwater resources, truly the 'hidden reserves' that have been long ignored, today are an important stake for these zones, among all the large communities of the world, which are considered to be the most deprived of natural water resources.

Many years ago, UNESCO launched an international programme of scientific co-operation in this domain – the International Hydrological Decade (1965–1974). This was followed by successive stages of the International Hydrological Programme (IHP). The main objective of these programmes has been to develop the scientific and technological basis for a rational management of water resources, concerning both quantity and quality, while taking into account the protection of the environment.

From the beginning, the study of the hydrology of arid and semi-arid regions has been studied regularly in the IHP. Phase V (1996–2001) will accord a particular importance to the integrated management of water resources in arid and semi-arid regions, the study of pollution and the protection of groundwater.

The Sahara and Sahel Observatory (OSS) has, since its creation, accorded a particular importance to the domain of water. Both an agent of degradation of ecosystems and an indicator of this degradation, water is an element whose quantitative and qualitative measurements play a major role in the understanding of desertification phenomena. Since 1992, the OSS has shown a special interest in the development of a platform for dialogue among countries sharing nonrenewable water resources.

An attempt is made to promote a 'basin awareness' by working to increase and exchange knowledge on these units (geological and hydrogeological definition as well as improvement of models, etc.), creation of effective joint structures in the face of still poorly mastered resource management, and a harmonization of legislation.

The OSS and UNESCO have established a fruitful cooperation on this theme and work together to distribute this reflection on the challenges which the OSS region faces for the future as concerns these limited resources. This reflection was done with the participation of Jean Margat. Today, it takes on a particular importance in light of the recent International Agreement to Combat Desertification, already signed by more than 187 countries.

The updating of its data base relative to the year 2000, makes it a document of assistance in planning.

If each country can give substance to this joint 'awareness', rapid progress can be made and will enable each country to plan for the future more effectively.

We will then be nearer to and more respectful of the vital functions of this precious element.

Andràs Szöllösi-Nagy

Director
UNESCO Water Sciences Division

Chedli Fezzani

Executive Director
OSS

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Introduction

The part of the African continent covered by the Sahara and Sahel Observatory is one of the regions of the world where the scarcity of water resources, combined with poverty, can constitute a major obstacle to sustainable development. In most of the countries of the region, it is vital that water policy and water conservation, both now and in the future, confront the problems posed by the growing tension between the limited water resources on the one hand and the growing water requirement on the other. Water management is therefore becoming crucial for development. Great efforts are required everywhere in water management and distribution, and occasionally already in unconventional water production techniques, in the organization and adaptation of water use, notably by reducing needs and increasing conservation, as well as in the arbitration of resource allocation and the distribution of the associated costs which are increasing more rapidly than the GNP in most of the countries concerned.

Depending on the degree of strain between water resources and uses in each country (or even within a region in the largest countries), the structure and nature of the resources, the socio-economic resources and policies of each country, and the present and possible future trends in water use (i.e. water needs), the approach, relative importance and priority ascribed to the possible solutions are different:

- improvement of water management structures and the development of new techniques;
- inter-regional water transfer;
- more or less temporary exploitation of non-renewable resources;
- industrial water production (desalination);
- reuse of waste water;
- development of water conservation efforts, recycling, more efficient water use by actions on demand;
- redeployment of uses and demand.

This study, carried out by the OSS, first of all draws up a comparative assessment of the situation and an inventory of the problems and conflicts to be resolved by water management. It then summarises the technical solutions and gives an outline of the means and instruments of an integrated water management system.

This new version updates and completes the first edition published by OSS and UNESCO in May 1995.

1 Water resources

Water resources in most of the OSS countries have been the subject of several recent monographs and evaluations, usually within the framework of preliminary studies for water resource development master plans linked to development plans. There have also been a number of regional synthesis reports on water resources, illustrated by maps, either of the Arab countries, under the auspices of ACSAD and UNESCO-ROSTAS (Khouri et al., 1990; Shahin, 1989), or of the Sahelian countries of West Africa, under the auspices of the ICHS

It is outside of the scope of this report to present, even in concise form, all of the results of these studies. Only the essential global figures will be presented here. Before presenting the problems and objectives of water management, two main points must be highlighted:

- Of all the large geopolitical regions in the world, after the Middle East, the OSS region has the least natural water resources, both in absolute terms and in relation to its population.
- Within this region, water resources are distributed in different and unequal manners. The type and structure of resources vary greatly from country to country, as does their degree of independence. This creates very diverse conditions for water management.

1.1 The OSS region

Some basic statistics:

	Surface area (in millions of km²)	*Population, 2000 (Source: United Nations)*	*Renewable natural fresh water resources (in thousands of millions of m³/yr)*
The OSS region	16.57	359	Internal: 407 Total: 520
World-wide	149	6,000	42,600 (Source: UNESCO)

The OSS region covers 11% of the world's dry land surface and holds 6% of its population (in 2000) but its internal natural renewable water resources amount to only around 1% of the world's total resources or an average overall water yield of 24,600 m^3/yr per km^2, whereas the global average is approximately 290,000 m^3/yr per km^2. This is of course due to the fact that most of the region is arid or semi-arid, as illustrated in the UNESCO map of average annual water yield for the whole region (Fig.1). Local input, nevertheless, varies greatly, ranging from barely 1,000 to more than 100,000 m^3/yr in an average year, and is very unevenly distributed throughout the region, which leads to great disparities in total internal resources from country to country (see below, 1.3). Furthermore, the great seasonal and annual irregularity in flow further accentuates the low averages.

The internal resources of the OSS region are supplemented (to the overall tune of 20%) by rivers flowing in from more humid zones – principally in the West African countries of the Sahel, more so, the southern banks of Lake Victoria – although this does little to correct the overall disparity, whilst creating a certain dependency in a number of recipient countries.

The OSS region clearly has the least water of all the geopolitical regions of the world, after the Middle East (Table 1).

Table 1. The world's natural renewable water resources (rounded figures)

Geopolitical regions (groups of countries)	*Total average internal and external resources (km^3/yr)*	*Portion coming from outside of the region (external resources) (km^3/yr)*	*Relatively constant portion (surface and groundwater) (km^3/yr)*
OSS Region (1)	520	113	~ 200
Europe	1,900	10	600
Ex-USSR (the former USSR)	4,400	430	1,400
North America (USA and Canada)	6,700	0	1,700
Latin America (including the Caribbean)	13,000	3	4,000
Africa, excluding the OSS region (but including Madagascar)	3,500	0	1,200
Near and Middle East	480	17	100
Indian sub-continent and Southeast Asia	6,600	1,000	1,600
China (including Mongolia and North Korea)	2,800	0	1,000
Japan and the 'Four Dragons'	700	0	200
Australia and Oceania	2,000	0	300
TOTAL (without overlap)	**42,600**		**12,300**

(1) OSS Region:
Arabic Maghreb Union (AMU) countries: Algeria, Egypt, Libya, Mauritania, Morocco and Tunisia.
Permanent Interstate Committee for Drought Control in the Sahel (CILSS) countries: Burkina Faso, Cape Verde, Chad, Gambia, Guinea-Bissau, Mali, Mauritania, Niger and Senegal.
Intergovernmental Authority on Development (IGAD) countries: Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan and Uganda.

The yield of natural resources per inhabitant displays a similar degree of inequality. In 2000, the average figures for the whole region were 1,135 m^3/yr (internal resources) and 1,450 m^3/yr (including external resources) per inhabitant (and less than 1,000 m^3/yr per inhabitant in some countries), compared to a global average of 7,500 m^3/yr (Fig. 2).

An average water resource of 1,000 m^3/yr per inhabitant (which corresponds to a population density of 1,000 inhabitants per million m^3/yr of resource) in countries where food self-sufficiency makes irrigation necessary, is generally considered to be the threshold below which tensions arise between needs and resources, with the risk of local or cyclical water shortages. At the present time, six countries of the OSS region have natural water resources below 1,000 m^3/yr per inhabitant (essentially the Maghreb, in addition to Egypt and Kenya). One of these, Libya, has less than 500 m^3/yr. In 2000, the

Figure 1. Distribution of potential mean annual flowrate in the OSS region. Geography of the input of renewable water resources

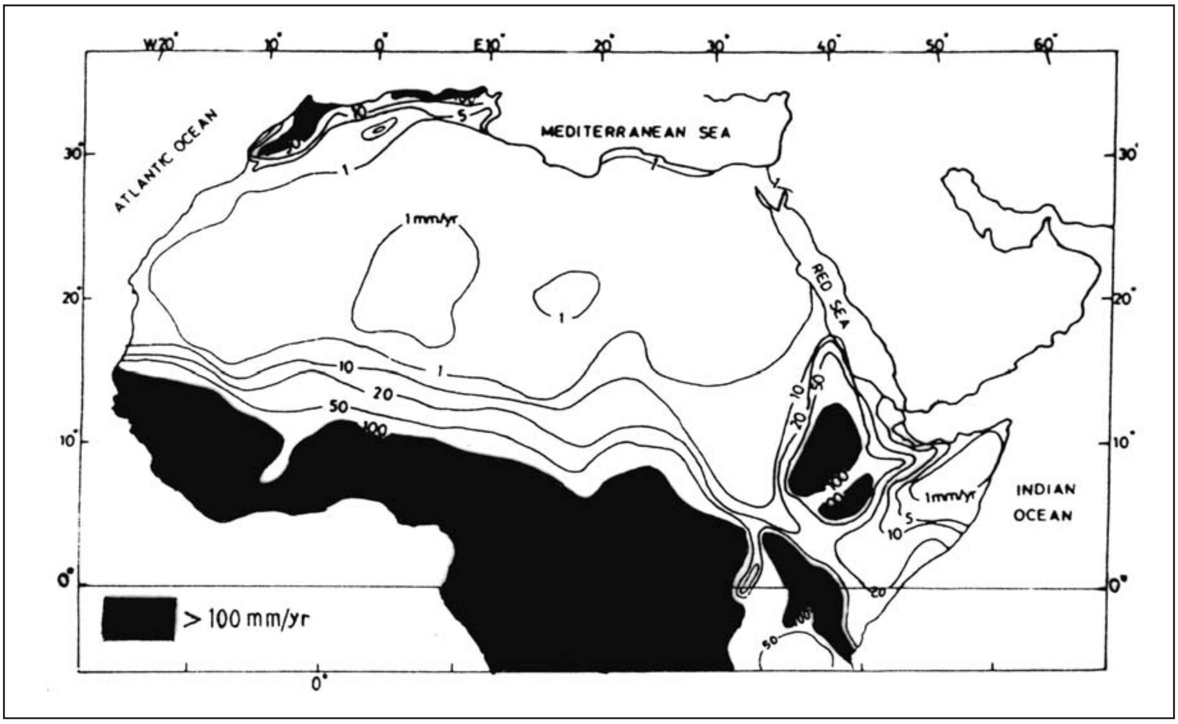
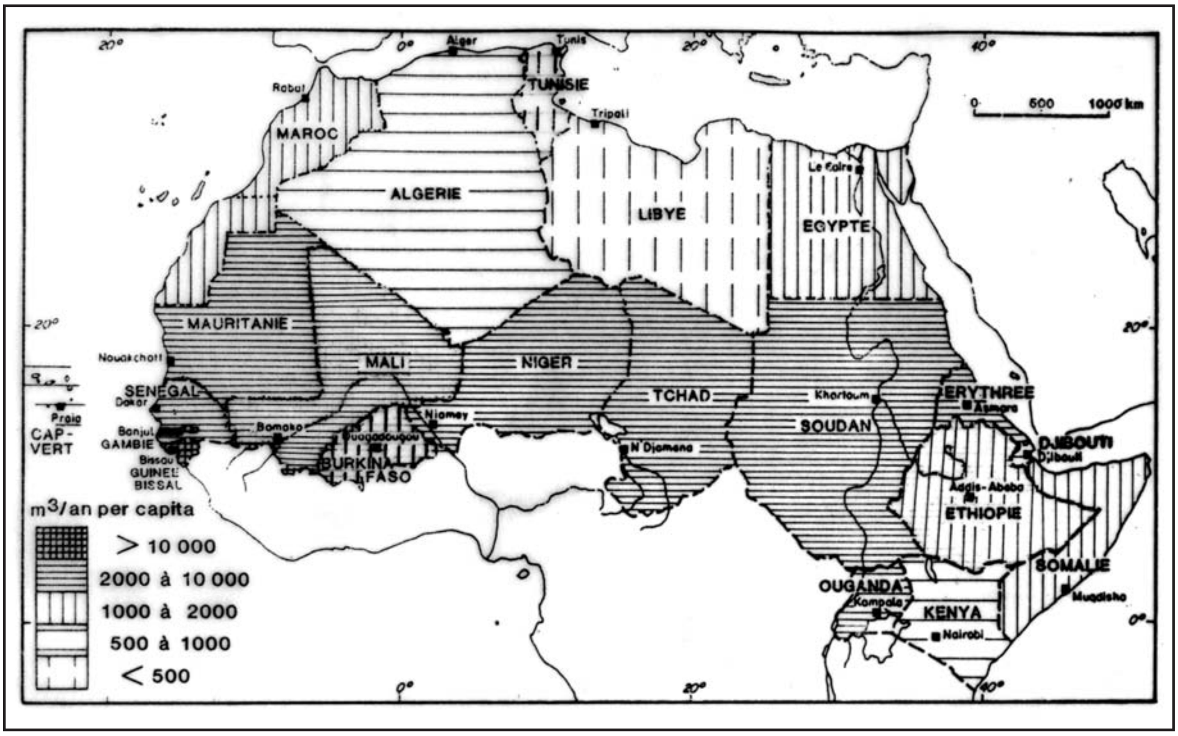
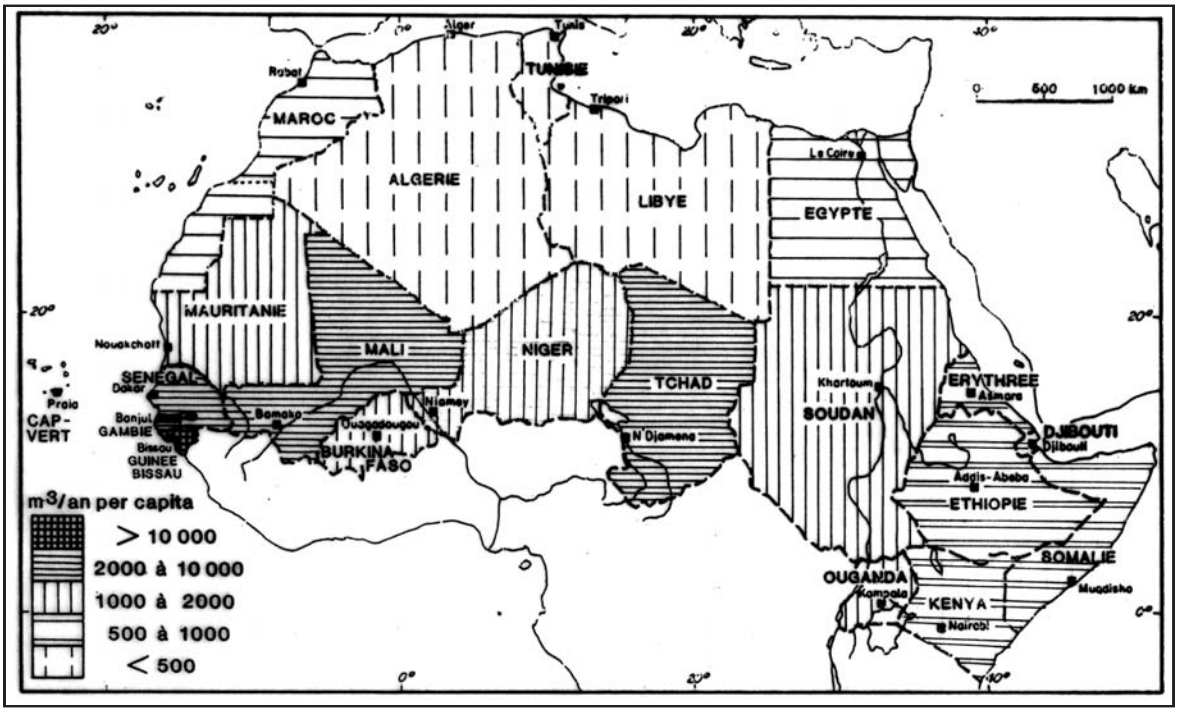


Figure 2. OSS countries classified according to their natural or potential renewable resources per inhabitant (based on 1990 population figures)



population of these countries was 145 million (40% of the total of all the OSS countries). This situation will worsen markedly during the 21st century in line with the population growth rates, which are generally high, notwithstanding differences from country to country (Fig. 3). In 2025, four more countries (Burkina Faso, Ethiopia, Morocco and Somalia) will have resources below 1,000 m^3/yr per inhabitant, making a total of ten countries and 405 million inhabitants (69% of the total of all the OSS countries).

Figure 3. OSS countries classified according to their natural or potential renewable resources per inhabitant (based on projected population figures for 2025, according to the mean assumptions of the United Nations)



1.2 Types and geography of resources

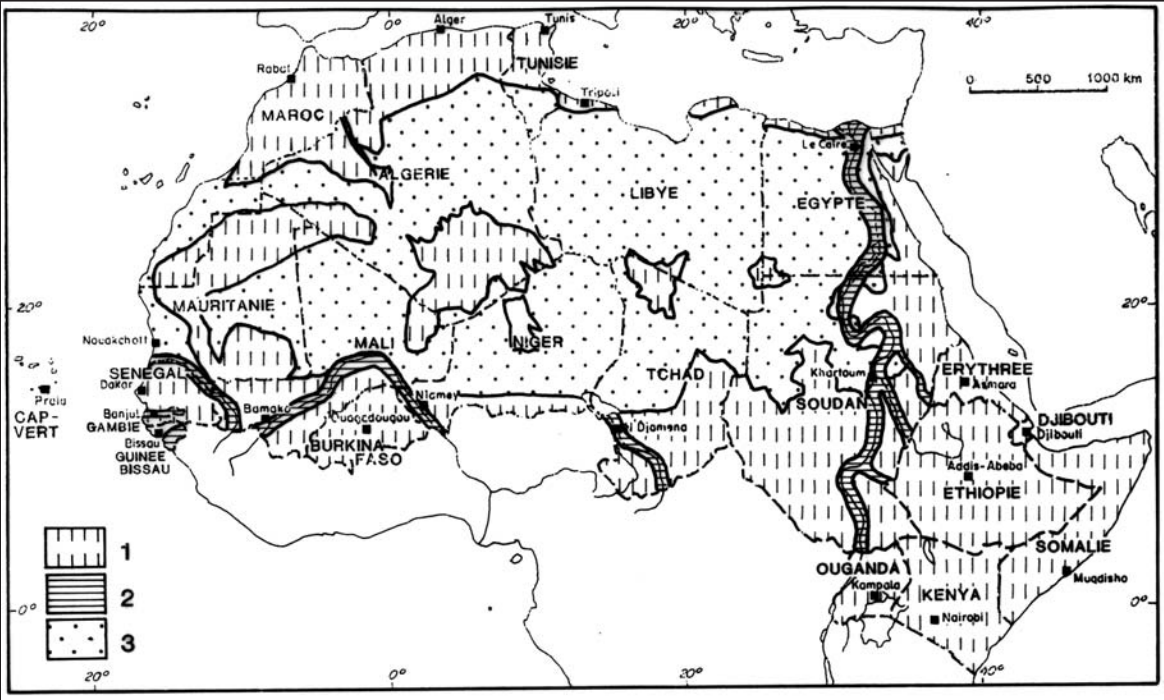
Within the OSS region, water resources are not only unequally distributed in terms of quantity, but they differ in terms of nature and structure. There are three main structural types of resource and each creates its own specific conditions of evaluation and management.

A geography of water resources can be drawn according to this typology (Fig. 4).

(1) A highly compartmentalized complex structure of predominantly internal water resources, principally surface water but with an appreciable groundwater component, essential for permanent, regular resources. This has three consequences:

- The manageability of the resources is dependent not only on the semi-arid climatic conditions (wherein seasonal and interannual changes and interannual are generally broad) and the hydrographic and hydrogeological networks, but also on the availability of potential dam sites, each successive installation generally having a diminished output.

Figure 4. Distribution of predominant water resource types in the OSS region



1. Predominance of internal renewable resources (surface and groundwater),
2. Predominance of fluvial resources of external origin,
3. Predominance of non-renewable resources (groundwater).

- Hierarchical complexity and multiplicity of those involved (public authorities, local communities, individual agencies), entailing a co-existence and complementarity of 'large-scale', and 'medium and small-scale hydraulic projects', notably for the exploitation of groundwater, and a partly decentralized management of resources.
- Independence from neighbouring countries and regionalization of resources, internal inequalities of which can sometimes be compensated for by water transfer.

This type of resource predominates in the Maghreb (north of the Sahara Desert), in the ancient massifs of the Sahara (Hoggar, Aïr, Tibesti, etc.), in the basement zones of the Sahelian countries (Burkina Faso, Southern Mali, Chad, etc.) and in Eastern Africa (Ethiopia and the countries bordering the Indian Ocean).

(2) A structure centred around a major river (Nile, Niger, Senegal), with a significant external input, often generating 'secondary' groundwater resources (subordinate alluvial aquifer), notably when used for irrigation. This has three consequences:

- The major role of 'large hydraulic projects' and public control of resource development and management.
- Use is structured and is concentrated in the river valleys, favouring 'reuse' (a portion of the resource can be used several times).

- Heavy dependence on countries upstream, and obligations to countries downstream.

This type predominates in Egypt, the Sudan, Mauritania, Niger and Chad. It also contributes notably to the resources of Mali and Senegal.

(3) A deep structure of a large groundwater basin with predominantly non-renewable groundwater resources and little surface water, having three consequences:

- Public authorities play a major role in the reconnaissance and exploitation of resources.
- The need for long-term groundwater resource management.
- The opportunity for concerted efforts between countries in the many cases where the aquifers cross national borders. This is one of the major themes of the OSS 'Aquifers of Large Basins' programme, in particular, the Northern Saharan Aquifer System (SASS) project launched in 1999, and in which Algeria, Libya and Tunisia cooperated.

This type predominates in the Sahara (the western desert of Egypt, Libya, the Algerian, Moroccan and Tunisian Sahara, the Saharan sedimentary zones of the Sahelian countries of Mali, Niger, Chad and the Sudan).

