THE NORTH WESTERN SAHARA AQUIFER

BASIN AWARNESS

ANALYSIS AND OUTLINES OF THE REPORTS ON THE WATER FUTURE NEEDS IN THE NORTH WESTERN SAHARA

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Introduction

The three countries of North Africa (Algeria, Libya and Tunisia) have been facing since the sixties vital stakes of economic, social and environmental nature, relating to the satisfaction of their growing needs in good quality water, particularly in the driest regions, namely the sub-Saharan and the Saharan regions, where the aquifer systems of the **Intercalary** Continental **Shelf** (I.C.S.) and of the **Terminal Complex** (T.C.) make up, if not the unique, but at least the main water resource. As early as 1972, the S.W.R.N.S. (Study on the Water Resources of the North Western Sahara) conducted by the UNESCO for the account of Algeria and Tunisia, had assessed the potentials of these aquifers and simulated their behaviour in front of an increasing demand in favour of different sectors of development in these regions. **The confrontation of the demand at that time with the offer from these aquifers** had resulted in the perspectives of a wide exploration of the resources up to the horizon of 2000. In 1983, the RAB study allowed to update these perspectives and to bring forward the corrective actions judged necessary for the preservation of the operation balance of these aquifers. In 2001, the ASSS project, sponsored by the Observatory of the Sahara and the Sahel « OSS », had as an assignment to review the situation of the aquifer systems of the North Western Sahara and to proceed with exploratory simulations about their reactions towards a demand, which is called to increase considerably in the long term.

The evolution of this demand during the coming decades made the object of three national reports, which tried to identify this evolution, as far as the various usages were concerned, based on assumptions that integrated the guidelines of the plans and the development objectives of each country. These three reports have been motivated by a national logic and have not adopted the same proceedings.

This report proposes to analyse first, as objectively as possible, both from the point of view methodology and results, each report, and to proceed thereafter with a general synthesis in order to reach some converging points towards the optimisation of the exploration of this "shared resource".

It is to be pointed out that these reports have been elaborated, analysed, amended and finalized, with the approval of the three concerned countries.

1ST PART

ANALYSIS OF THE REPORTS ON THE WATER FUTURE DEMAND IN THE NORTH WESTERN SAHARA

I – A L G E R I A :
ANALYSIS OF THE REPORT ON THE WATER FUTURE NEEDS IN THE NORTH WESTERN SAHARA

The purpose of this report is to estimate the demand in water for the Algerian Sahara regions, in the long term; it has referred to the early studies on the aquifers of the North Western Sahara in Algeria and Tunisia (ERESS 1972 and RAB 1983). It falls, besides, within the framework of the guidelines and objectives of the present Algerian national policy for development.

1 – Methodology elements

The data and information used in the projections are either taken from census operations, studies and national or regional investigations, or, in the absence of some of them, fixed by the author on the basis of a standard approach.

The projections of the various needs in water are expressed, taking into account the growth of the population in the zones at stake. For strategical reasons, the neighbouring populations to these zones outskirts were taken into consideration in the calculations, because, in due course, these populations would be forced to have recourse to the aquifers of the Intercalary Continental Shelf and of the Terminal Complex, object of these investigations.

Hence, in 1998, the total population of the study zone was 2,485,371 **inhabitants** (including nomads), namely the double of the population estimated in 1983 in the RAB study. Through applying the annual decreasing rate of **2,2 %** between 2020 and 2030, the projected populations will reach the values listed in the Chart 1.

Chart 1. Projected population in the Algerian Sahara zones

Year	1998	2000	2010	2020	2030
Population	2,485,371	2,631,277	3,395,943	4,33,688	5,346,249

Two sources for the overestimates of this population can be underlined:

- The extension of the study zone to cover the peripherical population, which presently uses other water resources than those of the I.C.S. and the T.C.
- The 2,2 % growth rate, taken into account for the period between 2020 and 2030 is most probably very high, considering the positive evolution on the socio-economic conditions and the customs which are guided towards a demographic transition as mentioned by the author himself.

The review of this rate downwards would lead to results, which are probably more realistic.

2 - The results

2.1 - The future needs for drinking and industrial water

Based on the WHO standards as "adapted" to the conditions of the region, some assigned shares of **150 l/day/inhabitant for the town dwellers and 80 l/day/inhabitant for nomads** have been adopted (with the following breakdown: **70%** for home consumption, **20%** for industry and **10%** for the town hall needs). Thus, the needs for home and industrial water

would revolve around **908 millions of cubic meters in case of a weak assumption and 1025 millions in case of a strong assumption by 2030**. The chart 2 gives the evolution of these needs.

Chart 2. The future home and industrial needs for water from the I.C.S. and the T.C. (In millions of m^3) in the Sahara zones in Algeria

	1998	2000	2010	2020	2030
Net needs	398	419	533	671	830
Total needs (W.A) *	**457**	**483**	**610**	**756**	**908**
Total needs (S.A)**	**457**	**483**	**630**	**812**	**1025**

** (W.A.) = Weak assumption, including losses*
***(S.A) = Strong assumption, including losses*

There is obviously, in these projections, an **over evaluation** of the needs, even in case of a weak assumption (**908 millions for 5.3 million inhabitants**). For comparison sake, Tunisia has in 2002 more than **10 million inhabitants** and **consumes** for the whole of its domestic and industrial needs **less** than the volume allocated to the populations of these Sahara zones. The needs per capita as applied to the dry zones, called to increase nonetheless in a context where the resources of good quality water, are becoming scarcer and scarcer, could be reasonably reviewed downwards. Furthermore, there has been no consideration to have recourse to the non-conventional waters, to cover certain usages, to account for the review downwards of the estimated needs.

2.2 – The future needs for irrigation water

For all the Algerian Sahara, the irrigated agriculture would have exceeded in **1998 150,000 ha**, covering **60,000 ha** of palm trees, **35,000** of market gardening and **60,000 ha** of cereals. For the **zone** exploiting the waters of the **I.C.S. and the T.C.**, the irrigated surface is presently of about **100,000 ha**. The evolution of the water consumption for the irrigation of the irrigated perimeters has not been linear because of the changes in the strategies that occurred during the last thirty years.

During the 70-80 decade, this consumption reached **16.8 m^3/s** only (with a growth rate of 1.1 %) whereas, based on the weak assumption of the ERESS in 1972, it was scheduled to reach **25 m^3/s**.

Between 1981 and 1998, the continuous fictive flow, worked out by an investigation, reached **55.3 m^3/s** (with a growth rate of 6.8% per year), whereas the farming statistics, based on different considerations, assessed these intakes at **82.8 m^3/s**. The total deficit is estimated at 13.86 **m^3/s**.

The assessment of the future needs for irrigation water takes into account the perspectives of the agricultural development in these zones, aiming in particular at:

- Rehabilitating the existing oases,
- Developing the small size and medium size peri-urban farming fields,
- Extending the "company's" cereal cultivation, based on a net endowment of **0.36l/s/ha** for the large development (LD), and a net endowment of **0.64 l/s/ha** for the small development (SD).

Considering the losses which would bring these endowments to **0.5 and 0.9 l/s/ha** and the extension in the irrigated areas, as per the two assumptions, a weak one and a strong one, namely 60,000 ha for the first case and 120,000 ha for the second case by 2030, the

calculated additional needs for irrigation water, have increased through time, as shown in the chart 3.

Chart 3. Additional needs for irrigation water (m^3/s)

By the end of	2000 Actual deficit	2010	2020	2030
Strong Assumption	13.86	31.6	58.02	89.06
Weak Assumption	13.86	23.6	36.96	53.46

Expressed in terms of volume, the share of the irrigated farming needs would thus reach in **2030**, **1.686 millions of m^3/year** in case of a weak assumption and **2.800 millions m^3/year in case of a strong assumption**.