Specific evaluation problems

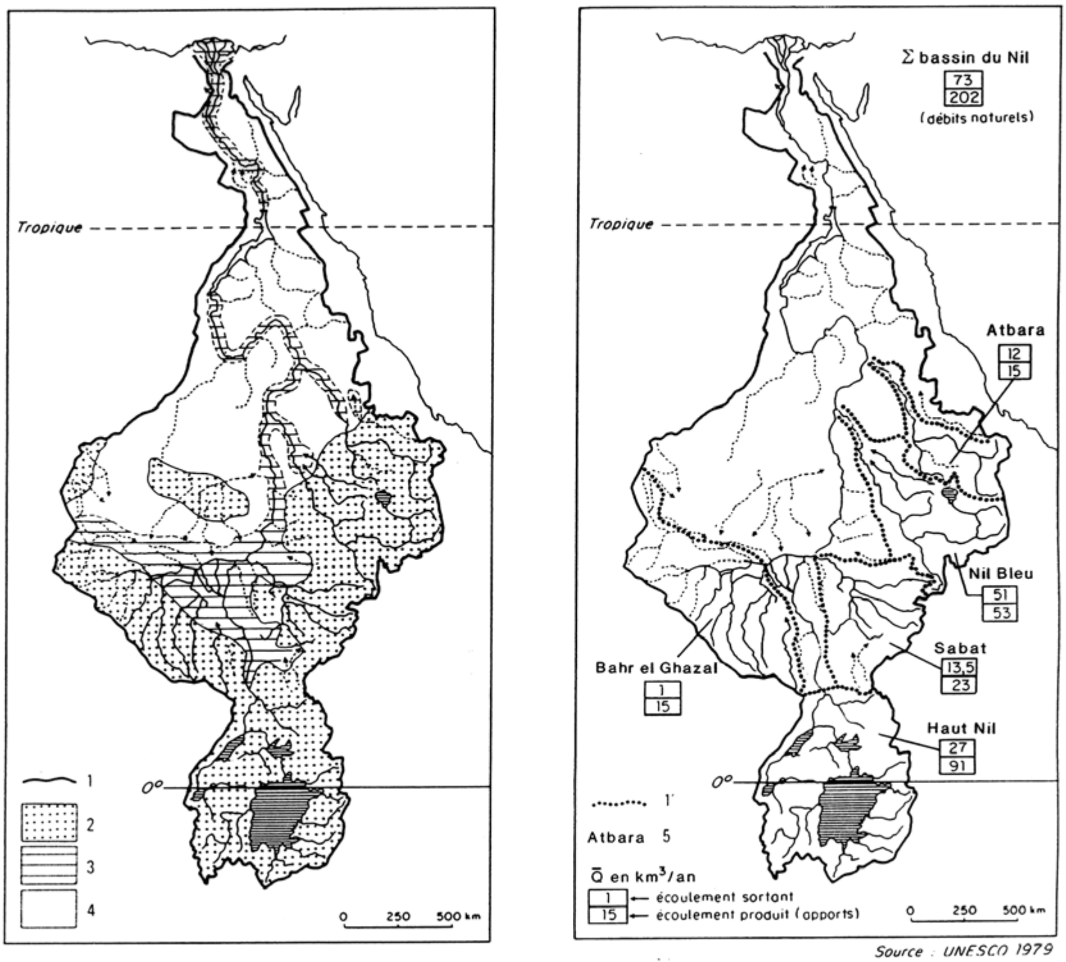
As a result of the arid or semi-arid climatic conditions which prevail in most of the region, the renewable surface water resources of types (1) and (2) are not only temporally irregular but also often difficult to store.

- *In time:* long periods of hydrological observations are required in order to estimate the averages and variabilities at an acceptable level of accuracy;

- *In space:* much of the river water evaporates, particularly in the inland deltas such as those of the Nile in Sudan (loss from Bahr-el-Ghazal and the inland delta of the Nile are estimated at 31 km^3/yr) or the Niger in Mali (estimated loss of 33 km^3/yr, on average, within the inner delta – 17 to 86 over to the years – in addition to 3.9 within the buckle of the Niger) which leads to a reduction in the flow as we move downstream (Figs. 5 and 6). In the whole Nile basin, natural water loss through evaporation (excluding irrigation) is approximately 130 km^3/yr, or 2/3 of all local input (Fig. 5). This phenomenon is even more pronounced in endorheic basins such as that of Lake Chad since the loss through evaporation is total. Estimations of surface water resources based on hydrological processes must take this into account and refer only to 'productive' areas or sub-basins.

Some of the input, local or from tributaries coming from neighbouring countries, is not included in the outflow figures, reducing the estimate of total resources. Before being lost, however, this flow contributes to the local resources which are to be taken into account.

Figure 5. Flow gain and loss in the Nile basin



Zones of gain and loss of flow | **Inflow and outflow of the principal sub-basins**

1: theoretical limit of the river basin;

1’: limit of the principal tributary sub-basins;

2: flow producing zone;

3: flow consuming zone; evaporation > precipitation;

4: vadose zone, little potential flow locally and no regional flow;

5: principal tributary sub-basins.

The vast lakes and marshes of the inland delta of the White Nile in the tropical zone form areas of evaporation which ‘consume’ much of the flow produced upstream. The extension of the basin into the arid zone accentuates these losses, further decreasing the flow.

Figure 6. Average discharge along the Niger River. Loss in the inland delta in Mali

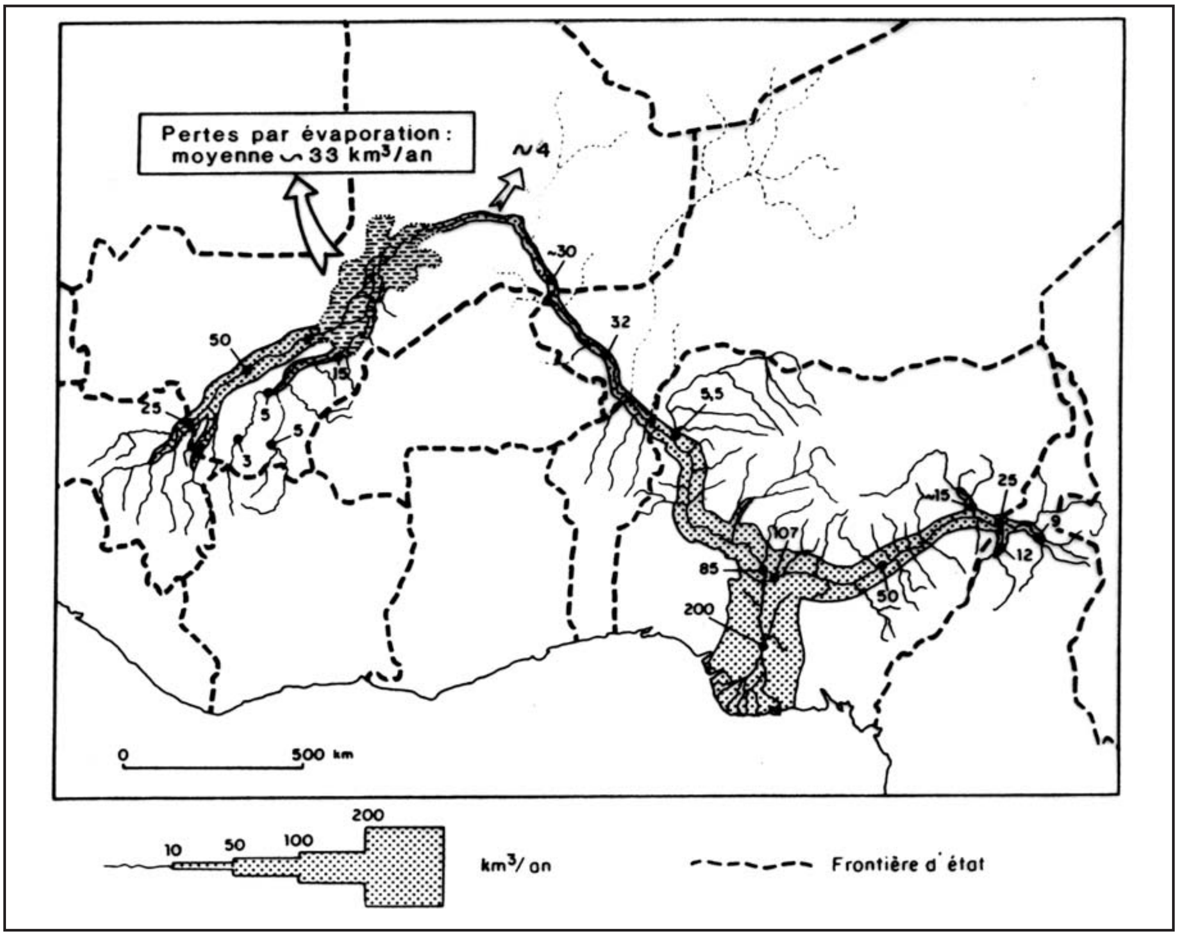


Figure 7. Principal transfer of water across borders (average annual discharge in km^3/yr)

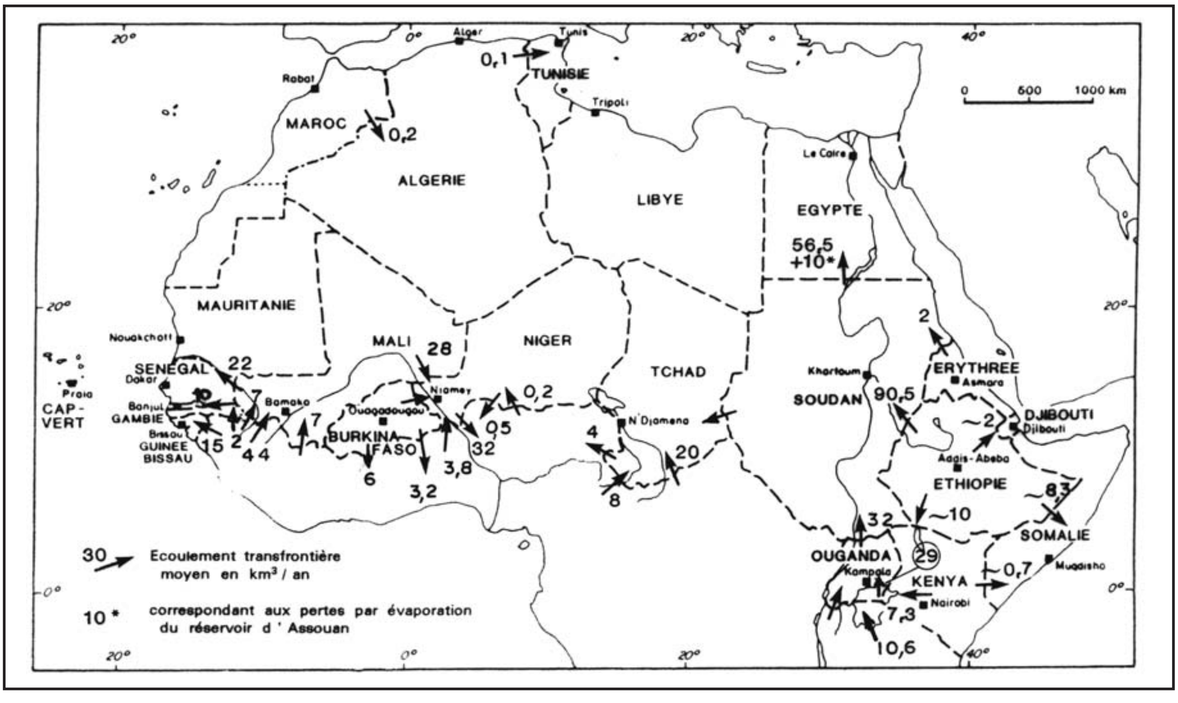


Table 2. Natural input, losses and flow in the Nile basin countries (Fig. 5)

Country	*Input in high productive basins (potential flow) (km³/yr)*	*Natural losses*	*Natural outflow from the area (km³/yr*
Burundi, Kenya, Rwanda Tanzania and Uganda	91	54	27
Ethiopia	91	1	90
Sudan:			
- Bahr-el-Ghazal	15	} 14	1
- Other basins	5		83
- Tributaries from upstream countries	~ 117	39	84
Total	137	~ 53	84
Egypt Inflow from upstream	84	21	theoretical natural outflow: 63

Part of these losses can be recovered if appropriate measures are taken, by reducing the size or permanence of marshes and consequently the quantities of water which evaporate: it is thus to be counted as a resource.

Similar problems arise when we attempt to estimate renewable groundwater resources: the local inflow by infiltration of a portion of the rainfall (aquifer recharge, apart from the particular case of their accretion by flood water ...) estimated by indirect methods, is greater than the outflow of groundwater which constitutes the base flow of perennial streams.

Examples of estimations of the natural groundwater resources of some Sahelian countries according to these two approaches:

Table 3. Estimation of the natural groundwater resources in some Sahelian countries

Country	*Natural groundwater flow estimated by calculating aquifer recharge (10^9 m³/yr)*	*Natural groundwater flow calculated using stream base flow (10^9 m³/yr)*
Burkina Faso	9.5 (4)	5 (2)
Mali	65 (1)	16 (3)
Senegal	9.3 (2)	7.6 (3)
Chad	20.6 (2)	11.5 (3)

References: (1) PNUD, 1990 [123]; (2) CIEH-BRGM, 1976 [102]; (3) L'Vovich, 1974 [55]; (4) Food and Agriculture Organization (FAO) [154]

The three types of resources are not equally vulnerable to climatic variations, notably *droughts*. Type (1) resources are the most vulnerable, type (2) resources are more given to centralized regulating development, while type (3) resources are not vulnerable. The areas where type (2) resources predominate are, therefore, the most vulnerable to droughts, especially in semi-arid zones with non-negligible (for dry farming) but highly irregular rainfall.

Moreover, an evaluation of the natural water resources of most of the countries within the region cannot be based solely upon mean data. Such evaluation requires knowledge of the variables, especially the interannual variables, so that a laying out of multiannual trends over a sufficiently long period of time, such as that which is described in the tables constructed by I. Shiklomanov in 1998 [197], from hydro-climatological and hydrological data concerning several Sahelian countries, for the period running from 1926 to 1985, the results of which are presented, as follows:

Table 4. Annual internal and external inputs of certain Sahelian countries

Country	Annual internal input				Annual external input			
	Average (km^3/year)	Max. (km^3/year)	Min. (km^3/year)	Coefficient of variation	Average (km^3/year)	Max. (km^3/year)	Min. (km^3/year)	Coefficient of variation
Senegal	21.4	31.1	6.31	0.28	0.32	21.9	59.2	0.3
Gambia	3.97	5.69	1.24	0.28	0.43	9.62	194.0	0.28
Mali	39.6	62.2	18.64	0.32	54.8	82.5	21.8	0.27
Niger	2.33	5.4	0.28	0.43	32.1	47.2	13.7	0.24
Chad	10.4	13.2	7.1	0.32	36.6	59.2	3.7	0.31
Sudan	34.6	65.3	9.74	0.43	132.0	194.0	88.7	0.14

From the same source, some examples of interannual variations in annual inputs which constitute the natural resources (internal and external) for several Sahelian countries and for the regions of North Africa and West Africa have been drawn and are depicted graphically (as described by I. Shiklomanov*). (Please see Fig. 8, *infra.*)

These historical trends show a tendency towards a decrease that is sufficiently marked for the Sahel and West Africa, but not with respect to North Africa.

- *North Africa:* Algeria, Egypt, Libya, Morocco, Sudan and Tunisia;
- West Africa: Benin, Burkina Faso, Gambia, Ghana, Mali, Mauritania, Niger, Nigeria, Senegal and Togo.

Water resources of each of these three types may be subject to **instabilities,** but in a very different manner:

- Type (1) resources, due to the progressive degradation of the ability of streams to control irregular discharge (inevitable long-term silting) and occasionally due to the impact of human activities on the regimen and quality of the water (desert formation, pollution) that water conservation measures can decrease or slow down, if not completely halt.

  These are also the only resources directly exposed to the consequences of *desertification* on the groundwater regimen, particularly in the Sahelian countries and Northeast Africa where the impact of deforestation and intensive land use are the most prominent. The hydrological consequences of desertification – very different from those of droughts – have, however, rarely been reported.
- Type (2) resources due to the evolution in water use in countries upstream (increase in consumption, evaporation in flow regulation dams, even input of pollutants). These resources can, however, be increased in certain cases if measures are taken to reduce evaporation in 'inland deltas' (with respect to the Nile, Sudan, Niger, and Mali).
- Type (3) resources, due to the normal depletion of reserves, because of reduced accessibility (lowering of levels) aggravated occasionally by a decrease in quality (increased salinity).

For various reasons, therefore, each type of resource can give rise to predictions. Planners and planning studies still usually consider natural water resources to be constant (on the average), a 'raw material' to be transformed by development so that the offer supplies an ever-increasing demand. Under the conditions prevailing in the OSS region, possible evolutions in resources must be taken into consideration – not only the effect of exploitation and development which reduces the remaining available reserves, but also the indirect impact of water use on resource recharge (the impact of hydraulic works on the replenishment of groundwater, for example) and more generally the impact of human activities on water regimen and quality – let alone the effect of possible changes in climate over the very long term, outside of the scope of this study (cf. Box 5).

Unequal exploitability

Each of these three types of water resource corresponds to a different conception and evaluation of what makes up 'exploitable' or 'usable' resources, thus specific management constraints.

- In the case of internal renewable resources (type 1), the exploitable or 'available' resources depend on physical water management conditions (dam sites, aquifer discharge capacity). These are initially evaluated according to the technical and economic criteria of the users but occasionally also according to external or 'environmental' criteria of water conservation. These evaluations are therefore not independent of socio-economic objectives and means available at a given stage of development. They can evolve, notably as availability decreases. Evaluating exploitable resources in a given socio-economic context is already a management choice. Take, for example, the flux of currently available water resources compared to natural resources in the Maghreb and Ethiopia, according to criteria particular to each country:

Table 5. Natural renewable and mobilizable water resources in the Maghreb countries and in Ethiopia

Country	*Natural renewable water resources average flow (km^3/year)*	*Surface water*	*Mobilizable groundwater resources (km^3/year)*	*Total*	*Reference (cf. Bibliography)*
Algeria	16.2	–6	1.9 (1)	7.9	[74], [180]
Libya	0.6 to 0.7	0,13 to 0.14	0.5	–0.635	[187]
Morocco	29	16	–4	20	[135], [164]
Tunisia	4.57	2.47	1.15	3.62	[122], [171]
Ethiopia	110	54.4	2.6	–	[1], [154]

(1) Renewable resources only. According to another estimation, the 'potential aquifer discharge capacity', taking into account limiting factors, would be 2.54 km^3/year, outside of the Sahara Desert (*Small and medium-scale hydraulic works,* Public Works Ministry, 1992).

For its part, the International Water Management Institute (IWMI) has evaluated for some countries in Northern Africa and within the Nile Basin, as part of the preparatory work for the 'Vision' of the World Forum, in The Hague, Netherlands (2000), of the 'usable water resources,' calculated on the basis of the 'potential utilization factor' (PUF), as shown below:

Table 6. Renewable and usable water resources in the Maghreb countries and in several countries of the Nile Basin

Country	*Natural renewable water resources (km^3/year)*	*PUF (%)*	*Usable water resources (km^3/year)*
Algeria	14	60	9
Morocco	30	65	20
Tunisia	4	60	2
Egypt	69	85 (1)	58
Sudan	165	60	99
Ethiopia	88	60	53

(1) Taking into account the return of remobilizable water (drainage): 'secondary resources'.

Source: IWMI 2000 [163].

Figure 8. Variation in annual internal and external input, from 1921 to 1985, in four Sahelian countries, from I. Shiklomanov (1998)

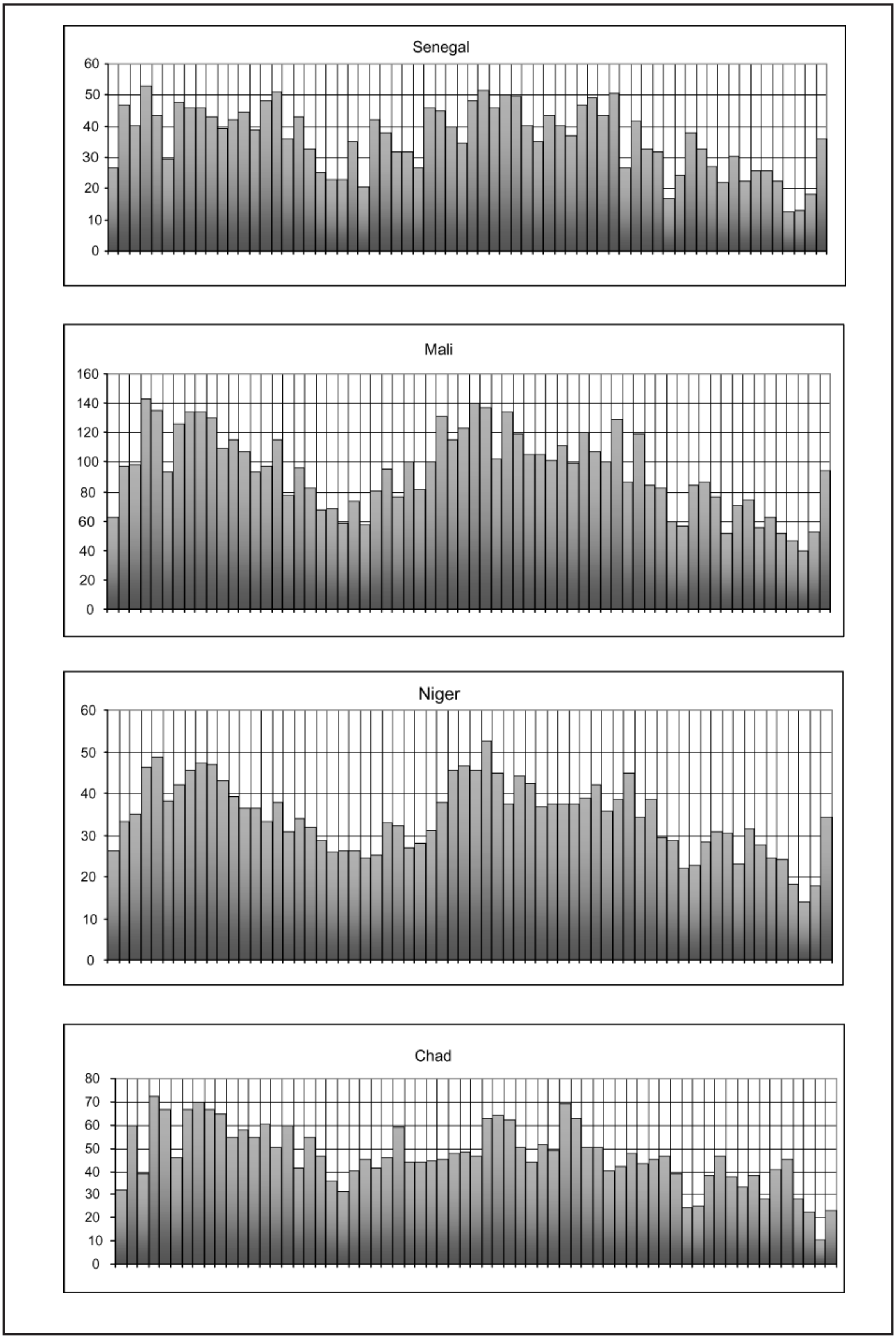
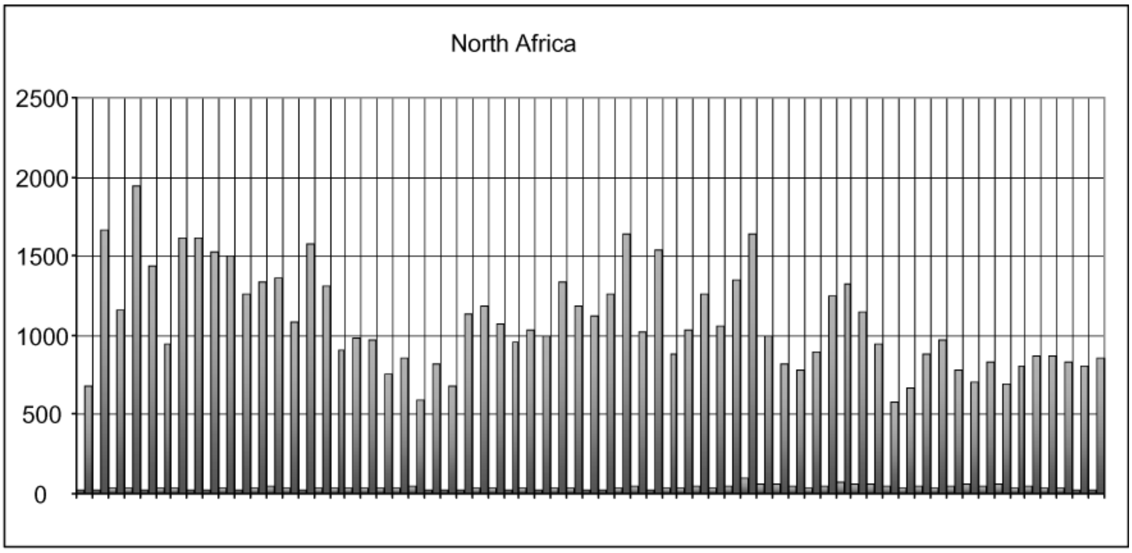
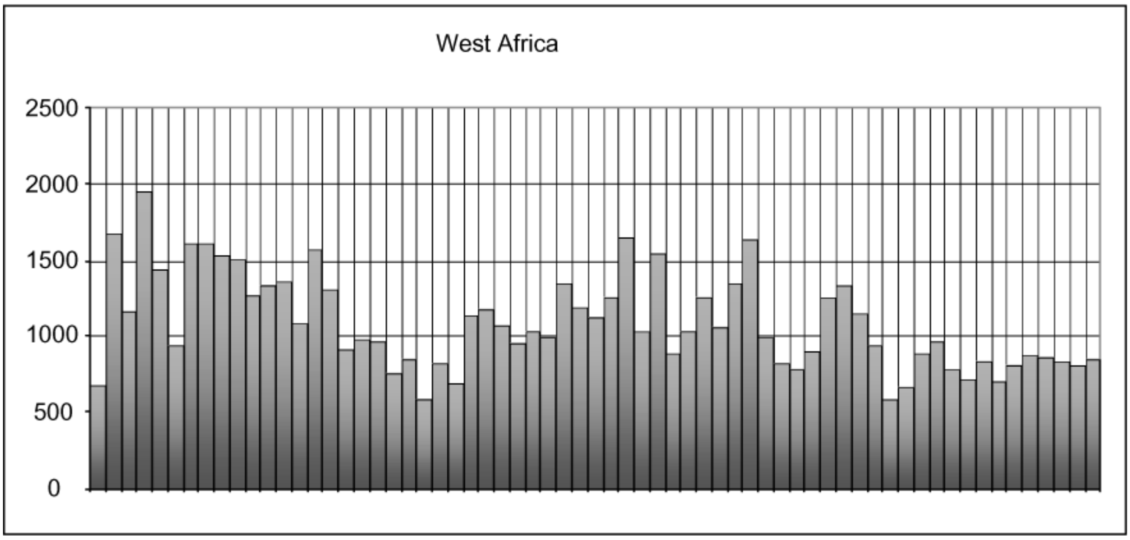


Figure 9. Variations in the annual internal and external natural water resources, from 1921 to 1985, within the subregions of North Africa and West Africa, from I. Shiklomanov (1998)





Such evaluations have not been made in the countries of the Sahel and North East Africa where their appropriateness has only been felt up until now because of the still generally low demand on resources. Medium-term plans aim for the most part to programme mobilizations of water needed, the limiting factors being the availability of investment capital rather than of physical resources. It is however in these countries that the 'exploitable resources' as a function of economic criteria would be most below natural resources, because of the very ill-assorted distribution of internal resources.