A gain of 20 % in the volume as far as irrigation is concerned, would entail a decrease of the total needs by 8 to 11%, which is quite achievable, through mastering the losses in the transportation and distribution networks on one hand, and through adopting the regional standards that are appropriate to the cultivation systems, on the other.

2.3 – The total future needs for water

Considering the assumptions that are presently selected for the future development of various usages of this resource, the total needs of the Algerian Sahara regions, using exclusively or partially the I.C.S. and T.C. aquifer resources would reach by 2030, **162 m^3/s in the case of a strong assumption and 123 m^3/s in the case of a weak assumption**. The evolution of these needs is detailed in Chart 4.

Chart 4. Total future needs of the Algerian Sahara regions For water from the I.C.S. and T.C. (m^3/s)

By the end of	2000	2010	2020	2030
Strong assumption	69.8	92	125	162
Weak assumption	69.8	83	101	123

In terms of volume, the total needs would go from about **2200** Mm^3/year presently to the volumes expressed within the allowance of strong and weak assumptions of **3880** Mm^3/an and 5100 Mm^3/year.

Besides, it is quite important to point out that the quality aspect of the waters, raising already serious problems in certain localities, was not taken into consideration in these projections. Still, the determination of this quality is closely related to the over exploitation of the aquifers at stake and its impact is double folded:

- A negative economic impact as a result of the decrease, more or less important (10 to 50 % if compared to the yields obtained with good quality waters) and the degradation of the market selling quality of the obtained products.

- An environmental impact which is equally negative, through the salination of the soils and the superficial sheets (ref. the incurred risks in the annex).

II – L Y B I A :
ANALYSIS OF THE REPORT ON THE PRESENT EXPLOITATION THE FUTURE NEEDS FOR WATER FROM THE HAMADA EL HAMRA BASIN

Libya was not covered either by the ERESS study (1972) or by that of RAB (1983). Furthermore, the report did not refer to any strategy or perspective, whether old or recent, relating to the development of water resources or their exploitation in this country.

1 - Methodology Approach

After a brief setting forth of the characters of the national environment in which irrigated agriculture is deployed, the main water consuming sector, the author underlines the scarcity of the data and information liable to be used in the assessment of water consumptions by the households, agriculture and industry and adopts, consequently, a standard approach, to estimate the present and future consumptions of this resource in the various sectors, proportionally to the population growth.

2 – Present water consumption

Based on the total present irrigated area estimated at **44,000 ha** including 12,753 ha as developed perimeters, and on an average general endowment of **12,275 m^3/ha** (Libyan National Committee of Water Resources), the present consumption of irrigated agriculture would be around **540 millions m^3/year**. This report underlines that, under the diversity of the agro-climatic situations of the Libyan Sahara space, this endowment per hectare is, by far, inferior to the theoretical needs calculated through applying various empiric formulas. This difference is accepted and justified by water saving which is supposed to be entailed by the sprankling (for cereals) or localized irrigation techniques.

However, several remarks can be put forward, in this respect in relation to the small size of this endowment for numerous situations and to the risks that it entails in the concerned desertic milieus both to the cultures (low yields) and the soils (salination in the absence of satisfying the needs for salt leaching, ref. the incurred risks in the annex).

In relation to the households present water consumption, a need for **170 l/day/inhabitant** was considered, which corresponds for a population of 995,000 inhabitants (in 2002) to a demand of **57 million m^3/year**. We have, here, most probably an exaggerated estimate of the water volumes necessary to meet the real needs of these populations.

Concerning industry, reduced to some activities, which are not heavily consuming water, its needs totalled **5.1 million m^3/year**.

Thus, **the total present water consumption** from the concerned aquifers in the Libyan Sahara zones would be of around 602.5 **million m^3/year**.

3 - Estimates for the future needs for water

2030 makes up the selected and target horizon for the sectors altogether. The calculation of the needs is based on the population growth, estimated during the 1995 census, with **an annual growth** during 1984-1995 of **2.8 %**. This rate was applied to all the projection period (2000-2030) without considering the strong probability to witness a decrease in this rate, as time passes by, as a result of the demographic transition, under the effect of the improvement of the socio-economic conditions of the concerned populations (school

attendance, sanitation …) Consequently, the projections of the needs for water for the whole of the sectors are significantly overestimated.

3.1 – Needs for irrigation water

For the agricultural sector, the overestimation source does not lie in the endowment of the water volume per hectare (**12.275 m^3/ha**), which is rather weak, but in the extension of the irrigated areas, proportionally to the population growth, on the basis of an endowment of 44.22 **ha for 1000 inhabitants**. Furthermore, the water saving liable to be achieved through adopting new techniques of localized irrigation, more adapted to the desertic environments than the sprankling technique presently used, is not taken into consideration. Thus, the farming needs for water would go from **540 million m^3/year** at the moment to **1260 million m^3/year in 2030** (chart 5).

Chart 5. Future needs for irrigation water

Horizon of	Population x 1000 inhabitants	Irrigated area	Needs for water Mm^3/year
2002	995	44,000	540
2010	1319	58,000	716
2020	1750	77,000	750
2030	2320	103,000	1260

3.2 – Needs for household water

Based on needs of **200 l/day** per capita during the 2000-2010 decade then of **170 l/day** during the period between 2010-2030, the water volumes necessary to meet the household needs grow according to chart 6.

Chart 6. Needs for household water

Horizon of	Population x 1000 inhabitants	Water volume Mm^3/year
2002	995	5
2010	1319	96
2020	1750	128
2030	2320	170

These needs are enormous, because they are over assessed as far as the real consumption is concerned, however, they are just necessary to cover the non-extravagant needs, in a desert environment, where "every drop of water should count". These needs could be reduced by half without bearing prejudice to the population comfort.

3.3 – Needs for industrial water

They are relatively low if compared to those of the other end uses. They increase in proportion to the population growth based on an estimate of the real consumptions. Chart 7 takes up the evolution of these needs.

Chart 7. Needs for industrial water

Horizon of	Population x 1000 inhabitants	Water volume Mm^3/year
2002	995	5
2010	1315	6.6
2020	1750	8.8
2030	2320	11.6

3.4 – Total needs for water

Chart 8 takes up the evolution of the sums of the needs in different sectors for water on different horizons. Around 2030, they reach the volume of 1442 **million m^3**, with a **global deficit of 740 million m^3**. The problem is to make up this shortage with new resources.

Chart 8. Total needs for water in the Libyan Sahara zones Using the I.C.S. and T.C. aquifers (Mm^3)

Horizon of	Total needs	Available %	Balance
2002	602	400	- 202
2010	820	715	- 105
2020	1087	700	- 387
2030	1440	700	- 740

On that horizon, **the additional needs of 840 Mm^3/year** correspond to a flow **of around 27 Mm^3/s**. This corresponds to an annual need per capita of **620 m^3/year**. This endowment is however low, compared to the critical threshold of 1000 m^3/year/inhabitant (still questionable, to a large extent), but it is, by far, superior to the present offer per capita in Libya.

In front of these growing needs, measures of a different nature and at different levels (legislative, institutional, technical and economic) are proposed to make up for this deficit.

However, the quality aspect (not to be ignored) of the water and its evolution in time and space are not taken up at all in this report.

Besides, considering the scarcity of these resources, the most determinating challenge would be, in future, relating not to the growth of the offer but especially to the optimisation of the demand in water by the different users for a better physical and economic efficiency.

In terms of irrigation, the working allowance is still large with numerous solutions for water saving and the improvement of its productivity. In this respect, the projection drawn out by this report keeps in the present status the water using modes in the irrigation fields with all the technical deficiencies and the low economic yield resulting there from.