In spite of their relativity and their possible review, it is to these **mobilizable** resources that present demand and planned needs should be compared, knowing that the exploitability criteria are related to demand and to the degrees of tension that they exert henceforth on the resources. In other words, the mobilizable resources and demand will evolve in an interactive fashion. Whilst referring more explicitly than the natural resources to socio-economic criteria, the **exploitable** resources in a given region and at a given time reflect a relationship of supply/demand more than supply alone.

- Moreover, geopolitical constraints may also limit the 'availability' of internal resources for all countries with bordering neighbors downstream, whether or not such constraints have been conventionalized. This is particularly the case with respect to all countries that are 'landlocked,' that is, without any maritime borders, whose resources are simultaneously the external resources for their neighbors. This is evidently the case for all transboundary rivers whose outflow may be subject to sharing (the Nile) or constraint; it is also the case with respect to a basin that is endoreic with a terminal lake semi-closed and divided among several countries, such as is the case with respect to Chad: two countries, Niger and Nigeria, reaching the Chari basin resource only by way of Lake Chad.
- In the case of external resources (type 2), the resources to be defined and managed are less the theoretical 'natural' discharge than the potential discharge determined by the distributions of rights or of fluvial flow across borders, taking into account, among other things, the flow reserved for a down stream country (case of Sudan and Egypt). Only these real external resources should be added to the internal resources in order to define the total resources to be compared to demand (cf. Table 10).
- Concerning non-renewable resources (type 3), destined for storage management, evaluation of their exploitability again depends on physical conditions (aquifer discharge capacity and long-term behaviour of exploited aquifers) and technicoeconomic criteria of users, but also on the exploitation strategies chosen, notably to reach desired production durations while keeping unit production costs below the acceptable maximum. The exploitability criteria are thus subject to usage objectives and distribution of costs (rates of subsidy) set by economic policy.

Table 8. Matrix of transboundary exchanges of water within the OSS region

	Receiving countries / Transmitting countries	OSS countries																				Neighboring countries										
		Algeria	Burkina Faso	Djibouti	Egypt	Eritrea	Ethiopia	Gambia	Guinea-Bissau	Kenya	Libya	Mali	Morocco	Mauritania	Niger	Uganda	Senegal	Somalia	Sudan	Chad	Tunisia	Benin	Cameroon	D. R. Congo	Côte d'Ivoire	Ghana	Guinea	Nigeria	Central Afr Rep.	Tanzaina	Togo	Total emitted
OSS countries	Argelia										0	?		0	?						0,31											0,31
	Burkina Faso											?			1,3							0			1,3	8,7						12,5
	Djibouti				0	0												0														0
	Egypt																		0													0
	Eritrea			0			0,1												2,1													2,2
	Ethiopia			0		0				10	0							7	80													97
	Gambia																0															0
	Guinea-Bissau																0															0
	Kenya						0									8,4		0,5	0											?		8,9
	Libya	0			?										0				0	?	0											?
	Mali		0											11	30		11								0		0					52
	Morocco																															
	Mauritania	0										?	?				0															
	Niger	0	0								0									0		0						32,6				32,6
	Uganda									?									37					0						0		37
	Senegal							5	0,4			0		0																		5,4
	Somalia			0			0			0																						0
	Sudan				85						0																					85
	Chad										?								?													4
	Tunisia																															
Neighboring countries	Benin																															
	Cameroon																			4,7												
	D. R. Congo															2			0													
	Côte d'd'Ivoire		0									6																				
	Ghana		0																													
	Guinea								15			53					2,17															
	Nigeria														0,2					0												
	Central Afr. Rep.																		0	23,3												
	Tanzania									0						10,7																
	Togo		0																													
	Total received	0,39	0	0	85	0	0,1	5	15,4	10	0	59	?	11	31,5	21,1	13,17	7,5	119,1	28	0,31											

Notes:

- Ethiopia – Djibouti: saltwater not taken into account
- Kenya and Tanzania - Uganda: *via* Lake Victoria
- Mali – Mauritania and Senegal: river Senegal divided ½ and ½

Source: FAO/AQUASTAT 2001

This typology of water resources enables schematic classification of the different countries of the region according to predominant resource structures and the specific management constraints determined by them, without minimizing other types of resources in certain areas of these countries.

Table 7. Classification of OSS countries, according to their resources

(1) Predominance of renewable internal resources		*(2) Predominance of external fluvial resources (* plus down-stream constraint)*	*(3) Predominance of non- renewable internal resources*
*No down-stream reserve constraint (*except locally)*	*With down stream reserve constraint (formal or not)*		
Algeria*	Burkina Faso	Djibouti	Libya
Cape Verde	Ethiopia	Egypt	
Djibouti	Mali	Gambia	
Eritrea	Uganda	Guinea-Bissau	
Kenya*		Mauritania	
Morocco*		Niger*	
Senegal*		Sudan*	
Somalia		Chad	
Tunisia			

Cross-border river flow (Fig. 7), both between OSS countries and with others, renders most of the renewable water resources of the OSS region common to many countries, especially those of the Sahel sub-regions and the African Nile Basin in the NE. The largest river basins in the region – those of the Nile, Niger and Senegal Rivers – are shared. There is around 300 km^3/year of common resources to be shared, or 60% of the total resources in the region (cf. *ad ho*c map, OSS (1995)).

A run of numbers with these transboundary exchanges among all the OSS countries and their Southern neighbors, in matrix form, is presented in Table 8.

The common resources to be shared are approximately 300 km^3/year, that is, 60% of the total resources within the region

The non-renewable resources in the large aquifer reservoirs of the region are also for the most part shared by several countries.

This aspect of the geography of water resources in the region naturally has paramount geopolitical implications.

Box 1

Estimations of water resources

Available water resource statistics of the OSS countries contain discrepancies and must therefore be used with caution. The principal causes for discrepancies are:

- The differences in reference times used for calculating average values or of variability.
- The differences of approach in regionalization of flow based on hydraulic data, in basins poorly retaining locally formed flow, thus the different degrees of underestimation of the global flows produced.
- The summation of surface and groundwater flows estimated separately and non-additional, even occasionally the summation of spring discharge (counted as surface water discharge) and the discharge of the aquifer from which these springs emerge. All of these double-counts lead to overestimations.
- Discrepancies in the average discharge of cross-border rivers in the statistics of delivering and receiver countries, as well as different ways of taking into account border river discharge.
- The unwarranted summation of rather long term ‘exploitable potential’ or of aquifer discharge capacity (non-renewable resource) with flow (renewable resource).
- The inclusion, in certain cases, of ‘secondary’ resources (return of water after it has been used, notably of water used for irrigation) in primary natural resource figures.
- The correction of estimations, usually increasing, due to advanced knowledge. Thus, for example, for the three Maghreb countries, the estimated average global flow has increased by 26% in 20 years, going from 38 km^3/year in 1970 to 46 km^3/year in 1990; this estimation has then stabilized at 49 km^3/year up to the present.

Despite attempts to check validity and verify available data, the synthesis tables can lack homogeneity and comparatively.

1.3 Quantitative data: large discrepancies

The figures for average discharge of the renewable, internal and external, natural resources of each country convey only imperfectly this structural diversity and, consequently, the inequalities of controllability and exploitability of these physical resources, rendering comparison of total or per capita estimations difficult. The principal macro-hydrological data on natural water resources for each of the countries and sub-regions of the OSS region, selected primarily by compilation of the most recent national documents, supplemented by data on the potential external resources, are given here (Table 2). The data in this table occasionally differ somewhat from those presented in previous reports whose sources are not coherent. These discrepancies do not however affect the orders of magnitude. Without discussing here the question of quantitative estimation of national water resources, despite its importance, certain observations are made in Box 1.

The analysis of these globalized quantitative data per country reveals large differences in:

- The natural or potential resources of each country, ranging from a few hundred million (Cape Verde, Djibouti, Libya) to 100 billion m^3/year (Mali, Ethiopia), 3 countries having more than 50 thousand million (Egypt, Sudan, Uganda).
- Per capita resources (Fig. 2) ranging from approximately 100 (Libya) to more than 25,000 m^3/year (Guinea Bissau).
- The degree of independence (proportion of total resources which are internal) which varies from 2% (Egypt) to 100%. Six countries have external resources exceeding their internal resources, occasionally by a substantial amount (Chad, Egypt, Gambia, Mauritania, Niger, Somalia and Sudan).

A significant portion of these external resources, those of the Sahel countries essentially, originate from countries other than those belonging to the OSS: West African coastal countries, at approximately 50 km^3/year (or 50 billion m^3/year).

Evidently, these global, average assessment figures for flows by country describe much too summarily the natural resources, notably, the internal resources, by evening out the strong differences in internal distribution, as well as distributions during periods of seasonal and interannual variations. On the other hand, the space-time flows, evidently, are as important as their globalization for the purpose of characterizing the resources quantitatively.

The first significant complement would consist of combining the assessment figures of annual averages with those interannual variabilities or annual inputs of specified frequency, especially those 'guaranteed' to occur 9 years out of every 10 years or 19 years out of every 20 years – in other words, those for the dry year out of every ten or twenty years, calculating beginning with the historical multiannual trends, such as those constructed by Shiklomanov, *supra*.

For example:

Table 9. Internal inputs of some OSS countries, with differentiation by average year and dry year in tenth frequency

	Internal input (km^3/year)	
Country	*Average year*	*Dry year in tenth frequency*
Morocco	29	6.3
Tunisia	3.52	0.97
Mali	39.6	22.6
Niger	2.33	1.2
Senegal	21.4	13.4
Sudan	34.6	22.3
Chad	10.4	8.4
Gambia	3.96	2.26

The global indicators brought together assembled in Table 2, fail to show less significant differences among countries.

Creating slightly arbitrary 'sub-regions' reveals significant differences:

- The Maghreb has the fewest resources, on the average less than 1000 m^3/year per inhabitant, but they are essentially internal, with a notable part of non-renewable resources in the Sahara area.
- The Sahel countries are for the most part richer in water (nearly 4,000 m^3/year per inhabitant on the average, except for Cape Verde) due essentially to the fact that they have relatively small populations but also since their southern part lies within the more humid Sudanese zone and they are replenished by significant external resources. However, these resources, concentrated in some major valleys (Senegal, Niger, Chari) are very unevenly distributed, and global indicators mask large internal differences.
- The countries of the Nile Basin and the 'Horn of Africa', much more populated (63% of the total population of all the countries of the OSS) have, despite the Nile and the extension of its high basin into a humid tropical zone (Lake Victoria), relatively low per capita resources (1,000 m^3/year on the average). These resources are for the most part autonomous, but are common to all of the countries in the Nile Basin (Ethiopia, Kenya, Uganda, Sudan, Egypt), and are a source of potential conflicts.

Table 10. Data on renewable water resources, by country and by subregion

Subregion and country	*Natural renewable water resources (average annual runoff, (km^3/year)*					*Average water resources per capita in the year 2000 [4], (m^3/year)*	*Water resources per capita in the year 2025 (according to average population figures projected by the UN (1998)) (m^3/year)*	*Rate of independence (internal flow/ total flow) (%)*	*Reference (cf. Bibliography)*
	Total flow natural and internal (surface and underground) [1]	*Tributary flow of border country*		*Total R: with actual external resource*	*Portion relatively stable included in the total (surface flow and flow underground)*				
		Natural [2]	*Actual* [3]						
Maghreb	49.75	0		49.75	9.6	663	466	100	
Algeria	16 [5]	0.2		16.2	2.7	515	348	99	180
Libya	0.6	0		0.6	0.4	107	69	100	187
Morocco	29	0		29	5	1,023	750	100	182, 135, 164
Tunisia	4.15 [5]	0.42		4.57	1.5	477	356	91	132, 171
Sahel	142.1	94.2		236.3	~50	4,171	2,223	60	
Burkina Faso	17.5	0		17.5	5	1,46	75	100	181
Cape Verde	0.3	0		0.3	0.1	698	448	100	154
Gambia	3	5		8	1	6,107	3,721	37.5	154
Guinea-Bissau	16	15.4		31.4	9	25,950	16,103	51	154, 186
Mali	60 [6]	~40	?	~100	13	8,905	4,695	60	154
Mauritania	0.4	11 [7]	?	11.4	1.5 [8]	4,270	2,390	3.5	154, 155
Niger	3.5 [15]	29	?	32.5	5	3,029	1,512	10.8	154
Senegal	26.4	13 [9]		39.4	7	4,156	2,354	67	154
Chad	15	~28		~43	8	5,621	3,091	35	154
The Nile Basin and Northeast Africa	215.1	19.2		234.3	~144 [11]	1,032	629	92	
Djibouti	0.3	2		2.3	0.2	3,594	2,233	13	154, 155
Egypt	1.8	85	56.5 [10]	R 58.3	55.8 [11]	R 851	R 610	2	60, 130, 155
Eritrea	2.8	6		8.8	~1	2,286	1,317	32	154, 155
Ethiopia	110	0		110	30	1,758	953	100	125, 154
Kenya	20.2	~10		»30	~5	997	718	67	154
Uganda	39	27		66	~30	3,030	1,485	59	154
Somalia	6	7.5		13.5	~2	1,537	636	44	154
Sudan	35	119 [13]	34.5 [12]	(nat. 154) [14] R 69.5	~20	R 2,357	R 1,502	nat. 22.7 R50	154
Rounded total	407	113		520	204	1,450	887	78	

Notes on Table 10

(1) Estimation excluding, to the extent possible, all double counting.

(2) Flows partially adding to the level of the sub-regions due to flow between countries. The figures for the sub-regions do not overlap.

(3) Real flow according to a share of right or fact, taking into account flow to be reserved for a down-stream country (the case of Mali and Sudan).

(4) Based on UN (1998) demographic statistics and estimations. Related to the actual potential resources when they are different from natural resources.

(5) Excluding exploitation potential of non-renewable resources occasionally included in national statistics.

(6) Of which 55 km^3/year is groundwater, according to project study PNUD MLI/84/005 (1989). This calculated mean discharge appears however to be overestimated and is in any case greater than the estimated 16 km^3/year of groundwater flowing into surface streams.

(7) 50% of the average discharge of the Senegal River which is a border (arbitrary hypothesis): 11 km^3/year.

(8) Not taking into account the regulation of the Senegal river by the Manantali Dam.

(9) Including 50% of the average discharge of the Senegal River (arbitrary hypothesis, i.e. 11 km^3/year, plus the Gambia River 2 km^3/year).

(10) Including 55.5 km^3/year: part of the regularised Nile flow allocated to Egypt by treaty.

(11) Taking into account the regularized Nile at Assouan.

(12) Difference between the natural flows (100) and the portion of the flow adjusted stabilized by the Nile allocated to Egypt (55.5 km^3/year) and average losses by evaporation of the Assouan Dam (10 km^3/yr). Internal losses by evaporation in the marshes not included.

(13) Including 117.5 in the Nile basin: Blue Nile and tributaries (Ethiopia) 90.5; White Nile (Uganda) 27.

(14) These total natural supplies include the part lost by evaporation, around 50 km^3/year.

(15) Including 2.5 of ‘ground water flow’ and 1 of surface flow according to the master plan (Sept. 1993).

Table 11. Population and internal and external renewable resources, total and per capita, for each subregion

OSS Subregions	*Maghreb, North Africa*	*Sahel, West Africa*	*Nile Basin and East Africa*
Area (millions of km^2)	5,015	5,343	6,207
Population in the year 2000 (millions of inhabitants and %)	75.01 (21%)	56.65 (16%)	226.97 (63%)
Average internal natural renewable resources (km^3/year)	49.75 (12%)	142.1 (35%)	215.1 (53%)
External resources (km^3/year)	0	94	19
Total resources per capita in the year 2000 (m^3/year per capita)	663	4,171	1,032
Population in the year 2025, according to average projections from the UN (millions of inhabitants and %)	106.8 (18%)	106.3 (18%)	372.4 (64%)
Total resources per capita in the year 2025 (m^3/year per capita)	466	2,223	625

These figures do not take into account the non-renewable resources, which are paramount for the countries where type (3) is predominant but must only be estimated strictly in terms of exploitable stock and not of flow. The statistics of certain countries add the projected annual long-term discharge capacity to the renewable resources, but this presentation which combines temporary flows and permanent flows is not pertinent and creates confusion. Whether they are expressed in volume of reserve considered to be extractable or in capacity of annual mean production relative to a fixed duration, the non-renewable resources must be given separately. Table 12 gives data on this subject, from different sources, apparently not homogeneous.

Table 12. Data on the non-renewable resources

Country	*Volume of theoretical or estimated 'exploitable' (1) reserves (km^3)*	*Exploitable potential, relatively long term (average annual discharge capacity)*		*References (cf. Bibliography)*
		Year of reference	*km^3/year*	
Algeria	1,500	?	5	[49], [39], [74]
Libya	4,000			[49]
		?	2.8 (2)	[76]
		?	3.9	[82]
		2025	~16 (9)	[187]
Morocco (3)	3	–	–	
Tunisia	1,700		49	[49]
			~1	[132], [171]
Mali (4)	80–190 (5)	–	–	
	2,000	–	–	
	~2,700 (6)	–	–	[119]
Mauritania	400	–	–	[49]
Niger	260–550 (5)	–	–	[124]
	~2,000 (7)	–	–	
	2,500 (8)	–	–	
Senegal (4)	80–180	–	–	[84]
Chad (4)	170–340 (5)	–	–	[85]
Egypt	6,000	–	–	[49]
Sudan	40	–	–	[49]

Notes on Table 12

(1) Estimations based on non-homogeneous methods and criteria of exploitability.
(2) Including 1.6 to 2.2 km^3/year up to 2025 (*Great Man Made River Project*).
(3) Laayoune-Dakhla Basin. Calculation with S of confined aquifer.
(4) All sedimentary aquifers, except those of the Quaternary and Plio-Quaternary.
(5) Calculations based on effective porosities (unconfined aquifers) and defined generalized maximum drawdown: 10 m in Mali, 10 m or max. depth of 100 m in Niger, max. depth of 100 m in Senegal, max. drawdown of 5 to 10 m in Chad.
(6) Theoretical total resource.
(7) Western part of the sedimentary basin only.
(8) Estimation based on effective porosities and generalisation for 100 m of drawdown of the mobilisable volumes in each reservoir calculated for 1 m of drawdown.
(9) Planned development.

In sum, flow irregularities, making water control more difficult, and deficiencies in water quality often aggravate the scarcity of resources in countries that are the most deprived (namely, the arid zone). The climate's aridity brings two consequences to water quality: a relative frequent occurrence of surface and underground saltwaters, in particular, with respect to permanent waters; and a weakness in the portion of steady flows thereby causing it to be all the more susceptible to pollution. Therefore, the management of water quality forms an integral part of the management of water resources.

1.4 Comparative look at the southernmost countries

The OSS region has only a terrestrial boundary in the South where it is bordered by countries whose climatic and hydrological conditions are quite different and which supply it with, as we have seen, a great part of its resources in external waters: more than 100 billion m^3/year, on average.

Thus, an outline view of the water resources of the bordering countries, from Guinea to Tanzania, is evidently instructive (see Table 13).

This comparative panorama view is based largely on monographic works that the FAO has dedicated to Africa [154, 156].

If the water resources of this group of tropic and equatorial countries, taken as a whole, are quite abundant, with almost 2.4 billion m^3 annually on average (that is, six times more than the resources of the OSS countries), then, nevertheless, strong contrasts among them are presented, as follows:

- two superabundant resource poles: Liberia, Guinea and Sierra Leone from a part where the natural resources per capita exceeds 30,000 m^3/year and even 70,000 in Liberia; Central African Republic, Democratic Republic of the Congo and Cameroon, on the other hand, with resources running anywhere from 20,000 to 40,000 m^3/year per capita;
- an area of modest resources in the center of West Africa (especially, Ghana and Togo), where the resources drop below 3,000 m^3/year per capita, as in the case of Nigeria (especially due to its large population);
- two countries with very weak resources at less than 1,000 m^3/year per capita: Burundi and Rwanda.

Table 13. Data for natural renewable water resources in countries bordering the OSS region

Countries (from West to East)	*Renewable water resources (average annual runoff) (km^3/year)*				*Water resources per capita in the year 2000 (m^3/year)*	*Water resources per capita in the year 2025 (according to average population projections by the UN (1998)) (m^3/year)*	*Rate of independence (internal flow/ total flow) (%)*
	Total internal natural flow (surface and underground)	*Natural tributary flow from the neighboring country*	*Total*	*Of which surface input goes into the neighboring country*			
Guinea	226	0	226	–100 [a]	30,417	18,080	100
Sierra Leone	160	0	160	0	33,000	19,802	100
Liberia	200	32	232	0	73,650	35,045	86
Côte d'Ivoire	76.7	1	77.7	–6 [b]	5,253	3,328	99
Ghana	30.3	22.9	53.2	0	2,632	1,442	57
Togo	11.5	0.5	12	–7 [c]	2,592	1,415	96
Benin	10.3	15.5	25.8	0	4,230	2,322	40
Nigeria	221	59	280	0.2 [d]	2,511	1,530	79
Cameroon	268	12.5	280.5	–40 [e]	18,600	10,593	95
Central African Rep.	141	–	141	141 [f]	39,058	24,737	100
Congo	935	84	1,019	0	19,730	9,724	92
Rwanda	6.3	0	6.3	6.3 [g]	815	507	100
Burundi	3.6	0	3.6	1.5 [g]	538	311	100
Tanzania	80	9	89	10.7 [g]	2,655	1,537	90

Notes:

a: of which 40 ' Mali, 15 ' Guinea-Bissau, 32 ' Liberia, 2 ' Senegal
b.: to Mali
c: to Ghand: to Niger
e: to Nigeria, Chad and Congo
f: to Chad and Congo
g: to Uganda, via Lake Victoria

Source: FAO/AQUASTAT 1995 [154].

2 Present uses: situation and consequences

The knowledge of water usage in the OSS region, like in many other regions of the world, is extremely approximate, subject to wide areas of shade and, to say the least, unequal depending on the country. In Box 2 the difficulties and the causes of uncertainty are given.

On the basis of reports already mentioned and the most recent documents given in the reference list, the principal macroscopic numerical data of which are given in Table 5, an effort will be made to highlight the predominant facts which determine the management of water in this region.

Global quantity and geography of uses

In spite of the lack of synchronicity and the unequal timings of the national estimations that are available (which vary between the latter years of the 1980s and the end of the 1990s), one can estimate that the total amounts of water used within the region as a whole is currently around 120 billion m^3/year. These amounts are quite unevenly distributed: 76% is used in the Nile Basin and in Northeast Africa; 70% is used in the Nile's only valley – Egypt and Sudan; 19% is used in the Maghreb; and only 5% is used in the Sahel countries. This disparity obviously signifies heavy irrigation in the Nile Valley.Towards the end of the 1980's, the total quantity of water used in the entire region was approximately 100 billion m^3/year. The quantities are very unevenly distributed: 80% is used in the Nile Basin and NE Africa – 70% in the valley of the Nile: Egypt and Sudan alone, 25% in the Maghreb and only 5% in the Sahel countries. This disparity reveals the preponderant impact of irrigation in the Nile valley.

In comparison, data on the uses of water in African countries bordering the OSS, as we have seen with respect to the resources, are presented in Table 15.

As a whole, the contemporary demands for water in these countries are around 10 billion m^3/year (half of which is in Nigeria and in Tanzania), in other words, less than one-tenth of that for the OSS countries. The slight agricultural use, combined with a mediocre supply of drinking water to the urban and rural populations, are the cause. The demand for water per capita, for all uses, almost everywhere, is less than 100 m^3/year, often 50 m^3/year, and barely 10 m^3/year with respect to Congo.

Recent trends

In so much as historical data enables us to judge trends or the current evolution of demand, the increase in these has accelerated during the last 50 years, and slowed down slightly in some countries however because of a lack of supply or delay in installations. This global increase is due more to that of populations than to an increase in per capita demand. In the northern Sahara countries for which some historical data were available (Table 16), it appears that these unitary demands have tended to decrease where they are the highest (Egypt, Sudan, Morocco), and conversely have tended to increase where they are relatively low (Algeria, Tunisia). During the 1980s, at least, Libya presented a special case, with strong growth between 1985 and 1990 (over 1,000 m^3/year), apparently followed by a decrease (see Fig. 10).

Box 2

Knowledge of water uses

A precise and complete knowledge of the present uses of water by all of the economic sectors is necessary if we are to determine future demand and are required for resource management. This knowledge is however still imperfect and encounters various difficulties which are not specific to the OSS region.

- The available statistics on demand and pumping are based more on estimations than on measurements. They are affected by varied uncertainties, which are prominent especially in the agricultural sector. They do not always distinguish clearly between the supply requested by users and the quantities pumped from the resources or water 'production', in the countries where these do not coincide..
- There are few historical data and they lack synchronism: they do not rest solely upon these consistent, successive estimations. They reflect as much the evolution of the level of knowledge (precision and validity of figures) as that of the real variables themselves, which makes them difficult to compare (Table 5). Moreover, dates of the statistics are not always given in the sources, which frequently refer to the 'present' without specifying whether this refers to the year of publication or a previous date.
- Water consumed by water works (evaporation in storage tanks) not generally attributable to specific usage sectors, is rarely considered. The same is true of losses by evaporation in irrigation water transport systems, included in certain estimations and not in others (in Egypt, for example).
- There is occasionally confusion between the amounts of water which are actually requested and used and the resource allocations, notably in the agricultural sector. That may explain differences in the macro-economic statistics (significant in some cases) for close dates, and the apparent inconsistencies in the historical data) within a given country.
- The distribution of the sectorial demands depending on the source of the supply is frequently omitted.
- Data on the return flow and total consumption, including in the dams, are rare.
- The impact of uses, notably of discharges, are incompletely described, quantified and evaluated.
- The macro-economic statistics on the weight of the water sector (public and private expense) in the national economies are rarely available

Efforts to improve the knowledge of usage are particularly advisable in the countries where the management of water must and should increasingly combine the management of demand with that of the resources.

Table 14. The uses of water (years 1985 to 1995, for most of the countries)

Subregion and country	Value date	Demand for water (a)					Withdrawals		Other sources of supply					
			Proportions of use by sector											
		1 Total (km^3/year)	2 Com-munities (drinking water) (%)	3 Agri-culture (irrigation) (%)	4 Industries self-supplied and energy (%)	5 Demand per capita (b) (m^3/year)	6 Total (km^3/year)	7 That which is on the non-renewable resources (km^3/year)	8 desali-nation of seawater (km^3/year)	9 Used water and reused drainage water (km^3/year)	10 Rate of exploitation from renewable resources (6/natural or actual resources) (%)	11 Estimated final con-sumption (unrestored portions of amounts withdrawn) (km^3/year)	12 Rate of final consumption of renewable resources (11/real natural resources) (%)	13 References (cf. Bibliography)
Maghreb	**1995–98**	**22.7**	**13**	**82**	**5**	**370**	**22.5**	**3.63**	**–0.14**	**0.53**	**86**	**–20**	**40**	
Algeria	1990	4.5	25	60	15	180	–4	–0.4	0.06	–0.4	25	3.8	17	[39]
Libya	1995	3.9	8.6	90	1.4	809	3.65	3	–0.07	0.07	180	3.5	158	[76], [155]
Morocco	1996	11.5	9.6	88.7	1.7	420	11.5		(0.0034)	0.05	47	9.6	33	DRPE (1999)
Tunisia	1996	2.83	13	86	1	248	2.83	0.23	0.008	0.01	57	2.7	37	DGRE(1998)
Sahel	**1985–96**	**–6**	**11**	**87**	**–**	**–6**				**2.5**	**–4.3**	**1.8**		
Burkina Faso	1996	0.64	45	55 (f)	0	40	0.64	0	0	0	3.6	0.5	0.35	[181]
Cape Verde	1990	0.026	12	88	0	70	0.026	0	0	0	8.6	0.02	15	[154]
Gambia	1962	0.02	7	93		29	0.02	0	0	0	0.25	0.015	0.05	[154]
Guinea-Bissau	1991	0.017	59	35	6	17	0.017	0	0	0	0.05	0.005	0.02	[154]
Mali	1990	1.36	4	96	0	160	1.36	0	0	0	1.4	–1.0	1	[154]
Mauritania	1985	1.6	6	94		865	1.6			0	14	~1.3	18	[82], [154]
Niger	1988–93	0.5	15.5	82 (f)	2.5	67	0.5		0	0	1.5	0.4	0.01	[136], [154]
Senegal	1992–93	1.36	5	92	3	200	1.36	0.001	0	0	3.5	1.0	3	[130], [154]
Chad	1990	0.16	15	85 (f)	0	32	0.16		0	0	0.4	0.1	0.2	[130]
The Nile Basin and Northeast Africa	**1985–96**	**–90**	**–7**	**–84**	**–9**	**–**	**78**				**~33**	**56 (d)**	**–24**	
Djibouti	1985	0.075	13	87		208	0.075				3.3	0.07	23	[49]
Egypt	1995–96	66	7	82	11	1,064	53 (c)		–0.003	0.7 (g)	R 92	38	R 88	[140]
Eritrea and Ethiopia (e)	1987	2.21	11	86	3	48	2.21	0	0	0	~	1.5	1.3	[130]
Kenya	1990	2.05	19.5	76.5	4	87	2.05	0	0	0	~7	~1.5	4.7	[154]
Uganda	1970	0.2	42	58	0	20	0.2	0	0	0	0.3	0.1	0.15	[130], [154]
Somalia	1987	0.81	3	97	0	99	0.81	0	0	0	6	0.7	6	[82], [130], [154]
Sudan	1995	17.8	4.5	94.5	1	651	17.8	0	0	0	R 26	~14	R –18	[154]
Total (rounded off)	**–**	**~120**	**8**	**84**	**8**		**~104.5**	**~3.7**			**20**	**~70**	**~13.5**	

DRPE: Directeur de la Recherche et de la Planification de l'Eau.
DGRE: Direction Générale des Ressources en Eau de Tunisie.
Notes:
- (a) Including, in principle, the losses during supply and distribution
- (b) Related to the population from the year of estimated withdrawal.
- (c) Not including the flow reserved for navigation (1.8 km3/year), or the losses by evaporation in the Assouan Dam. Including the losses by evaporation of the irrigation system (2 km3/year).
- (d) Including drainage water flowing into the sea.
- (e) Including losses by evaporation of the Assouan Dam (10 km3/year on average).
- (f) Eritrea and Ethiopia non-separable in available data.
- (g) Plus water in the amount of 12.6 km3/year from drainage.

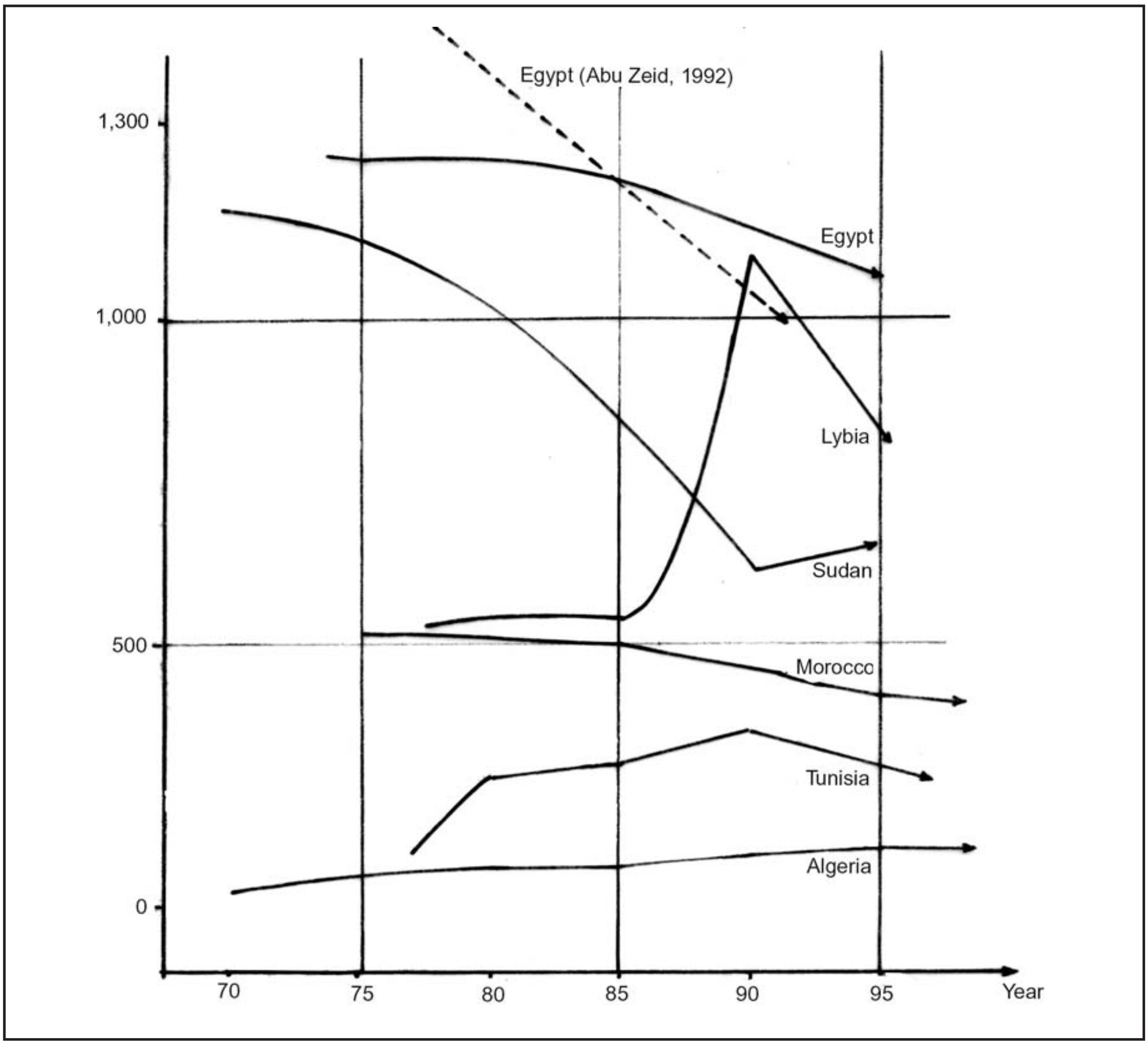
Table 15. Contemporary use of water in the African countries bordering the region

			Demand for water [a]			
			Portions of use sectors			
Country	*Value date*	*1 Total (km^3/year)*	*2 Communities (drinking water) (%)*	*3 Agriculture (ilrrigation) (%)*	*4 Industries self-supplied and energy (%)*	*5 Demand per capita [b] (m^3/year)*
Guinea	1987	0.74	10	87	3	139
Sierra Leone	1987	0.37	7	89	4	96
Liberia	1987	0.13	27	60	13	55
Côte d'Ivoire	1987	0.71	22	67	11	64
Ghana	1970	0.30	35	52	13	35
Togo	1987	0.09	62	25	13	28
Benin	1994	0.145	23	67	10	28
Nigeria	1990	4.0	31	54	15	46
Cameroon	1987	0.40	46	35	19	31
Central Afr. Rep.	1987	0.07	21	74	5	26
Dem. Rep. of Congo	1990–1995	0.357	60	23	17	9
Rwanda	1993	0.768	5	94	1	102
Burundi	1987	0.10	36	64	0	20
Tanzania	1970–1994	1.16	9	90	1	40

Notes:
a) Normally including losses from adductions and distributions.
b) Relating to the population in the year of the estimation of demand (= deductions).

Source: FAO (1995) (AQUASTAT), except for Nigeria: World Resources Institute (WRI) (2000).

Figure 10. Trends in the demand for water per capita in certain OSS countries



Differences in per capita demand

For all uses combined, the present per capita water demand in the region, approximately 380 m^3/year, is for the most part well below the world average (600 to 700 m^3/year). Nevertheless, demand is very unequal depending on the country (Fig. 11), exceeding 1,000 m^3/year in Egypt and Libya and dropping to less than 50 m^3/year in several Sahel countries (range varying in the report from 1 to 50). This difference is due more to the climatic differences which makes irrigation less necessary for agro-alimentary production, thus different degrees of development of irrigation, in some areas, than to differences in the level of socio-economic development. The countries with highly-developed intensive irrigation (Egypt, Libya, Mauritania, Sudan) use greater quantities of water per inhabitant. The relatively low demand per inhabitant in other countries corresponds to a lower development of irrigation but may also be due in certain countries to the delay in hydraulic equipment (both for drink water supply and for irrigation: Algeria, Sahel countries, Ethiopia and SE Africa).

Table 16. Evolution of the estimated demand for water per capita in some countries within the OSS region, during the last three decades

Country	*Value date*	*Total demand for water (km³/year)*	*Demand for water per capita (m³/year)*	*References*
Algeria	1970	~2	135	UN 1971
	1975	~2.5		
	1980	3.0	161	INRH 1986, Blue Plan 1987, Sem. Alger. 1990, WRI 1992–93
	1980	3.38		INRH 1986, cited by J. J. Perennes 1986
	1980–85	3.5		ACSAD 1988
	1985	3.34–3.5	160	M. Shahin 1989 (forecast)
	1990	4.5	180	T. Hadji, S. Zeglache, Conf. Med. Rome 1992
	1999	5.7	188	B. Benguedach 1999 (forecast)
Burkina Faso	1987–1992	0.15–0.38	20–40	WRI 1992–93
	1996	0.64	40	FAO/AQUASTAT 1995
				Ministry of Environment and Water 1996
Egypt	1972	~43	1,236	Iz. Kinawy 1976
	1974	51.4		IC.I.D. 1981 (with losses from irrigation), SAMAHA 1979
	1976	~45		K. Hefny, UN 1977
	1980–85	59.5		ROSTAS-ACSAD 1988
	1985	55.13–59.5		M. Shahin 1980 (forecast)
	1985	56.4	1,202	ABD El Rahman/Blue Plan 1987, WRI 1988–89 and 1992–93
	1985	52.9		Sem. Alger 1990
	1987–88	55.5		El Kady/IWRA Ottawa 1988
	1990	59.4	1,141	M. Abu-Zeid/IWRA Rabat 1991
	1990	59.2	1,133	Water Master Plan/ALECSO Cairo 1992, ROSTAS-ACSAD 1993
	1995–96	66	1,064	AMER, Conf. Bari 1999
Libya	1974	1.2	492	GWA 1974
	1977–78	1.47		GWA 1978, Ph. PALLAS 1979
	1985	2.0–2.11		M. Shahin 1989 (forecast)
	1985	2.12	589	ROSTAS-ACSAD 1988
	1985	2.62		UN-DTCD 1987
	1985	2.83		WRI 1992–93 (with desalination capacity)
	1990	4.76	1,087	O.M. Salem, Water Res. Dev. 1992, ALECSO Cairo 1992, ROSTAS-ACSAD 1993
	1994	4.6	880	FAO 1997
	1994–95	3.89	809	O. Salem/1997, FAO/AQUASTAT 1998
Morocco	1968	8		M. Combe 1969
	1972	8		Dir. Hydr. 1974, M. Combe 1974
	1975	~9	505	
	1980	10.05	516	N. Dinia 1980
	1985	11.0	501	WRI 1988–89 and 92–93 Sem. Alger 1990
	1990	10.9		ALECSO Cairo 1992, ROSTAS-ACSAD 1993
	1991	11.7	455	Conf. Med. Water, Rome 1992
	1991–92	11.04	436	FAO/AQUASTAT 1998
	1996	12		El Hebil, CMDD 1997
	1998	11.05	420	DGH-DRPE 1999
Mauritania	1978	0.73		A.Moulaye 1979, WRI 1988–89 and 92–93
	1985	1.52–1.66	865	M. Shahin 1989 (forecast)
Sudan	1970	~18.15	1,156	UN Water Conf. 1977
	1977	18.61	1,060	I.Y. Bannaga 1978, WRI 1988–89 and 92–93
	1985	13.96–14.11		ROSTAS-ACSAD 1988, M. Shahin 1989 (forecast)
	1990	7	615	International Conference Dublin 1992
	1991	15.5		ALECSO Cairo 1992, ROSTAS-ACSAD 1993
	1995	17.35	651	FAO 1995
		17.8		
Tunisia	1977	1.07	184	K. Alouini 1978
	~1980	1.9	297	ACSAD 1988
	1985	2.3		WRI 1988–89 and 1992–93/H. Zebidi 1986–87
	1985	2.28–2.48	319	M. Shahin 1989, Sem. Alger 1990
	1990	3.0	367	DGRE 1990
	1995	2.27	254	A.Hamdane, CMDD 1997
	1996	2.68	291	DGRE 1999
	1996	2.83	248	DGRE 1999

Figure 11. OSS countries classified according to their actual demands for water, per capita, for all uses (for the years 1985–95)