But, if it is already possible presently to improve the use of this source through capitalizing the Libyan success stories and those of the countries in the region in this respect, it is sure that the coming thirty years will witness agronomic technological jumps which are more performing than those available today. These considerations were not taken into account in the analyzed report.

III – T U N I S I A :
ANALYSIS OF THE REPORT ON « THE PRESENT USE OF THE DEEP WATER SHEETS IN THE SOUTH OF TUNISIA AND THE PERSPECTIVES »

The purpose of this report is to assess the future total needs for water in the Tunisian south, exploiting the I.C.S. and T.C. aquifers. This exercise is based on the results of the ERESS studies (1972) and those of RAB (1983) as well as on the present status of the intakes in these aquifers and it is part of the perspectives of the socio-economic development strategies in the different considered zones.

1 - Methodology Approach

The report started by an evaluation of the present water intakes for the various sectors in order to proceed, then, with the projections based on a growth rate of the population by **3 %**, of a fixed objective for the touristic development and the satisfaction of the needs of the irrigated perimeters, considered as of today as illicit, without extending significantly the irrigated areas, and an increase by 30 **%** of the industry needs.

2 - Evolution of the water demand up to the year 2000

The Master Plan for the Exploitation of the Water and Soil Resources (SDERES) of the regions in the Tunisian South and the Water Master Plan in the South (PDES) were the first applications of the results of the ERESS study in 1972, through the analysis of the water consumption systems as well as the analysis of the water global consumption which are forecast in the region. We already knew that between 1950 and 1970, the evolution of the intakes in the I.C.S. and the T.C. and the aquifer of the Jeffara, reached the critical threshold of exceeding the feeding of these aquifers. For this reason, it was recommended **not to draw down the sheets** to a point exceeding **60m** deep.

Chart 9. Intakes of the different uses in the three aquifers (I.C.S, T.C. and Jeffara) for the Period 1965-1973

Irrigated areas (ha)	Irrigation water intakes m3/s	Total intakes m^3/s
15.520	8.02	8.8

The use of the water for farming represents then **91 %** of the total of the intakes and in 1973, the irrigated surface (estimated in the PDES) in these zones reached **18,237 ha** (PDES) with an exploitation flow of **9534 l/s** and a **deficit evaluated at 3.6 m^3/s**. Concerning the other water usages, they required, on the same date, **470 l/s**, with the following breakdown:

- 165 l/s : For urban consumption
- 60 l/s : For tourism (excluding the intakes of Nefzaoua supposed to be nil in the report)
- 245 l/s : For industry

Several development strategies for these regions were worked out and the actual achievements made within the framework of a sustained policy for economic growth, supported by various concomitant measures, gave the following results:

- The population of the two big regions of the South East and the South West recorded between 1975 and 1989 a global increase of about 50 %, going from **786,000 to 1182,000 inhabitants**.
- A growth of the tourism sector and the chemical industry,
- An extension of the irrigated areas to reach **25,000 ha**, including 6,800 (6000 in Nefzaoua and 800 in the Jerid) created by non-authorized private initiatives, on illicit drillings.

This evolution was translated by **total intakes** reaching in **1981, 7300 l/s**, namely a flow inferior to the needs estimated by the PDES at 12020 l/s. For **1999-2000**, the authorized intakes, estimated at **16800 l/s**, were reached and slightly exceeded only because of the intakes that are considered as illicit (the authorized intakes were of about 13,300 l/s and the illicit intakes reached 4800 l/s). However the report does not bring along an assessment of the fictive continuous average present flow. It would fall within the range of **17.64 m^3/s to 25.2 m^3/s**, depending on an endowment of **0.7 l/s/ha** or of **1 l/s/ha**.

Throughout this period, the pressure developed on this resource did affect the quality of the waters (salinisation) and increased the speed of the sheets draw down, namely those of the T.C. which are most solicited. **Since 1993** an annual average of **5 m/year draw down was experienced**. The cost price of the water and consequently its productivity in irrigated agricultural activities were affected accordingly.