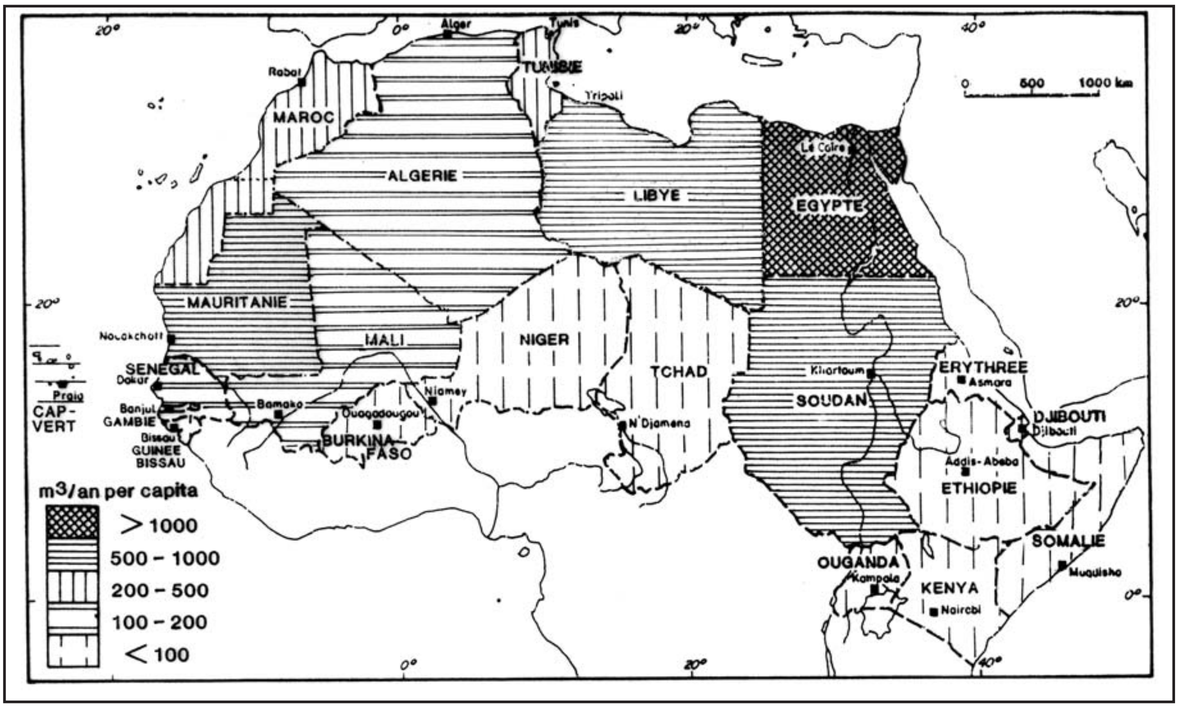
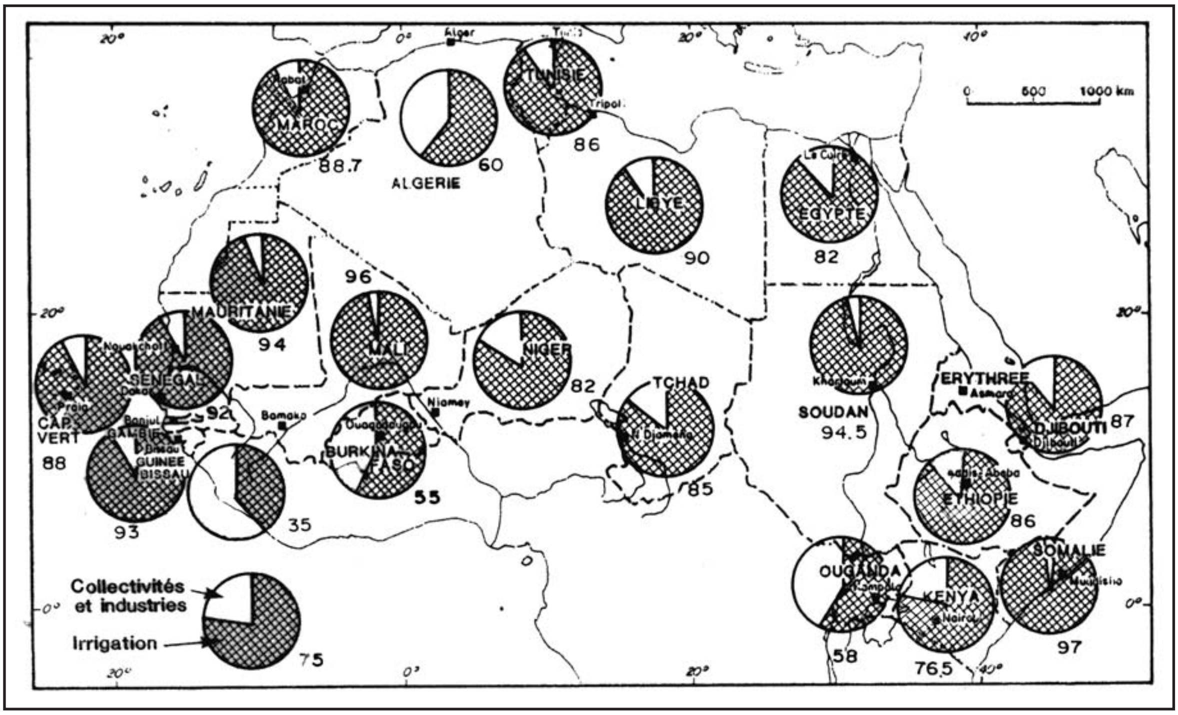


Figure 12. Proportions of present sectorial uses of water in OSS countries



Sectorial distribution

The structure of uses is quite uniform in the region with two major sectors:

- Irrigation, which is predominant everywhere, is often greater than 80% to 90% in nearly one country out of two.
  The total volume of water used at present in the region for irrigation would be about 90 thousand million m^3/year (86% of all water used), of which 72% would be in the Nile valley. Irrigation in Egypt and Sudan consumes approximately 60% of the total quantity of water used in the OSS region.
- Community drinking water supply, especially in urban areas, is everywhere below irrigation but is generally increasing more rapidly. It is primarily between these two sectors that conflicts of use risk arising. The industrial water demands are, on the other hand, minor and little dissociated from the demands for drinking water (except those of the mining sector, significant in some countries, such as Niger where, nevertheless, it is in recession). The energy sector (thermoelectric power stations) also uses small quantities of fresh water for cooling. With respect to hydroelectricity, which was a major objective of the 'first generation' modern hydraulic works (Egypt, the Maghreb ...), it is now second place as regards exploitation objectives of developments with numerous goals, after irrigation.

Total consumption

The predominance of irrigation leads to high rates of total consumption, which are amplified in certain cases by the possible reuse in sequential use structures (reuse of drainage water in the Nile valley, for example) and also by the coastal location of numerous urban areas where waste water is discharged into the sea (in particular, the Mediterranean coast but also the Atlantic (Dakar) or the Indian Ocean).

Efficiency

Efficiency is variable, and most often poor in irrigated agriculture (around 40 to 50% in gravitational irrigation). The output of urban distribution networks is rarely greater than 60 to 70%. The margin of possible increased efficiency, at costs lower than those of complementary mobilization or production of water, is great in most of the countries.

Pressures on resources: range of exploitation rates

The demand on natural resources varies a lot according to the sub-regions and the OSS countries. Generally it is high in the Maghreb and in the Nile basin and is still low, indeed minimal, in the Sahel, Eastern Africa and Egypt. The global volume of withdrawals is near to the average discharge of renewable resources in Egypt and in Tunisia, and exceeds it substantially in Libya due to intensive exploitation of non-renewable resources. Overpumping of groundwater from renewable resources in Algeria, Mauritania or Senegal may also increase the apparent exploitation rate, as well as the fact that part of the resources may be used several times (remobilized returns of water, notably in Egypt). On the other hand, in the Sahel countries and the 'Horn of Africa' demands on resources are still very low due to the lack of agricultural wells and urban and rural drinking water networks.

The exploitation rates (ratio of total withdrawals from renewable resources/average flow of these resource) of the OSS countries range from scarcely 1% to over 100% (Table 14, col. 10 and Fig. 13).

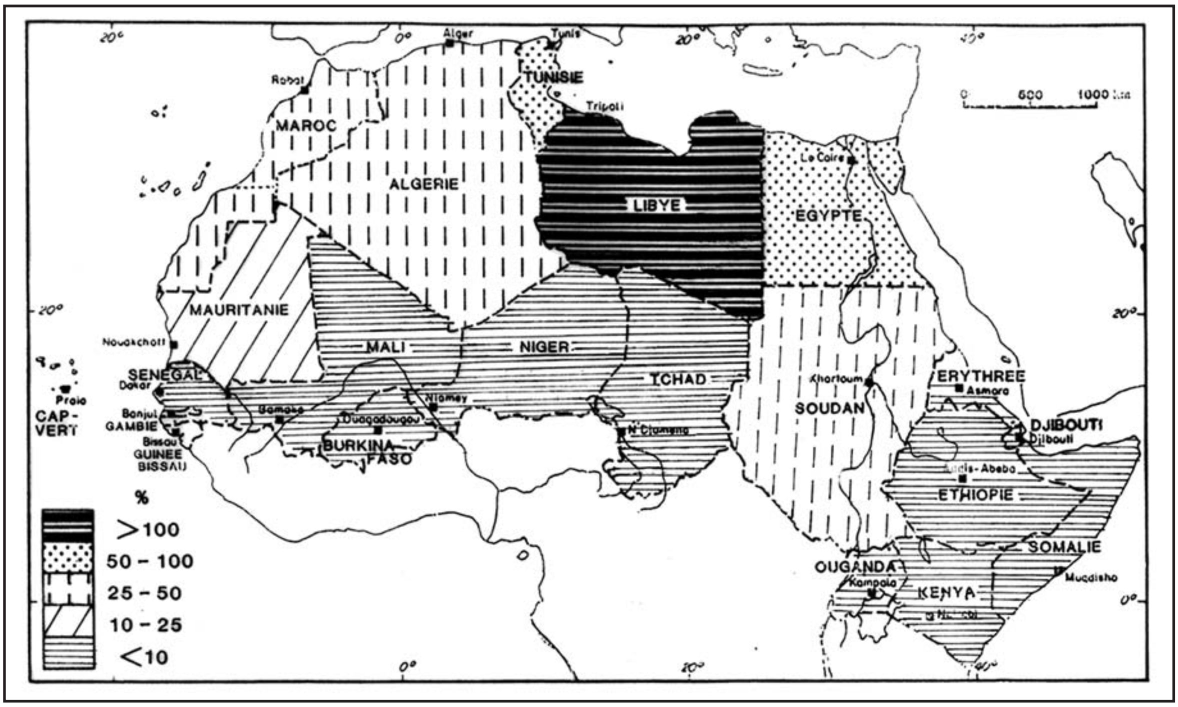
Naturally, this rate would be higher if reference were made to the only resources considered at present to be *exploitable,* in the countries where internal resources of type (1) predominate, such as those of the Maghreb:

Table 17. Current rate of the exploitation of renewable resources

Country	Current rate of exploitation related to renewable resources	
	Natural (%)	'Mobilizable'* (%)
Algeria	25	52
Morocco	47	57.5
Tunisia	57	72

* Noted in Ch. 1 (1.2).

Figure 13. Countries of the OSS region classified according to the current rate of exploitation of their natural or actual renewable water resources



Unequal development of water works

As shown by the differences in exploitation rates, water development, notably for the regulation of surface water, is still very unequally developed in the countries with predominant internal or external renewable resources. These hydraulic works for regulating water whose dams are the essential parts, are the most advanced in Egypt, followed by Morocco and Tunisia, and to a lesser degree Algeria, Sudan and Mali (development of the Senegal River). In the present state of hydraulic development, the performances for controlling water in different OSS countries are summarised in Table 18.

Table 18. Hydraulic installations: dams-reservoirs

Country	*Number of large and average-sized dams*	*Total capacity of the reservoirs (km^2)*	*Regulated or mobilized flow (km^3/year)*	*Rate of regulation (%)*
Algeria (1999)	44	4.15	2	14
Burkina Faso (1996)	8 (principal ones)	4.67		
Egypt	10	169	~74 [d]	84 [e]
Egypt's Assouan region		164		
Eritrea (1999)	2	0.04		
Libya (1998)	16	0.39	0.06	17
Mali (1992)	4			
Senegal River (Manantali)	1	11	9.5	43
Morocco (1997)	90	14.3	~7	55 [a]
Mauritania (1994)		0.9		
Niger (1990)		0.1 [c]		
Uganda (Owen Fall Dam) [g]	1	120		
Senegal (1994)	1	0.4		
Guiers Lake	–	1.2		
Sudan (2000)	4	8.8 [f]		
Tunisia (1998)	21	1.6	1.07 [c]	66 [a]/53 [b]

a. Related to mobilisable potential.
b. Related to natural flow.
c. Including small reservoirs and hill lakes.
d. Of which 55.5% is for Egypt.
e. Of which 12% is for the evaporation in Assouan Dam.
f. Initial capacities. The actual useful capacities are 5.7 km^3.
g. Regulation of the Nile by the Lake Victoria Dam.

In the northern countries the proportion of surface water resources still controllable are still great, in Morocco and especially in Algeria. Nevertheless, the costs of their mobilization will increase due to the decreasing output of hydraulic works still feasible. These proportions are much greater in the Sahel and in the Upper Nile Basin (Ethiopia, southern Sudan...) where developments may be not only resource regulators but also 'producers' by reducing losses by evaporation as already indicated (example of the Jonglei Canal under construction, in order to short circuit the inland delta of the Nile in southern Sudan).

Increase in 'waste-water resources'

In the countries with a high and increasing use of natural resources, the quantities of waste water increase likewise, offering 'secondary resources' whose volumes can occasionally be nearly as great as those of remaining 'primary' natural resources (increasingly difficult to mobilize). However, the output of treatment plants leaves much to be desired: it rarely exceeds 30% of the quantities of water distributed and is frequently lower than 20%, which limits the volumes of reusable waste water. In addition to urban waste water, drainage water, particularly abundant in Egypt, is also reusable and approximately 5 km^3/year is already being used.

In the countries of the northern Sahara, these unconventional water resources will increase in the future, in the face of diminishing exploitable natural availability. For example, according to projections cited by Khouri, 1991 [51], the production of collected waste water could reach, by the year 2000: 1,800 km^3/year in Egypt, 555 in Morocco and 227 in Tunisia. In these countries, the quantities of waste water effectively regenerated and available for reuse would currently (that is, the years 1995 or those close to that time) be 700 hm^3/year in Egypt, 70 hm^3/year in Libya, 120 hm^3/year in Tunisia (against a potential of 25 hm^3/year), and 50 hm^3/year at Morocco.. An increasing reuse of drainage water is also predicted by the Egyptian master plan: it could be 7.5 to 8 km^3/year after 2000 [134].

Diversification of sources of supply

It is in several north Sahara countries of the OSS region that the water supply sources are now the most diversified and the demands can be most distinguished from the withdrawals from traditional resources. To the mobilization of renewable, surface or ground resources, and in varied proportions according to the countries and already noticeable in several, can be added:

- the exploitation of non-renewable resources: this is the major source of supply in Libya (77% at present) and an already significant contribution (about 10%) in Algeria and Tunisia;
- the reuse of drainage water and waste water (Egypt, nearly 10%; Tunisia);
- the production of fresh water by desalination of brine or sea water, still very localized and rather experimental (Table 19 and Fig. 11).

Furthermore brine or salt water is occasionally used in several countries not only as raw material for producing fresh water, but also directly for certain uses or after mixing with fresher water (Tunisia...).

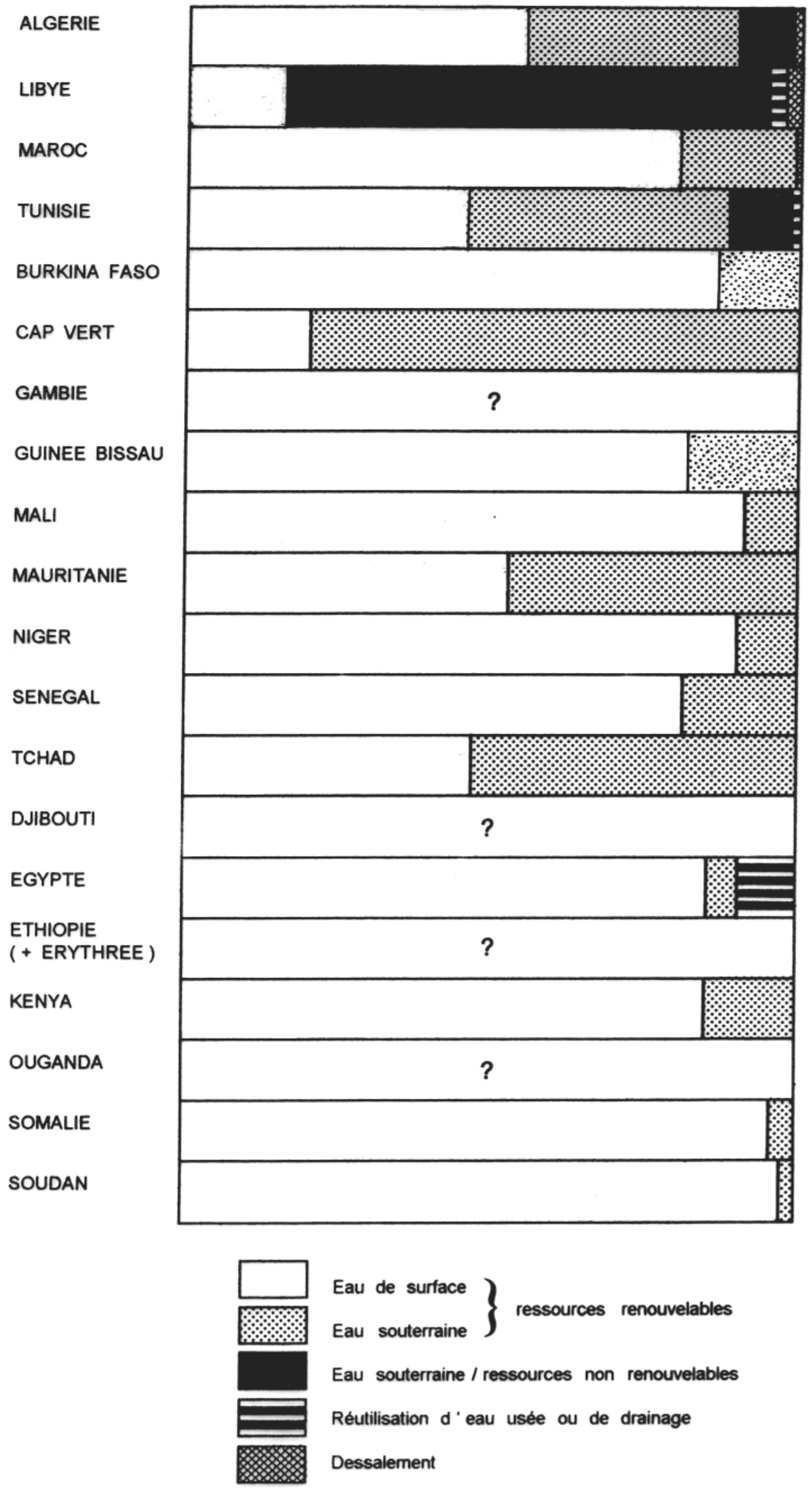
One part of the OSS region is now involved in new water economics, tending to disconnect itself partially from the cycle of natural water, first fruits of an evolution which will necessarily increase as the exploitation rates increase and the natural resources become scarcer per inhabitant: Maghreb, Egypt and the coastal nations of the Indian Ocean are the most given to this evolution in the 21st century.

Table 19. Current water supply sources (dates of Table 5) in % (base 100: col. 1 of table 5)

Country	*Surface water*	*Groundwater*	*Total*	*Exploitation of groundwater reserves Non-renewable resources*	*Reuse of waste- or drainage water*	*Desalination of brine or sea water*
Algeria	~50	~40	~90	~9	0	1
Libya	3	17	20	77	1.5	1.5
Morocco	79.6	20	99.6	*	0.4	*
Tunisia	40	50	90	8	1.5	* (0.004)
Burkina Faso	86	14	100			
Cape Verde	20	80	100			
Gambia			100			
Guinea-Bissau	~82	~18	100			
Mali	92	8	100			
Mauritania	53	47	100		0	0
Niger	91	9	100			
Senegal	82	18	100	*		
Chad	47	53	100			
Djibouti			100	0	0	0
Egypt	86.1	4.5	90.6	*	9.4	*
Ethiopia (with Eritrea)			100			
Kenya	~86	~4	100			
Uganda			100			
Somalia	96.5	3.5	100	0	0	0
Sudan	98	2	100	0	0	0

* Low value.

Figure 14. Proportions of current water supply sources (1985–90) in OSS countries (cf. Table 19)



Environmental impact

The negative impact of exploitation and use of water on the environment and more particularly the retrospective effects on resources, notably on water quality, is still relatively localized in most of the countries of the region, but is already noticeable. It is especially a question of:

- invasion of sea water in the excessively exploited coastal aquifers (frequent on the Mediterranean coast);
- effects of lack of water treatment in large urban areas;

Percentages of irrigated land affected by salination, cited in a *World Resources 1987* table (World Resources Institute):	
Algeria	10 to 15%
Egypt	30 to 40%
Senegal	10 to 15%
Sudan	< 20%

- effects of lack of drainage of irrigated perimeters: water and soil salination;
- pollution due to the lack of insulation of urban, industrial or mining waste disposal sites.

These various impacts are still unevenly inventoried and assessed in the region. Other external effects of exploitation or use of water threaten the environment:

- overgrazing favoured by ill-considered multiplication of pastoral water points has increased desertification;
- local subsidence may be the consequence of intensive groundwater pumping, with a significant drop in water tables (in the Sahara basins).

Economic aspects

Two essential elements characterize water economics in the OSS region, as in most 'developing' nations:

- Hydraulic and exploitation works to supply water to the different sectors fall for the most part outside of the market economy. Most of water used – notably for irrigation – is not commercial but is pumped directly by the individual users, public operators or collective users and distributors. Only a part of drinking water is commercial.
- The cost of control, treatment and distribution work (investment and operation are only more often than not very partially paid by the users, whether the water is directly pumped or commercial distributed, drinking water or irrigation water. Heavy subsidies render the costs actually borne and the price of commercial water much lower than its real cost, as shown by some figures here (for countries in the region) by Khouri (The World Bank, 1991):

Estimates in US$ for 1989 per m^3

	Drinking water distributed to the communities		*Irrigation water*	
Country	*Cost*	*Price**	*Cost*	*Price**
Egypt (urban areas)	0.26	0.05		
Morocco (Casablanca and Doukkalas)	0.5	0.33	0.46	0.04
Tunisia (entire country)	0.44		0.31	

* Average of the prices and fees (for irrigation water).
Source: The World Bank.

Selected more recent data show the same deviations (in current US$ per m^3).

Country	Drinking water distributed to the communities		Irrigation water	
	Cost	Price*	Cost	Price*
Lybia (1977)	0.035–0.6	0.025–0.05	0.3–0.65	0.065
Tunisia (1977)	0.43	0.38	0.11	0.065 (00.3–0.09)
Algeria (1996)	(30 to 35 DH)	0.057–0.27	(0.5 to 0.6 DH)	0.015
Morocco (1996)			0.45	0.19 9–0.048

Other examples have been cited in the *World Resources 1987* table (World Resources Institute, 1987):

Country	'Production cost and price for drinking water'(early 1980s) in US$/ m^3	
	Cost ('Operation cost')	Price ('Tariff')
Cape Verde	1.84	0.16
Libya	0.80	0.07
Mali	0.20	0.14
Senegal	0.40	0.22

Similar differences exist for treatment. These distributions of costs, far removed from a market economy and the 'real prices', initially convey the fact that many users, individually, could not afford all the costs inherent to the public and collective modes of distribution of drinking or irrigation water.

The average costs of producing drinking water, for example, have been compared by the OMS to the GNP per inhabitant in various countries in the region (classified in decreasing order of costs):

Country	Costs of production ($/m^3)	GNP per capita (US$)	Ratio Unit cost GNP per capita (%)
Cape Verde	4.65	317	1.50
Tunisia	0.50	1,277	0.04
Djibouti	0.40	480	0.08
Mali	0.33	142	0.23
Morocco	0.14	512	0.03

Source: World Water/WHO 1987 [116].

These distributions of costs are the result of voluntary socio-economic policies, occasionally facilitated by income from mining or oil in certain countries which highlight the subsidised 'public service' aspect of water supply. However, they do not favour the instigation of a price system in order to regulate demand (see section 4.3) where it would be appropriate.This imposes particular conditions on water management.

In the 'mixture of market economy policies and direct intervention of the government to manage their water resources' indicated in the FAO report on the world situation of food and agriculture (1993), the public sector is largely predominant in the region.

3 Future requirements and demand: prospective test

Due to the present rates of use of conventional water resources, already very high in several countries, and the nascent recourse to unconventional resources, as well as to constraints already placed on demands, it is important particularly in this region, especially in the future, to distinguish between water needs and demand, just as it is important to distinguish between the supply demands for users and the withdrawals from the traditional resources which these motivate. (Box 3). More than elsewhere, the prediction of needs has two distinct objectives: to programme and prepare the means to satisfy them or orient and regulate them, to predict the pressures which would be exerted on the resources in order to determine if – and up until when – they would be bearable, then if they would not, to plan to limit demand which could result therefrom.

The various predictions which have been made, often within the framework of water resource master plans and national planning scheme studies (Table 9 gives several recent national predictions), or regional synthesis reports like those already cited[1], refer more to water needs, although the terms used are not always coherent (i.e., the graphic representation of 'Projected Water Demands' up to the year 2030, in several African Arab countries, according to the estimates published by Shahin, 1989 [82] (Fig. 13)). These future requirements are well estimated and projections are generally independent of the supply, based on foreseeable evolutions of water use factors, essentially population figures (separating urban and rural populations) and irrigated surfaces, deduced mainly from of the need to produce food (and strongly related to efforts to become self-sufficient). These forward-looking approaches, based on use sectors, are pertinent but could be improved if they were based on a larger number of variables and more diversified evolution scenarios – the two hypotheses are based solely on population growth but occasionally also on the degree of self-sufficiency sought. Possible methodological orientations are given in Box 4.

Taking into account all the determining factors in each use sector, combined with a fine meshed territorial spatialization, according to different scenarios, varying by the contexts of economic development and priorities of objectives, involves modelling of water needs. An example of such an approach: the 'MADH2O' model (Modèle Automatisé de Demande en eau, or automated model of water demand) has been used in Algeria (Arrus and Garadi 1991, 1993 [12, 36]. This is the 'first stage' in a later modelling enlarged to take into account supply/demand interactions. The projections of water 'needs' used up until now must not therefore be confused with demand forecasts, even if it appears that in some cases supply may be occasionally implicitly taken into account.

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1. For the Arab countries, the ACSAD/UNESCO-ROSTAS/IHEE 1988–93 study: '*Future water requirements*' for the years 2000, 2010 and 2030 for each country. Shahin 1989: '*Projected demands on water*' for the years 2000, 2010 and 2030 for each country. Khouri 1990: '*Projection of domestic and industrial water demands*' for the years 2000, 2010, 2020 for each country and global prospects of '*irrigation water requirements*'. In the southern countries, notably the Sahel where the quantities of water used represent only a small proportion of the resources and where the comparison of future requirements and available resources is consequently not a major concern, master plans are often based on required development projects – for example village water points in relation to objectives of bringing water supply to rural areas – in order to estimate how much funding should be budgeted, rather than on projected water requirements which are not generally globalized. Plus, for the African nations bordering the Mediterranean, the future exercise of the Blue Plan in the years 2000 and 2025 (J. Margat 1992).

Box 3

Distinguishing between water needs and demand

A precise and complete knowledge of the present uses of water by all of the economic sectors is necessary if we are to determine future demand and are required for resource management. This knowledge is however still imperfect and encounters various difficulties which are not specific to the OSS region.

- Water requirement or the need for water is a theoretical concept determined by the objectives of the activity which create it, and by the relationship of efficiency between its uses, for a given quantity and quality, and the results obtained. It is therefore usually expressed 'unitarily' (per capita, per irrigated hectare, per head of cattle, per unit of product, etc.). The need for water is normative and forward-looking (reference for evaluation of present demand). It is independent of supply.

- Water demand is an observable real fact, not only determined by the requirements of the user activity but also influenced by supply: be it natural (the resource), or from an intermediary production-distribution sector. The demand may then be higher than the need (where there is an abundant and easily accessible supply) or lower (in the case of a rare and costly supply), in terms of both quantity and quality.

- Water consumed by water works (evaporation in storage tanks) not generally attributable to specific usage sectors, is rarely considered. The same is true of losses by evaporation in irrigation water transport systems, included in certain estimations and not in others (in Egypt, for example).

Distinguishing between user demands for supply and demands on the resource (withdrawal)

- If user supply demands are met solely by exploiting conventional resources, the quantities pumped are higher than the demand due to transport losses.

- On the other hand, if part of the demand is met by other supply sources, whether by remobilizing water already used once and returned to the environment ('secondary resources'), or in resorting to unconventional resources (direct reuse of waste water or desalinated water), these demands may exceed withdrawals and they must be assessed and predicted separately.

Box 4

Projecting water needs

■ Two inappropriate approaches are to be excluded :

- Extrapolating past evolution trends in demand, rarely known with enough reliability, that 'retroprospective' analysis generally invalidates

- Applying assumed annual rates of increase to the globalized present or even sectorial demands, which make future evolutions exponential.

■ The most pertinent approach consists in proceeding by use sector :

- Define the principal exogenous variables which determine water needs, for example :
  - For with respect to the supply of community drinking water needs: urban and rural population figures, average percentage of distribution networks, per capita needs, average distribution output.
  - For with respect to irrigation water needs: irrigated surface, intensity coefficient (part having more than one crop), average need per hectare (possibly divided according to irrigation methods if the respective surfaces are known), transport output.

- Determine the initial state of these variables, average values for each projected territorial unit (basin, zone), verifying whether these determining variables are really coherent with the estimated present demands (or whether differences are explainable, notably, by restrictions resulting from deficiencies in that which is available).

- Attempt to predict the evolution of each of these variables, or, more precisely, their probable value(s) at specific times in the future (based as much as possible on the predictions already made: urban and rural population, irrigated surfaces, industrial production, thermo-electric production), with at least two hypotheses (high, low).

- Finally, calculate projected future requirements for each scenario, for the chosen years, distinguishing between the water supply needs of each sector and the gross 'productions of water' (withdrawal) required, taking into account transport and distribution output (including losses by evaporation in dams), assuming that these needs would be satisfied only by conventional resources. Then add up the sectorial needs and 'theoretical withdrawals'.

It is assumed, in this approach, that the needs of the different sectors do not overlap and that they can be added up.

To the projected supply needs, from which will be subtracted all or part of the projected withdrawals, we must add projected return of water, and consequently total consumption in relation to the resources.

Table 20. Some projections on future requirements or 'demands' for water, sectorial and total, for countries within the OSS region, according to recent national and international sources (figures in km³/year)

Country	*Year in the future*	*Community sector (drinking water)*	*Irrigation sector*	*Total for all sectors*	*Reference (cf. Bibliography)*
Algeria		(with industries)			
	2010	42			39
	2025	4.8 (a)			
	2010	4.6 to 5	2.8 to 3.6	7.4 to 8.65	178
	2010	2.0 to 3.26	3.74 to 5.11	7.11 to 10.24	36
	2025	3.06 to 4.91 (b)	5.20 to 8.35 (b)	9.87 to 15.63 (b)	
	2025			7.23 to 8.21	189
	2025	6.5 to 7.4 – 0.9 to 1.0	3.1 to 4.6 – 5.85 to 9.0	9.5 to 12.3 – 6.95 to 10.24	178
	2010		9.0	10.24	
	2025	9.56	4.64	14.2	209
	2030			8.7 to 12.7 (c)	82
Libya	Libya	1.02	5.85 to 11.98	6.58 to 13.23	76
	2010	0.9 to 1.0	5.85 to 9.0	6.95 to 10.24 (b)(g)	178
	2010	1.5 to 1.76	8.7 to 11.9	10.7 to 14.2	178
	2025	1.93	10.78	13.27	209 (j)
	2025	1.76 (d)	6.64(e) to 17.21(f)	8.97 to 19.54	76
	2025	6.7 to 8.5 (c)			82
	2030				
Morocco	2010	1.59	15.26	18.2	99
(a)	2020	1.98	17 (g)(b)	21.0 (b)(g)	
	2025	1.2	13.5	15.6	196
(c)	2025	1.50 to 1.57	12 to 17.2	12.8 to 18.3	178
	2025	1.97	17.2	21.05	209 (j)
	2030	12.4 to 14.9			82
Tunisia (c)	2010	0.37 to 0.63	2.54	3.0 to 3.3	158
	2010	0.46	2.54	3.16	179
	2010	0.40	2.5 to 3.37	3 to 3.95	178
	2020	0.48	2.08	2.72	139
	2025	0.50 to 0.53	2.05 to 4.23	2.72 to 5.02	178
	2030	–	–	5.5 to 6.4	82
	2030	0.55	2.03	2.77	13
Mauritania	2025	0.27	3.10	3.57	209 (j)
(c)	2030			4.5 to 5	82
Niger	2025	–	–	0.9 to 1	189
Senegal	2025	–	–	2.44 to 2.77	189
Chad	2025	–	–	0.31 to 0.35	189
Djibouti (c)	2030			0.21 to 0.35	82
Egypt	2010	4 to 5	60 to 75	73 to 90	178
	2020	3.1	49	58.2	141
(d)	2025	3.1	43.5 to 49.7	53.4 to 64.6	5
	2025	5 to 6	65 to 25	81 to 115	178
	2025	6.3	95.1	118.2	209 (j)
(c)	2030			92.3 to 112.8	82
Ethiopia (h)	2025			3.09 to 3.51	189
	2025	0.9	1.2	2.4	196
Sudan	2010			28 (i)	129
	2025	2.64	39.75	43.71	209 (j)
	2025	0.6	24.1	26.6	196
	2025			25.5 to	189
	2030			29.32 (c)	82

Notes to Table 20

a. 'Water needs'.
b. Results of modelling of sectorial demands, according to several scenarios, trends or more or less voluntary.
c. 'Projected Demands' in the sense of need, according to two hypotheses of population increase: 'natural' or 'modified'.
d. 'Water demand'.
e. 'Water demand with lower limit in food production'.
f. 'Water requirements for 100 % self sufficiency in food production'.
g. Allowance of mobilized resources.
h. 'Needs'.
i. 'Actual use'.

A simplified preliminary approach to prediction of global demand total demand for water (for all uses) in each country could be based solely on the projected population figures, assuming a constant demand per inhabitant/current, placing more importance on the population factor in the evolution of demand. This hypothesis fails to take into account the sociably desirable increases in per capita demand in countries, the least developed, with low water consumption. Nor does it take into account the projected decreases in demand in other countries where this decrease has already begun due to the scarcity of the resource.

This approach therefore risks leading to:

- underestimated predictions in the Sahel countries and the Horn of Africa where present per capita demand is currently very low (see Table 6), although their difficult economic situation does not guarantee that consumption of water per inhabitant in the large urban areas will grow, or even remain steady, nor that there will be significantly more irrigation.
- overestimated predictions in the northern countries (Maghreb, Egypt) where the present unitary demands are high but have already started to decrease because global demands will reach maximum at the height of supply (see Fig. 10);

Table 21 presents the results of predictions for the year 2025 according to this hypothesis. This must be seen only as an attempt at a theoretical prediction of the significance of population growth on future demand. We see that, according to this approach, demand would more than double by 2025. The slightly greater increase in demand, assumed in the southern countries (Sahel, Horn of Africa), will probably not compensate for a slower real increase in demand in the countries in the North.

A global exercise on the future uses of water, expressed in projections for withdrawals, by 2025, has been undertaken within the framework of works from the United Nations Commission on Sustainable Development (1997), following a more pertinent approach - relating the future demands for water simultaneously with the population and level of development ('water intensity' = the ratio of the amount of water used in US$ as part of the GNP – however, in total and without any differentiation by sector. Table 22 shows the results for the OSS countries, calculated following three scenarios of 'conventional' development. One notes that these projections amount to uniformly increasing the estimated withdrawals in 1995 of 43% as a low assumption, 53% as an average assumption, and 63% as a high assumption: is this truly realistic?

Table 21. Predicted water demand in OSS countries for the year 2025, as a function of population increases, assuming the present per capita demands do not change (see Table 14, col. 5)

Country	*Population in the year 2025 (UN average projection) (millions of inhabitants)*	*Total calculated demand for water (km^3/year)*
Algeria	46.6	8.39
Libya	8.65	7.0
Morocco	38.67	16.2
Tunisia	12.84	3.18
Σ Maghreb	**106.76**	**34.77**
Burkina Faso	23.32	0.93
Cape Verde	0.67	0.047
Gambia	2.15	0.062
Guinea-Bissau	1.95	0.033
Mali	21.3	3.83
Mauritania	4.77	4.13
Niger	21.50	1.44
Senegal	16.74	3.35
Chad	13.91	0.45
Σ Sahel	**106.31**	**14.27**
Djibouti	1.03	0.21
Egypt	95.61	101.7
Eritrea and Ethiopia	122.06	5.86
Kenya	41.76	3.63
Uganda	44.43	0.89
Somalia	21.21	2.10
Sudan	46.26	30.1
Σ The Nile Basin and East Africa	**372.36**	**144.49**
Total	**586.43**	**193.53**

Table 22. Projections for withdrawals of water in 2025 within the OSS countries, following three scenarios of conventional development, estimations for the United Nations Commission on Sustainable Development (UNCSD) in 1997

		Projections in 2025 in km³/year		
Country	*Status in 1995 (km³/year)*	*Low*	*Average*	*High*
Algeria	5.04	7.23	7.71	8.21
Burkina Faso	0.41	0.59	0.63	0.67
Cape Verde	0.03	0.04	0.045	0.05
Djibouti	0.011	0.016	0.017	0.018
Egypt	55.43	79.49	84.72	90.28
Eritrea	0.24	0.34	0.37	0.39
Ethiopia	2.16	3.09	3.30	3.51
Gambia	0.04	0.052	0.056	0.059
Guinea-Bissau	0.02	0.031	0.033	0.035
Kenya	2.45	3.52	3.75	4.00
Libya	4.75	6.81	7.26	7.74
Mali	1.75	2.50	2.67	2.84
Morocco	11.54	16.55	17.64	18.79
Mauritania	1.85	2.65	2.83	3.01
Niger	0.63	0.90	0.96	1.02
Senegal	1.70	2.44	2.60	2.77
Somalia	0.91	1.31	1.40	1.49
Sudan	17.80	25.52	27.20	29.00
Chad	0.22	0.31	0.33	0.35
Tunisia	3.39	4.86	5.18	5.52
Uganda	0.22	0.31	0.33	0.35

Source: P. Raskin et al., *Water Futures: Assessment of Long-Range Patterns and Problems,* Stockholm Environment Institute (1997).

The approaches of more differentiated patterns (cf. Box 4) have directed the exercises regarding the prospective on future demands (and to a certain extent, the supplies) for water, previously noted, that have contributed toward the works of the 'World Water Vision' as proposed by the World Water Council (WWC) and the Global Water Partnership (GWP) for the World Water Forum in The Hague, Netherlands, in 2000.

In the OSS region, these exercises, nevertheless, have concerned only the Arab countries, either those within the Mediterranean region (the Blue Plan), following two scenarios (see Table 23 and Fig. 15), or as a whole (WWC experts, following three scenarios (see Tables 24 and 25).

For its part, with the same objective, the International Water Management Institute (IWMI) has also proceeded with making projections for the demand for water by sector, by the year 2025, for various countries in the world, including only six OSS countries (see Table 26).

In sum, the future requirements for water for irrigation purposes for all African countries, including OSS countries, by the years 2015, 2025 and 2030, were the subject of rather precise calculations (taking into consideration farming practices, monthly deficits, and equipment) by the FAO in the year 2000. (see Table 27). The projected withdrawals, similar to the actual withdrawals (1996), are very much distinguished here from the hypothetical requirements that caused them and appreciably higher than the latter, taking into account mainly losses resulting from transport and lack of efficiency.

Table 23. Prospectives on the demands for water in the African countries bordering the Mediterranean, according to 'Mediterranean Vision,' prepared for the 'World Water Vision' (2000)

		Demand by sector in km³/year								Total demand km³/year	
		Communities		Agriculture		Industry		Energy			
Scenario	Country	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025
Moderate trends projections	Egypt	5.0	6.0	75.0	95	10	14	0	0	90	115.0
	Libya	1.0	1.76	9	11.9	0.24	0.57	0	0	10.24	14.2
	Tunisia	0.42	0.53	3.37	4.23	0.16	0.26	0	0	3.95	5.02
	Algeria	4.1	6.05	3.6	4.64	0.95	1.4	0.2	0.2	8.85	12.29
	Morocco	1.6	1.57	15.3	17.19	1.4	1.51	0	0	18.3	20.27
Sustainable development scenario	Egypt	4.0	5.0	60.0	65	8.6	11.4	0	0	72.6	81.4
	Libya	0.9	1.5	5.85	8.7	0.20	0.5	0	0	6.95	10.7
	Tunisia	0.4	0.5	2.5	2.05	0.12	0.17	0	0	3.02	2.72
	Algeria	3.5	4.9	2.8	3.1	1.1	1.5	0	0	7.4	9.5
	Morocco	1.0	1.5	11.0	12.0	0.8	1.3	0	0	12.8	14.8

Source: GWP/MEDTAC/Blue Plan, J. Margat and D. Vallée (2000).

Table 24. Projected 'water use' in African Arab countries in the year 2025, according to the conventional scenario, for the 'provisional vision for Arab countries', in km³/year (1999)

	Use sectors			
Country	'Household'	Irrigation	Industry	Total
Algeria	7.26	4.64	2.30	14.20
Djibouti	0.064	0.191	0.018	0.273
Egypt	6.30	95.13	16.73	118.17
Libya	1.93	10.78	0.56	13.27
Morocco	1.97	17.19	1.89	21.05
Mauritania	0.27	3.10	0.20	3.57
Somalia	1.0	1.81	0	0.81
Sudan	2.64	39.75	1.32	43.71
Tunisia	0.27	3.1	0.20	3.57

The total demand for water projected for the year 2025, has been calculated only by subregion and by the same source, according to two other scenarios:

Table 26. Total demand for water in 2025 by subregion (in km³/year)

	Great Maghreb	The Nile Basin and East Africa
Scenario No. 1, Conventional (see above)	57.29	164.96
Scenario No. 2 (assumes an increase in exploitable resources, especially from the reduction of losses from the Nile to Sudan)	53.82	159.35
Scenario No. 3 (the same assumption as the one made in Scenario No. 2, with an effective increase in effort with respect to demand management)	48.44	143.41
Base year of 1995	25.74	83.44
Increase in 'available resources' projected for 2025, following Scenario Nos. 2 and 3	0.97	8.57

Table 26. Projections for demands for water within several African countries, by sector and in total, by the year 2025, according to the IWMI base scenario (2000)

	Communities			*Irrigation*		
Country	*Per capita (m^3/year)*	*Total km^3/year*		*Total (km^3/year)*	*Portion that concerns the primary resource (km^3/year)*	*Total (km^3year)*
Algeria	44.3	2	1.3	4.3	3.3	7.6
Egypt	74.1	6.8	10.5	47.9	37	65.2
Ethiopia	8.3	0.9	0.3	1.2	1	2.4
Morocco	32.9	1.2	0.9	13.5	8.7	15.6
Sudan	41.3	1.9	0.6	24.1	19.4	26.6
Tunisia	42.8	0.5	0.2	2.0	1.6	2.8

Source: IWMI, D. Seckler et al. (2000).

Table 27. Requirements for irrigation water ('net irrigation water use') and withdrawals of water for irrigation purposes ('water withdrawals') within the OSS countries, calculated for the year 1996 and projections for the year 2030, from the FAO (2000), data expressed in km^3/year

		Status in the year 1996		*Projections for the year 2030*	
Subregion	*Country*	*Requirements for irrigation water*	*Withdrawals*	*Requirements for irrigation water*	*Withdrawals*
Northern	Algeria	1.27	2.70	1.71	2.99
	Egypt	28.25	47.08	41.61	51.21
	Libya	1.10	2.34	1.49	2.17
	Morocco	4.20	8.95	5.34	9.14
Africa	Tunisia	1.0	2.13	1.24	1.65
Sub-Saharan	Burkina Faso	0.11	0.35	0.20	0.63
	Eritrea	0	0	0.01	0.02
	Ethiopia	0.42	1.37	0.99	3.14
	The Gambia	0.01	0.02	0.01	0.03
	Guinea-Bissau	0	0	0	0
	Kenya	0.14	0.45	0.71	2.19
Africa	Mali	2.48	8.01	3.46	8.68
	Mauritania	0.18	0.60	0.29	0.78
	Niger	0.21	0.69	0.53	1.64
	Uganda	0.01	0.04	0.02	0.07
	Senegal	0.46	1.50	1.08	3.28
	Somalia	0.89	2.86	1.45	3.35
	Sudan	13.46	22.43	19.35	29.48
	Chad	0.05	0.15	0.09	0.30

Source: *Agriculture: Toward 2015/30,* FAO, Global Perspective Studies Unit (April 2000).

Figure 15. Evolutions during the latter half of the 20th century and projections to the year 2025, for the total demand for water in North African countries, according to the scenarios described in 'Mediterranean Vision' (2000) (see Table 23) .

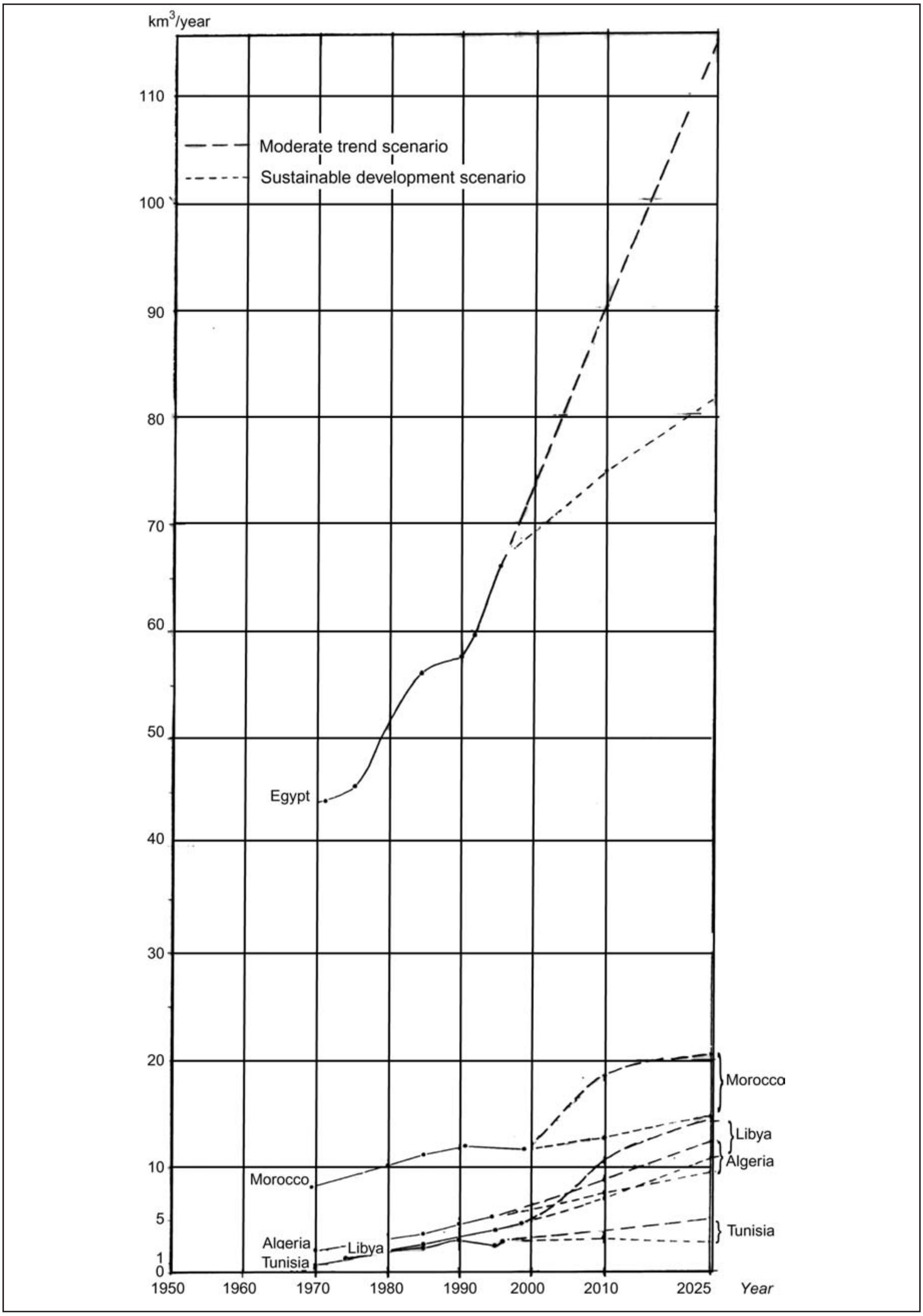
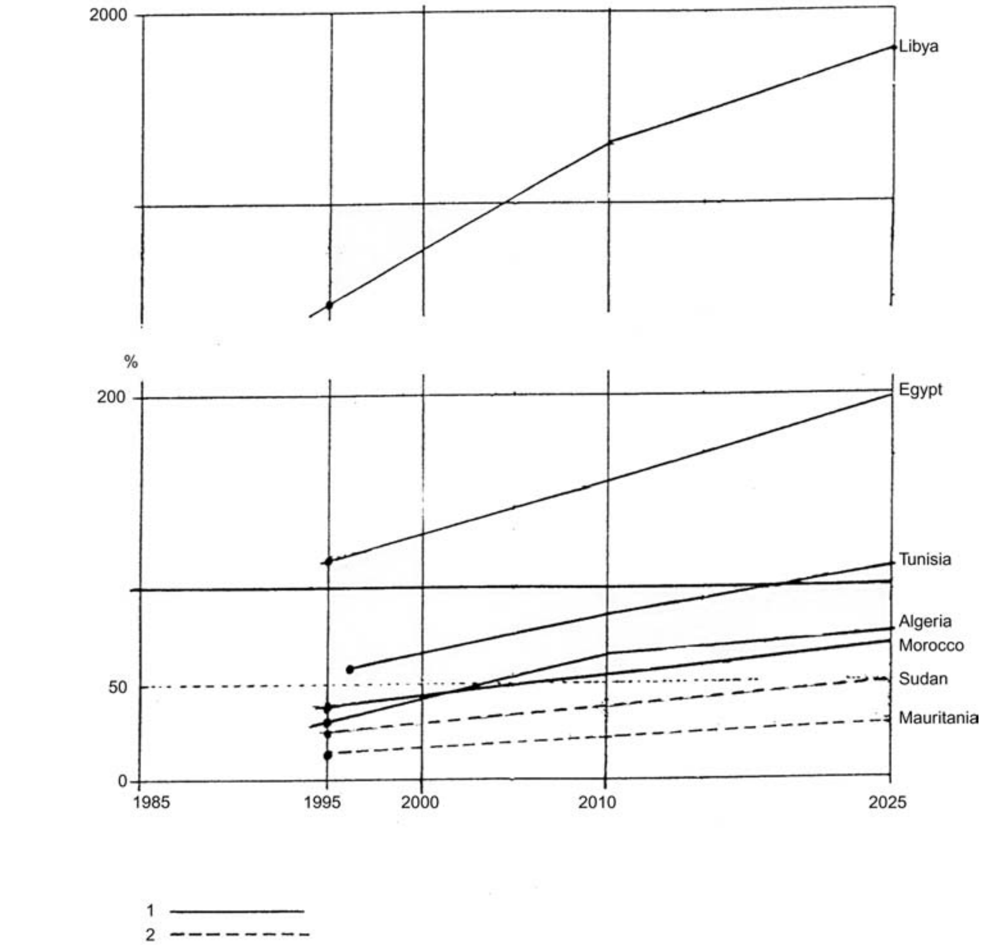


Figure 16. Projected increases in the ratios of demand/natural and actual renewable water resources for several countries within the OSS region up to the year 2025 (see Table 24)



1: According to the demand projections for the moderate trend scenario described in 'Mediterranean Vision' for North African countries (see Table 23).

2: According to nationwide projections for other countries according to the demand projections for the moderate trend scenario described in 'Mediterranean Vision' for North African Countries (see Table 23).

What do these exercises of rather 'plural' prospectives on the requirements or demands for water (not very far apart) say that differ with respect to their approaches, sometimes trends, sometimes anticipatory or voluntary, insofar as their taking into consideration the interaction with the conditions of availability – by their assumptions, indeed, by their initial conditions?

The frequently marked deviations in their results, to a common future year (most frequently in the year 2025), emphasize the broad uncertainties that are tied especially to the margins of choice with respect to the assumptions resting on the principal factors in the demands for water, as well as the future means for satisfy such demands.

In any case, a major contrast will remain among the following:

- the Northern Countries (the Maghreb) and the Nile Basin, where the already strong demands for water should grow more, while facing a levelling off of the resources currently very much used;

- the Sub-Saharan Countries within the Sahel and within the Horn of Africa, where the growth in demand will remain slow and limited more by economic capacities, rather than by physical conditions.

The weighty difference regarding irrigation with respect to the uses of water will remain the principal factor for this contrast.

The presumed deviations among the scenarios appear to be of second order when compared to this geographical contrast.

Foreseeable pressures on resources and consequences

This prediction of needs aims at enabling their comparison to potential conventional resources in the reference territory in order to estimate for one or more targeted years the global relationships between them and the possible stresses, or even the surmisable inadequacies in quantity. Several situations might occur:

(1) As long as the requirements remain generally low with regard to the natural resources – let us say not exceeding a tenth of these – they are classified as demands totally met by traditional water works and withdrawals.

(2) If the requirements are around several tenths, and notably if they exceed half, of average natural resources, there is a risk of inadequacy (i.e. shortages), either locally or arising from certain economic conditions. Water works and withdrawals are the principal means of meeting these these demands, however, an increase in the ratio of demand/resources indicate the increase in effort required, taking into account the decreasing output of necessary equipment, including water transport between 'surplus' and 'deficit' regions within one country, or between countries. An early stage of separation of need and demand has begun at least in certain zones and in dry years.

(3) When the need comes close to, or, a fortiori, exceeds the natural resources, in other words, quantitative inadequacies (chronic and structural shortages) are predictable in the more or less near future (or where they already exist), it is no longer a question of meeting them solely by the exploitation of conventional resources, therefore subtracting withdrawals directly from them, or identifying them with future demand. The prediction of needs aims at demonstrating the need to develop new supplies (long distance transport, 'unconventional resources'), and indicating the possibilities of adapting demand.

The demands/resources or total consumption/resources ratios, an increase in which can be deduced from these predictions, are less and less forward-looking indicators of exploitation or total consumption as they grow (identifying them would implicitly involve these requirements being irreducible and having to be totally met by the renewable conventional resources, even though this is no longer the case in several countries, as has been seen.) The prediction of these indicators (example: Fig. 15) has thus only an exploratory meaning and aims solely at facilitating diagnosis and clarifying choices of water policy to be pursued at present.

In this perspective, the prospective water needs per country compared to the potential and renewable resources may give rise to a dual interpretation:

- estimation of probable need/resources ratios for given years, for example 2010 and 2025,
- prediction of dates when need/resources ratios could exceed significant values such as 50 and 100% (if these values have not yet been reached).

Table 28 presents these results, to which it is advisable to attach only an exploratory and indicative value.

Table 28. Trial prospective on the demand*/resources ratios in the countries most threatened by structural water shortages**

Country	*Demand/probable resources (%) in future years*		*Demand/probable resources (%) in future years*	
	2010	*2025*	*50%*	*100%*
Algeria	50	60 to 90	2010	2035–2040
Libya	1200 to 1700	1700 to 2000	> at the present time	–
Morocco	40 to 60	50 to 70	2010	2035–2040
Tunisia	65 to 85	70 to 110	> at the present time	2015–2020
Mauritania	20	25 to 30	after the year 2030	–
Egypt	120 to 150	140 to 190	> at the present time	–
Sudan	30 to 40	40 to 60	2025–2030	–

* According to national and international sources (cf. Tables 20, 22 – 27).
** Actual renewable sources noted in Table 10 (cf. Table 10).

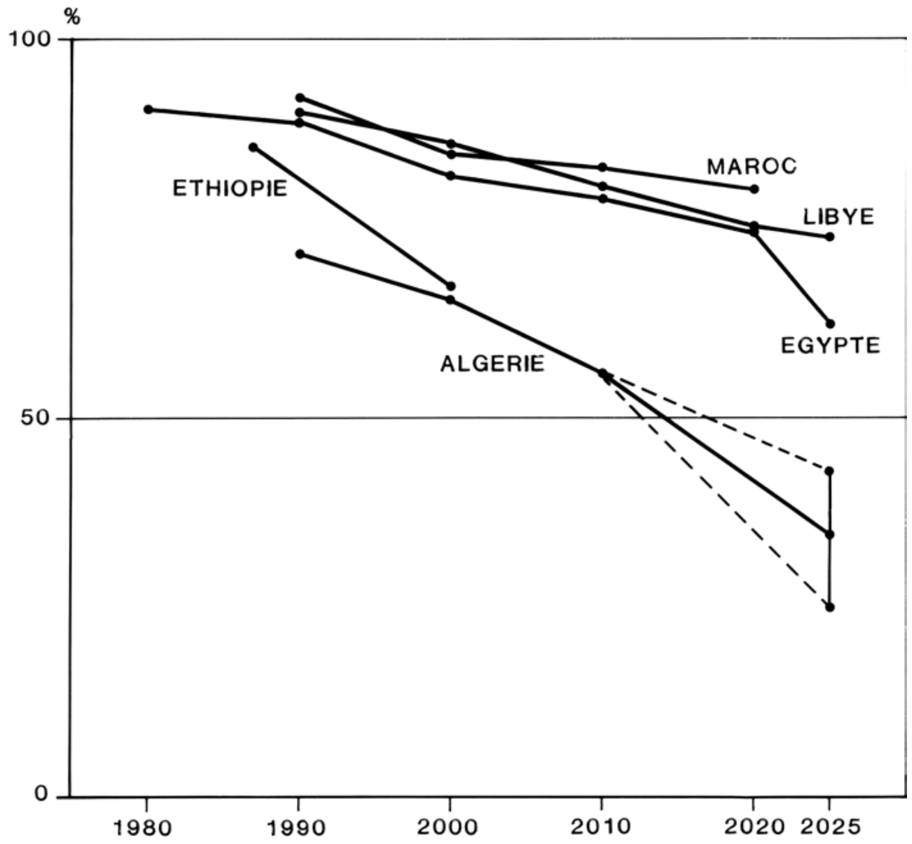
The future evolution in the ratios demand/resources is naturally very much bound to evolution of the water resources (natural and renewable) per capita, since these two indicators are already bound in their present state. The global pressure on resources presently is and in the future, will be all the more elevated as the resources per capita presently are and in the future, will be low. Below the limit of 500 m^3/year of resource per inhabitant shown above (Chapter 1), the 'exploitation rates' increase significantly and all the more so when irrigation is extensive, approaching or exceeding 50%.

Actually, the prediction of demands and their consequences must take into account not only the theoretical requirements projected but the supply/demand interactions, notably the reactions and adaptations of the demands to supply modified by shortages of natural availability and by the increase in production costs of water and/or distribution (transport), in order to make estimations. The demands are then less to be predicted or projected than planned. They become as much the object of previsional management as the resources, and are grouped with the planning of conventional or unconventional supply.

In this related prediction of supply and demand, the previsional and programmed allocation of resources tends to replace the projection of demands based on need and is the equivalent of planning of demands (for example: in Egypt, Morocco, Tunisia...). In this perspective the same approach is not used for the different use sectors:

- for community drinking water supply, a priority and relatively less flexible (despite water conservation projects), the projected demands is used and the planning aims at adjusting the supply to the demand;
- whereas for irrigation it is from the allocation of the 'left over' resource that the demand is deduced and availability is subject to the supply (for example in Algeria, in Egypt...). Thus in most of the countries, a reduction in the relative parts of the 'demands' on irrigation water is predicted (in fact resource allowances to that sector) in relation to the total demands on water (e.g. Fig. 17).

Figure 17. Projections for proportions of irrigation water demands on the total demands (or parts of mobilized water resources allocated to irrigation) in several countries



References: Algeria* [19], Egypt [5], Libya ** [76], Morocco [128], Ethiopia [125] (* from scenarios in 2025; ** from '*Lower limit of food production').*

In countries with very developed irrigation systems in the north and the Nile basin, the degrees of food self-sufficiency sought by socio-economic policies have naturally a great effect on the demands on irrigation water projected but reciprocally the resource allowances possible for irrigated agriculture impose a heavy constraint on choosing these degrees of self-sufficiency.

For example, in Libya two projected demands on irrigation water will be compared up to 2025 according to two hypotheses (from Salem, 1992):

	Demands on irrigation water in km³/year	
Year	*with 'lower limit of food production*	*'for 100% self-sufficiency production'*
1990	4.27	5.81
2000	4.80	8.51
2010	5.32	11.98
2020	5.85	15.69
2025	6.64	17.21

It can be seen in this example that the proportion of food production possible in the hypothesis of minimum increase in irrigation would diminish progressively from 73 % (in 1990) to 39 % (in 2025) of the objective of self-sufficiency, even when considering progress in irrigation efficiency.

As a consequence, the effects of evolution of the amounts of water used – an increase – on the resources cannot be directly deduced from the evolution of the demands projected but only from the part of these demands which will (and could) be covered by the exploitation of natural resources. The prediction of supply and demand will have to be increasingly integrated and be the subject of joint modelling in the countries of the region confronted with an increasing shortage of available water, as well as in the countries having a sufficient water resource but which poverty renders for the most part incapable of assuming the economic costs of a supply approach without restriction in order to satisfy 'needs'.

Comparing the projected demands only to the average and supposedly stable resources of course reduces the significance of these attempts to predict pressure on the resources. The variability and the possible instability of the resources must be taken into consideration.

- The increase in the exploited proportion of average natural resources makes the water supplies more and more vulnerable to input shortages, to droughts. Moreover, the evolution of the structure of uses also amplifies this vulnerability.

Droughts and their effects on renewable resources are a natural phenomenon which arise when certain conditions are met. Their probability depends solely on the climate.
The consequences of drought on humans are, on the other hand, dependent largely on the types of water usage and their vulnerability to shortages. In the arid and semi-arid zones of the region, vulnerability to drought has increased and should continue to increase in the future, due to:

- population increase,
- decrease in nomadic practices,
- urbanization.

which increase the inadaptation of life styles to the variability of water resources and amplify the desire to secure water supply.

Will water resources in the twentieth century be those of today ?

Without developing the point, which is now widely covered by the media, risk from lack of renewable water resources (in quantity), under the effect of the problematic change of climate due to the 'greenhouse effect', it is not possible to exclude this hypothesis in a part of the region, notably in the Maghreb and Sahel. Decreasing and increasingly irregular rainfall have been predicted by different models. But the 'predictions' regarding this matter – their amplitude and date – are still subject to debate (Box 5).

Box 5

Droughts and climate change : in addition to their inconstancy and fragility, are the water resources in the OSS region decreasing?

Are the long and severe droughts which have occurred during the course of last two decades the initial signs of a climate change attributable to the greenhouse effect? The relationship between the reality of some and the understandable concerns created by the interrogations on the other is certainly legitimate. Yet confusion is possible. It is advisable to not to confuse drought (dependent on circumstances) and aridity (type of geographic climate), or the relatively minor alternations of humid and dry periods within the present climatic period with major prehistoric climatic variations, at another time scale. There have already been periods of drought during the course of history but they were less known (lack of meteorology) and less divulged (lack of media) and they had fewer consequences on humans (due to smaller populations which did not increase as rapidly and were better adapted to the climatic hazards). Without being truly cyclic, the multiannual sequence alternations of dry and humid years, in a decennial way, appear, nevertheless, to be more marked in the Sub-Saharan Zone, especially, in the Sahel, rather than north of the Sahara, at least with respect to the 19th and 20th centuries.

Nothing allows us to confirm that the greenhouse effect on the average climate is already being felt, even if some recent research on long-term pluviometric (Mauritania, Démarée 1990) or hydrological studies (Niger, Senegal, Hubert et al., 1993 [42*bis*]; Olivry 1993 [65*bis*, revealed non-steady states in the evolution of these variables, i.e. tendency ruptures which are relatively synchronous but alternate. It is however true that the weak tendency which has persisted notably in tropical Africa during the last decades, with more marked droughts at the beginning of the 70s and in 1983–4, has no precedent, either in magnitude or duration, in the hydro-climatic chronicles of this century. These analyses lead us at the very least to lower the resource estimations (average, mean flows...) based on previous historical ones with greater components of humid years, taking into account more up-to-date historical ones and changes in trend in the mid term. This perspective, in particular, has led ORSTOM* to draw up, in the year 1996, two distinct isopluvial maps of West and Central Africa, based upon averages for the periods 1951–69 and 1970–89, respectively, in addition to a map showing averages for the period 1951–89.

These studies however reveal a better knowledge of resources rather than their transformation. The vigilant monitoring of hydro-climatic variables remains in any case, in the long term, an essential necessity.

* Today 'Institut de Recherche pour le Développement' (IRD).

4 Water management: problems and solutions

In most of the OSS region, future stresses and the increasing discrepancy between growing water needs and limited conventional resources will create aggravated problems and usage conflicts that water management will aim at resolving. Initially, the principal types of conflict, of varied natures which risk developing, will be studied, then the different means of action and appropriate technical instruments will be discussed, and ways and forms of joint management of supply and demand in the different conditions of the Region will be considered.

4.1 The present conflicts to be settled or future ones to be prevented

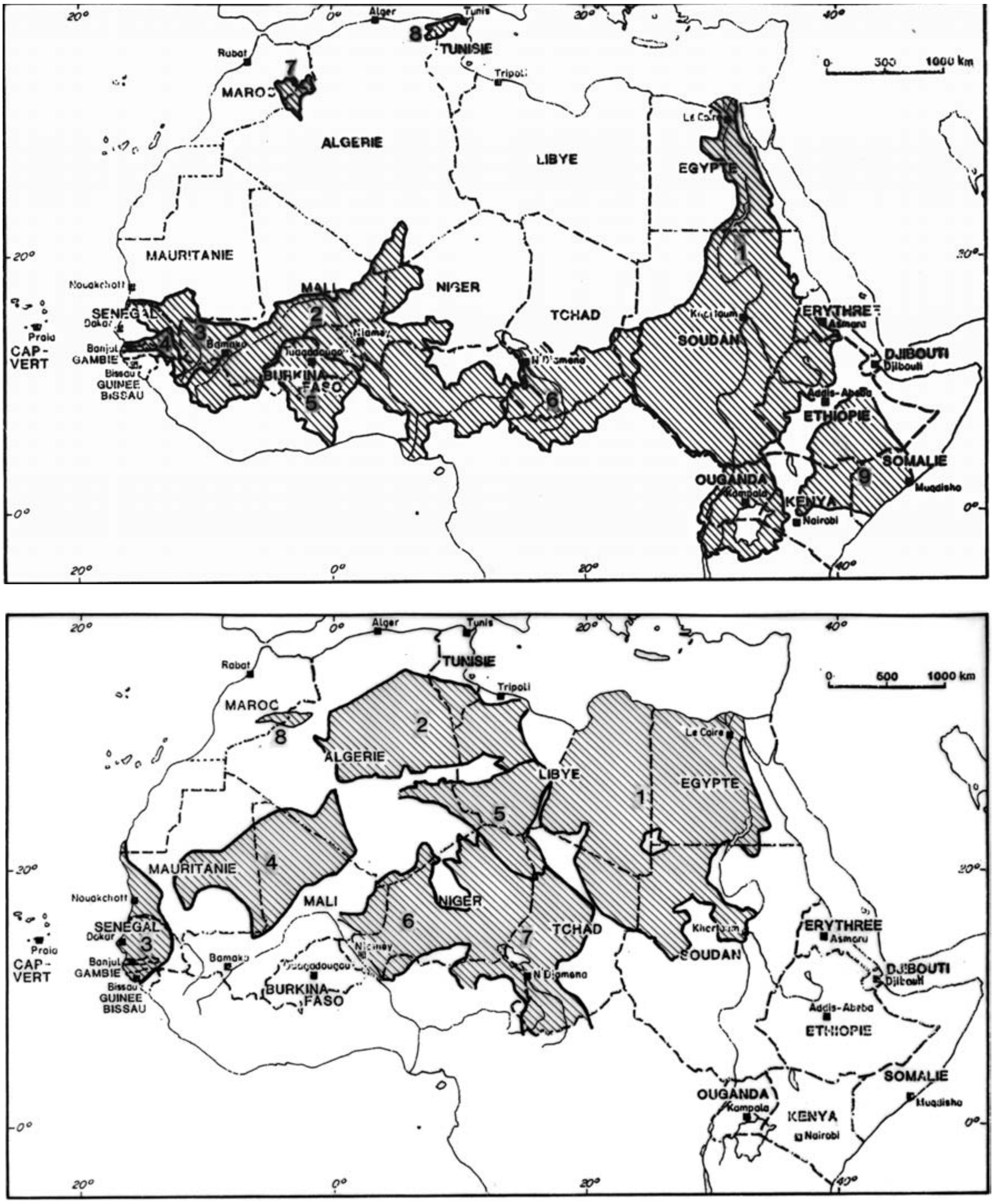
- The most classic and most widespread are the **conflicts of usage** (i.e. among users) that originate from the intensification of exploitation of a given surface or groundwater resource system. Well before reaching the maximum possible mobilization of renewable water resources, or even becoming involved in an 'overexploitation' in the case of aquifers, increased pumping reduces output and increases production costs, creating competition and tension between old and new users, whether their objectives are similar or, *a fortiori,* different, especially when the financial means of each are unequal. These conflicts of usage do not arise solely from sharing of scarce water resources but also from competition for access to the least costly and most easily mobilizable resources and those that offer the most security (internal, permanent, good quality water).

  These conflicts are naturally aggravated in times of drought which accentuates the water shortages in the regions with predominantly renewable water resource and where the population increase and changing life styles amplifies the vulnerability to drought.

  More generally, it is a question of competition between use of natural water resources and recourse to more costly unconventional resources.

- The conflicts of usage occasionally take the form of competition between interfering modes of water mobilization, although it is not immediately perceivable, notably between the exploitation of interdependent groundwater and surface water in the same basin: intensive pumping of ground water may reduce or dry up perennial springs or streams, while surface water regulation by means of dams may decrease or halt the recharge of groundwater by flooding. Both have occurred in the Maghreb, for example. Another form of conflict is due to the difficulties of coexistence between the traditional and modern exploitation processes, for example between the exploitation of groundwater by tapping tunnels with set potential (*Foggaras* of the Maghreb) and the exploitation by pumping which entails heavy drawdown: the development of more productive

Figure 18. Water resource systems common to several countries in the OSS region



a. Border crossing river basins:
1 - The Nile; 2 - Niger;3 - Senegal; 4 - Gambia; 5 - Volta; 6 - Chari; 7 - Guir-Saoura; 8 - Mejerdah; 9 - Juba-Shebelle.

b. Border crossing aquifers:
1 - Nubie Basin; 2 - Northern Sahara; 3 - Senegalo-Mauritanian Basin; 4 - Taoudeni Basin; 5 - Mourzouk-Djado Basin; 6 - Irhazer-Iullemeden Basin; 7 - Chad Basin; 8 - Errachidia Basin.

processes enables the increase in mobilized volumes of water and the improvement of the adaptation of water production to demand but it is not compatible with the conservation of old ways in an identical natural resource system, and that may oppose different categories of users. This problem occurs everywhere where these traditional gravitational modes of exploitation still operate (Oases in Egypt and Libya, the Maghreb and the Sahara).

- On the scale of hydrographical basins, conflicts may occur between upstream and downstream communities. Water works are frequently located upstream and that water is used – or is safer – downstream. The upstream communities may wish to benefit indirectly in the developments. This question is initially posed in the national framework in countries with predominant internal water resources (Type 1, Chap. 1). It obviously has more scope and a geopolitical dimension in the case of border crossing river basins, notably in the countries with predominant external resources where the problem of distribution of resources is acute (Type 2, Chap. 1). These cases are relatively rare in the Maghreb (Guir between Algeria and Morocco, Medjerdah between Algeria and Tunisia) whereas they are more common in the Sahel and in the Nile basin (Fig. 18a), where they are too widely known to be mentioned here.

- The great aquifer systems of the multi-national sedimentary basins[1] (Fig. 18b) may also give rise to conflicts which nevertheless are only potential at present. In this case, the aim of distribution to be settled is more complex than a flow: it is a matter of distributing, in an equitable manner, the influences, notably in the non-renewable resource development schemes.

- More widely, while remaining in the national frameworks, conflicts between provinces or regions thwart water transport plans which aim at realigning 'surplus' or 'deficit' regions or basins at the present and in the mid-term and which are already under way or programmed in the Maghreb, Libya, Egypt. Up to what point can water transfer prevail over displacements of activities? How does one compare the advantages of water transfer in the short term for the recipient region and those of resource conservation for a deferred development but calculated greater in the long term for the delivering region? How does one distribute the advantages of transferring: what benefit or what compensation is it necessary to grant to the 'exporter' region?

- Another sort of conflict may assume an inter-generational character in the particular cases of management of non-renewable resources ('mining' of groundwater) developed notably in Algeria, Tunisia and especially Libya: between an intensive and assured development in the short term, or a moderate and durable development, but in a more uncertain socio-economic context, in the long term. This is the classic problem of distribution of mining income in an 'uncertain future'. That also means extending the conflict between the use of natural resources in time, monopolising resources by the present generation, and forcing future generations to have recourse to unconventional resources.

- The inter-sectorial conflicts may be enlarged at a regional or national scale. The most important is the rivalry between the irrigated agriculture sector and that of the urban supply, the second generally having a higher priority and a greater economic capacity. Incidentally, competition may

1. See map 'Resources en eau communes des pays de la Région de l'OSS. Bassins fluviaux et aquifères profonds transfontières' (OSS, 1995).

also oppose industry and agriculture, or occasionally hydroelectric production and agriculture. In this second case, the conflict arises especially from certain economic conditions and it is exacerbated in seasons or years of drought. It has been noticed that the objectives of hydroelectric production, which motivated the first generation hydraulic equipment in the Maghreb and Egypt, have been relegated to second place behind irrigation in recent development plans. However, the low added value of the agricultural uses of water will handicap them in the future, in relation to urban and industrial uses.

- To these usage conflicts can be added the tensions between users of water and people subjected to the effects of external uses: the most extensive case of this is pollution by the return of water used in the fluvial systems which constitute another form of upstream/downstream conflict, including, naturally, the border crossing basins where they take on an international dimension. That poses the problem of distribution of the respective costs of upstream purification or downstream drinking water treatment, between the communities concerned.

  More widely, when the natural water resource exploitation rate is very high, the protection of their quality becomes increasingly and globally necessary. That imposes constraints and increasing costs on numerous people occupying the soil, such as farmers, in order to reduce or buffer the impact of their activities, but which they can ill afford.

  It is a question then of conflict between the requirements of water supply security, notably in quality, and those of socio-economic development, that the scarcity of available water renders incompatible.

- From an economic point of view, the general question of distribution of costs is posed, between beneficiary users on the one hand, public authorities and communities on the other, whether it be a matter of water development, production and water supply, treatment, purification or protection. The relative importance given to the public service or to the market mechanisms have an effect on the evolution of demand.

- Finally, concerning water policy orientation of each country, a certain competition is instituted between the appropriate ways and means to ensure a supply/demand balance: between the supply approach (development, production) which civil engineers prefer and the less costly demand approach which is more closely related to socioeconomic measures the effectiveness of which is less assured and temporally deferred.

The combination of the different types and sizes of water resources (Chap. 1) and different present or projected degrees of tension between demands and resources (Chap. 2) results in a wide geographic variety of problems and conflicts in the OSS region (Table 23). The ways and means of water management for resolving these problems are thus equally diversified and specific to each country.

Table 23. Water problems and major zonal conflicts in the OSS region

Sub-regions classified according to the predominant type of water resource (Fig. 4)	*Specific problems and conflicts*
Internal renewable resources	Conflicts of upstream/downstream usage. Conflicts due to interference of ground- and surface water uses, or of traditional and modern exploitation techniques. Imbalances and competition between regions: transfer problems. Competition between completion of conventional hydraulic development, with increasing cost and environmental impact, and recourse to unconventional resources.
Fluvial resource of external origin	Conflicts of upstream/downstream usage (quantity and quality), notably in the case of mobilizing resource development by reducing losses by evaporation, conflicts between downstream beneficiaries subject to impacts from upstream developments. Conflicts between traditional methods of water usage (e.g. irrigation) and need for water conservation (related to the intersectorial conflicts). Geopolitical constraints and rivalries.
Non-renewable resources	Conflicts between short and long term development objectives (which may correspond to conflicts between unfairly 'developing' uses). Competition between use of non-renewable resources and recourse to unconventional resources. Competition between regions and transfer problems.

4.2 The technical solutions

In order to resolve present or future problems, a very wide range of technical means is available, means of action on the supply as well as on the uses, which are all already in operation but with very unequal scopes depending on the countries to whose conditions they are adapted in different ways. These means are quite well known. They are therefore only briefly described here.

Supply side

- The classic hydraulic developments regulating surface water can still be expanded in the countries with predominantly internal or external renewable resources, (Fig. 4), where it nevertheless risks being slowed down by the decreasing output of structures and handicapped by the silting up of reservoirs, shortening their life span. To the development efforts can be added:
  - the progress in storage management techniques in real time, assisted by the improvement of hydrometeorological predictions;
  - the progress and the more extensive application of anti-erosion techniques in the catchment basins, which decreases sedimentation and which, together with the desilting operations (notably using dynamic methods), prolong the life span of the reservoirs.

In addition to large development projects, the 'small hydraulic works' can still contribute widely to amplifying water control. Adapted to relatively stable socio-economic conditions for a long time and in equilibrium with natural conditions, various 'traditional' techniques of water control and exploitation (direct collection of rain water, verification of local flow, small dams, cisterns, draining tunnels, etc. See 'Traditional Water System' work, UNESCO - ACSAD, 1986 [94]) could benefit from modern improvements facilitating their installation and improving their efficiency, while conserving the advantages of these multipliable 'micro-developments' without requiring centralized organization. The rehabilitations under way in Tunisia (El Amami, 1988) are a good example of this.

More generally, the techniques and efforts to conserve soil and vegetation, which come within the framework of 'combating desertification' contribute to preserving the water regime thus the recharge of renewable resources and in particular their regular component.

- Although the exploitation of groundwater is already often intensive and occasionally excessive in certain cases, there is a potential for increasing quantities in some countries. Increased production is possible, regulated by management models, in the case of large and controlled aquifer systems.

  A more complete water control will frequently involve a more integrated management of surface and groundwater, improving both artificial recharge operations and a more active and modulated exploitation of the regulating ability of these reservoirs, notably to back up the low water flow. Within this context, actions on springs beyond their simple derivation – raising the temporary level, regulatory pump – can play an significant role (Margat, 1981).

  The regulating storage capacities of alluvial aquifers can also be increased by the technique of underground dams. This has been done in the Maghreb, for example, and a systematic exploration of favourable sites would be profitable in other countries.

- In the countries with dominant external fluvial resources (Nile and Niger basins), developments reducing losses by evaporation from natural bodies of water, such as the project started in the Sudan (Jonglei Canal), are a means of increasing renewable resources destined to increase in scale but environmental impact of which cannot be ignored, therefore must be toned down and compensated for.

- Long distance water transfer projects, the techniques of which are perfectly mastered, are under way or planned in several countries in the region (the Maghreb, Libya, Egypt, Senegal) despite energy operation costs which are generally high. This means of compensating imbalances between regions – indeed between countries if an international water trade were created – can nevertheless cause socio-economic problems and must fall within the framework of long-term projects intimately linked to land use planning.

- The exploitation of non-renewable resources, possible with the large sedimentary aquifers, although not durable, is destined to increase in the countries where it is already well under way, notably in Libya where it could cover up to 95% of the total water demands in 2025, assuming the largest increase in these demands [76]. Since this exploitation aims especially at delaying as long as possible recourse to the more expensive 'unconventional' resources, that implies that its volume and its duration should be set coherently and should lie within the scope of a long-term plan.

- The industrial production of fresh water by sea water or brine desalination is under way in several countries in the north, at a scale which is still experimental whilst contributing only little to the supplies, especially to resolve particular cases. Due to its costs, it is used only in the last resort. However, in the future it could be developed in countries with an increasing shortage of fresh water.

- Finally, the treatment of waste water, adapted to specified uses, is also being developed as purifying techniques improve and is associated with the progress in urban water treatment. In several countries the increasing 'production of waste water', already exceeds (Libya) or will exceed in the foreseeable future (Egypt, Tunisia...) the available renewable natural resources, thus, a fortiori, their exploitable proportion.

Box 6

International water transfers

Are the internationalwater transfers for purposes of aiding the Sahel feasible or useful?

The regional contrast between the Sahelian countries and the countries bordering them insofar as water resources, as has been previously emphasized, suggests the possibility of water transfers South-North coming into 'vision' in the very long term.

In fact, nature already does this to a broad extent: the principal Sahelian river basins – Senegal, Niger, Chari, not including the Nile - draw the greatest portion of their flow from their beginning in the Southern countries (from Guinea to Central Africa).

Moreover, the natural water resources (internal and external) of the Sahel countries are still used only to a small extent, which would little justify somewhat the importing of supplements...

However, some years ago, the transfer project 'Transaqua' was conceived, calling for the diverting of water from the Ubangi Basin, in the Central African Republic, to the Chari River, in Chad, to help replenish Lake Chad, a body of water that had been in marked regression since the 1970s.

Still, the principal recipient of such a transfer, more so than Chad, would be Nigeria, the foremost user of the lake's water (pumpings for irrigation purposes).

Use and demand side

- The techniques for reducing losses during storage and transport have a wide field of application, as indicated above (chap. 2), in particular for improving the output of the drinking and irrigation water distribution networks. In addition to efforts to reduce leaks in domestic and industrial networks, a compensation for the increase in urban demand projected for the coming decade(s) can be expected.

- The modern control system techniques for water supply and demands in irrigation networks, thanks to progress in automation and remote control, may also contribute substantially to the reduction in extraction at the head of the network.

- Significant water conservation may be expected from increases in efficiency from both industrial uses (improved recycling) and irrigation (development of sprinklers and especially micro-irrigation) which makes the technical assistance and financial incentives very profitable for users.

- In general, the development of conservation practices on the part of the users are a result of education, information and incentives, notably the price when the water is commercial.

- The generalization of urban water treatment and improved output of collection and treatment plants also contribute to reducing the qualitative pressure on the resources when the waste water is returned to the natural environment.

- The increased reuse of waste water eliminates certain uses from direct extractions on the resource by substituting a 'secondary' resource for these, which means placing several uses in sequence for an identical withdrawal and increasing the total usage rate. The reuse may notably contribute to decreasing the competition between agricultural and urban demands on water; it may also improve the profitability of primary water production or costly transport, by enabling its use several times. This reuse nevertheless poses hygiene problems and its feasibility depends on an equitable distribution of treatment costs between the primary (producers of waste water) and secondary (reusers) users.

- The reuse of drainage water, already very developed in Egypt (El Gindy, 1986; Amer, 1992) and easier to implement, plays a similar role and it is an indirect means of improving the global efficiency of water use in an irrigation perimeter, which may compete with the improvements of irrigation techniques.
- Finally, the use of sea water or brine as a substitute for fresh water, for industrial cooling (thermo electric power stations notably), or a mixture of salt and fresh water, are already widely developed and may progress further. In particular, irrigation with briny water, tested since 1970 in Tunisia (project CRUESI, UNESCO) is possible in well defined conditions.

It is in the countries which now or in the near future will have a shortage of water that the advantages and disadvantages of these means of action can be compared and their advantages combined even though they may be unequal depending on the country. They differ however greatly by their nature and the conditions of their installation: quantities of water produced or saved per structure or operation unit, unit costs, investment/operating cost ratio, divisibility and possibility of spreading out investments over time, conditions of distribution of costs between the community (state) and users, location constraints and land costs, duration of production, response time, life span, energy costs, output hazards, environmental impact, social workers and owners, etc. It is therefore difficult to evaluate their feasibility and their cost/advantages ratio according to standard criteria and a common value scale.

This diversity does not make the integration of all these means into water development master plans easy, plans which still frequently favour the supply approach. However, the applicability and the extent of the possible role of each technique depend much on the specific conditions, and the physical and socio-economic context of each country.

4.3 Integrated water management

Satisfying the various demands on water under conditions which can be born by the economic participants and by the natural environment – i.e. without deterioration – and within the framework of sustained development, entails, particularly in the OSS region, integrated water management according to recognised procedures established by international authorities.[2] This integration of water management should be designed and implemented at several increasingly broad levels:

- integrated management of resources: surface and groundwater, quantity and quality, upstream and downstream basins;
- integration of resource development and water purification and treatment;
- integrated management of supply: renewable natural resources, non renewable resources, unconventional resources;
- integrated management of supply (resources) and uses involving a multisectorial management of the two (including in situ uses and the management of aquatic environments).

As the level rises and the field of integration is enlarged, an increasingly complex socioeconomic system and increasingly varied participants are involved, going beyond simple water conservation. Integrated water management is an integral part of land use management, development, and agricultural policy.

Ways and means of integrated management

The integration of water management and the resolving of conflicts can usually be achieved by a combination of institutional, technical, economical and financial means.

Institutional means

- Adaptation of water laws and regulations governing intervention and arbitration of government authorities (by regulation of development and exploitation of resources as well as uses, by financial incentives). The status of public property (or the public domain) of water resources,

2. Notably: *Declaration of the International Conference on Water and the Environment,* Dublin, January 1992.

written into most legislation, must be reconciled with the safeguarding of water rights and private appropriation of certain resources. The legal definition of the ranking of water uses (in Algeria and Tunisia, for example) determines the differences in price depending on the sector.

- Creation of intersectorial coordinating organizations or authorities at the government (e.g. National Water Council) or local (e.g. river basin) level. The hydrographic basin (or occasionally, the aquifer system) is the most appropriate physical management unit and the field of a management authority should correspond as closely as possible to them. These organizations should not be solely consultative but endowed with the power of decision and coordination functions should be defined at an interministerial level rather than attributed to an administration with sectorial competence. Coordination may be limited to public investments, notably in the field of pluri-annual planning of equipment (Master plans...), or be extended to the acts of other semi-public or private economic participants, by means of regulatory or financial intervention (authorizations, subsidies, credit...).

- Creation of consultative or deliberative institutions grouping the various public and private participants involved in the management of a given resource unit (river basin, aquifer). Their competence might include objectives of water development plans or schemes funded by the State, local authorities or groups of users, the 'flow allocation' to be reserved in certain rivers, definition of quality objectives, or even day-to-day management depending on the circumstances (restrictions in times of drought, etc.).

It goes without saying that in the case of border crossing river basins, or even aquifers, joint management is also quite desirable but requires political agreement at a national level.

Technical means

The numerous means mentioned above (4.2) usually provide only partial, local and occasionally temporary solutions. Therefore, for integrated water management, their application must be organized and coordinated – planned – in an optimal way, in space and also in time, for all uses, starting with the harmonization of actions on supply and demand, by coordinating, for example:

- efforts both to save water and reduce losses in urban networks, and increase water production and distribution;
- efforts to improve irrigation efficiency and those aimed at reusing drainage water, or to increase pumping of aquifers overcharged by excess irrigation water;
- efforts to increase output of treatment plants and the development of uses for waste water.

Economic and financial means

- Macro-economic criteria may be used to determine allocation of resources having different exploitation costs between productive use sectors with different added values (agriculture, industries...) or more widely between productive use sectors and the 'consumer' uses (food, hygiene and socio-cultural uses).

- Market mechanisms may contribute, up to a certain point, to this distribution, notably in the form of renting or transfer of water rights. However, it may be necessary to regulate the market to an extent which depends on the socio-economic policy of each country.
  From this point of view, an increase in the commercial proportion of water used, by means of distribution networks, may be appropriate, in conjunction with an attempt to balance exploitation accounts of the public water distribution services.
  Given the particular circumstances (shortage of water as a result of economic conditions during periods of drought) of the negotiated transfers of water between unequally vulnerable use sectors might be a means of modifying water distribution adapted to average situations (transfer of water from the energy or industrial sector to agriculture or community supply, for example).

- Price policies concerning water and commercial services or, more widely, the fiscal policies determining the charges passed on to the costs (taxes, fees) may be a means of distributing costs between unequally valorizing water use sectors (example: different prices for water distributed to tourist businesses, industry, populations or agriculture, in Algeria and Tunisia), without affecting the objective of overall financial balance. Prices may also be used as an incentive to save water by accentuating already generalized progress in most of the countries in the region.

- The 'polluter = payer' principle, backed up by funding of pollution reduction efforts financed by its application, has proved effective in industrialized countries. Its measured and evolutionary application, adapted to situations, could usefully complete public efforts to combat pollution.
  From the same angle, a certain readjustment of costs brought about by water conservation efforts – whose costs are not necessarily proportional to the quantities of water saved per sectors – could be the result of the application of a 'water waster = payer' principle: charging of fees for 'excessive consumption' in relation to fixed standards to finance water conservation efforts.

Educational and informative means

Consciousness-raising and informing all those involved in water management, especially users, is essential for effective application of regulatory, technical or financial means. This includes everything from education in school, to communication using all modern audiovisual means. The 'water culture' deeply rooted in many countries of the region offers a favourable terrain for necessary evolution.

***

Integrated water management, in the widest sense, means bringing together and 'orchestrating', as well as possible, all these means, and harmonizing the powers of decision: public and private, central and local, general and sectorial. It also involves integrating water management into the economic and environmental policies.

In general, the more the demand for water approaches and, a fortiori, exceeds conventional resources, as is already the case in several countries in the region, the more water management and policy objectives become indissociable from the objectives of socioeconomic and development policies, notably agricultural policy and food independence objectives.

5 Conclusions and suggestions

After this brief analysis of the situations and problems concerning water in the OSS region, followed by a summary of conditions, ways and means of water management capable of facing it, we shall conclude with suggestions.

- Despite a generally advanced state of knowledge concerning the resources, improvements are possible and desirable in most of the countries, not only to increase quantity but also to improve evaluations of exploitability and to better determine the vulnerability of the resources, their regimes and qualities to the impact of economic activities.

  Particularly in countries with exploitation rates which are already high and destined to increase (the Maghreb, Egypt), this knowledge should be more systematically analysed in the form of management models, whether the resources be renewable or nonrenewable, applied not only to the conception of development projects and exploitation plans but also to management control. This involves increased systematic monitoring of the resources (discharge, levels, quality parameters) by means of well adapted observation networks and the storing of the results in data bases.

- An effort must also be made to improve the knowledge of current uses of water and their passed evolution: statistics on the quantities removed and consumed – per source of supply, sector, resource unit (basin) and economic zone, on usage outputs, on discharges and treatment plant output to be updated periodically.

- In the particular case of the river basins or aquifers shared by several countries, the grouping of resource and use data in joint, open and regularly updated data bases would be timely for facilitating joint management.

- Projected water demands should be increasingly based on interactive previsional supply and demand models calculated according to different socio-economic development scenarios.

- A general macro-economic analysis of public and private expenses related to water – control and production, supply, treatment and drainage, etc. (investments, operating costs), would be appropriate in order to enable the evaluation of their relative weight in the national economy and compare their passed evolution to the necessary provisions in the mid and long term. An increase in all these costs greater than that of the GNP is likely in most countries.

- The development of national water accounting systems based on physical and financial data, according to coherent territorial and sectorial references, could facilitate the choices of water policy and management decisions.

- An exchange of experience on feasibility criteria and results obtained from various operations acting on the supply or on the uses implemented hereto in the countries of the region (or even in other countries) to equate water supply and demand (developments, transfers, desalination, reuse, water conservation, etc.) would be of great comparative usefulness and would be very instructive.

  To a certain degree, the situations and solutions used in the countries or provinces where the natural water shortages are the most acute represent the future for the countries in a less critical state. The experience of the first former may be enlightening for the others. This grouping of information and experience could take the form of an 'expert macro-system' gathering technical and economic data on the operations analysed, and usable in the supply/demand models mentioned above.
- The planning of development projects to control, exploit and supply water, to which 'master plans' still too often restrict themselves (the name of which, 'resource planning', being, moreover, indicative of a unilateral point of view) must be enlarged to water economics in its entirety, including uses and demand. This must not be limited to the conceptual of coordinated projects but be extended to their implementation, and include, to a varying degree, interventionism or incentives from public authorities, market mechanisms under various constraints, and making users responsible, as a function of both the socio-economic policy of each country and specific needs for the management of water resources as a 'common good', inseparable from the management of the environment.
- In allocation policies for limited water resources, the question is posed everywhere of the share which should be attributed to agriculture, the sector consuming the greatest quantities of water but producing the least added value. This question is inseparable from the degree of food self-sufficiency targeted by the socio-economic policy of each country and level of public subsidy allowed for irrigated agriculture.

  Be that as it may, it will be increasingly more difficult, in a viable water economy, to maintain the price of irrigation water much lower than its cost, a policy which does not encourage water conservation efforts nor improvement in efficiency, as indicated in the 1992 World Bank report on world development [131]:

  > *Stop subsidising the use of resources*
  >
  > *Subsidies which lead to environmental damage by encouraging the use of resources are common. It would be a good thing, from both an economical and an ecological point of view, to eliminate subsidies which encourage the consumption of coal, electricity, pesticides and irrigation water. These reforms will require a great political will as the subsidies generally benefit politically influential people or aim at attaining objectives such as food self-sufficiency or rapid industrialzation of the country.*

  It may appear preferable, in any case, to support irrigated agricultural production by means of aid to farmers (subsidies for products, fiscal policy...) other than subsidising the price and cost of water.

- When part of the resources used by agriculture corresponds to attributed and recognised water rights, associated or not with private property or ground collective, and when these rights are transferable (in other words, when there is a 'water market', similar to the 'Water Bank' which operates in California), sale of water rights, at quite a high price, by farmers could constitute a means of reducing the proportion of the resources allotted to agriculture which is not a very valorizing use, whilst enabling farmers to invest in order to improve the efficiency of irrigation, thus to maintain their production and their income by using less water.

- Water rights and legislation must be adapted, in so far as need, in order to facilitate both public regulatory or financial interventions, and possible market mechanisms.

- Water conservation must be encouraged by the joint implementation of technical assistance, financial incentives (pricing) and education.

In conclusion, 'water problems' in the OSS region are not uniform: they differ in nature and acuteness from country to country.

Several countries in the region are among the most advanced in the world in a new water economy and a management of the shortage tending towards a zero increase in use of natural resources and towards an increasing partial disconnection of water uses in relation to these resources.

In other countries, the main problem – common to many tropical developing countries – is related not to the scarcity of natural resources but to the scarcity of resources which their low level of socio-economic development enables them to exploit. A common management of exploitable resources and demand is required, in order to minimize the cost of ensuring a vital minimum supply of water – notably drinking water – to increasing populations, the costs to be distributed among users, taxpayers and possibly external money lenders.

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