3 - The perspectives for the future needs for water

The guidelines for the development of the considered zones are based on an economic enhancing of this scarce resource by the different sectors, with concomitant important measures, including the institutional reinforcement.

3.1- Needs for household water

For Kebili, Tozeur, El Hamma and Tataouine zones, the total population reached **315,081 inhabitants**. By applying a growth rate of **3 %** to this population until 2016, this population would reach **603.701 inhabitants**. With household needs estimated at **75 l/day/inhabitant** for the families connected to the distribution network and at **40 l/day/inhabitant** for the families which are not connected (they are a minority), with a general average of **65 l/day/inhabitant**, the **household needs** for water would reach **14.32 million m^3/year**.

Although these needs represent only a small portion of the total needs, one should point out that the growth rate of 3 % for the population, applied in the projections, is very high. Already the intermediate census by INS achieved in 1999, gives to the whole of the South West region in Tunisia an average of **1.45 %**, which does reflect the demographic transition which most of the regions in the country are experiencing, considering the general improvement of the living conditions. This low rate of growth will most probably, if not decrease, at least remain unchanged; accordingly the needs for household water would be, by far, lower than those estimated in the report on the basis of a 3 % rate.

3.2- Needs of the tourism sector for water

The number of beds estimated by the end of **2016** in the regions of Jerba-Zarzis and Kebili-Tozeur is 107,800.

Based on an endowment of **700 l/d/bed** and an average occupation rate of 70 %, the net endowment will be reduced to **490 l/d/bed** and lead, according to the report, to consumption

needs amounting to 192 **million m^3/year**. We have here, first of all, a calculation error to be pointed out. As a matter of fact, the volume should be **19.2 million m^3/year**. Furthermore, the applied endowment can be considered as excessive if we place this touristic activity in its desert context.

3.3 – Needs for water by the Industrial sector

These needs wee estimated on the horizon of the projection, based on an arbitrary increase by 30 % in the present consumptions, which gives a flow of **320 l/s**.

3.4 – Needs for irrigation water

If we consider the regional ERR values (with an average of 2100 mm/year for Kebili-Tozeur and 1700 mm/year for Gabès) the gross needs calculated for each hectare, including the losses, will reach the values listed in chart 10.

Chart 10. Needs for irrigation water m3/ha/year

Zones	Gross Needs	Losses
Tozeur	27,200	12,512
Kebili	27,200	12,512
Tataouine	19,400	8,900
Gabès	18,800	12,000

These losses occur all the way through the transportation of the water, starting from the water source up to the plot of land. They are very high, which reduces the global efficiency of this resource down to about 50 %. Obviously, there is a large room for water saving.

The projections were conducted based on the satisfaction of the future needs of the irrigated areas, at present, namely:

- Authorized area:
  7200 ha in the Jerid
  7700 ha in Nefzaoua
  400 ha in Jeffara
  3100 ha in the Big South

- Illicit areas to be, from now onwards, taken into account:
  6000 ha in Nefzaoua
  800 ha in the Jerid

Namely a total area of about 25.000 hectares.

Furthermore, the eventual extensions of these perimeters would not exceed 5000 hectares, which means that the report seems to favour the rehabilitation of the existing perimeters. The evolution of the needs, as per this scenario, is given in the chart 11.

Chart 11. Needs for irrigation water Mm^3/year

Horizon of	Water Volume
2000	448
2010	417
2020	375

The decrease of the needs, as the time passes by, corresponds to the expected control over the water losses.

3.5 – Water total needs

Based on the projection of the constant needs for the industry, the growth of the household, agricultural and touristic needs, the total needs will increase in the future as per the chart 12.

Chart 12. Total water needs Mm^3/an as per the report

Horizon of	Water volume
2000	555
2010	580
2020	594

Chart 13. Total needs Mm^3/an after correction

Horizon of	Water volume
2000	469
2010	438
2020	406

If we take into account the calculation error at the level of the touristic needs, these needs will be reduced as per the values listed in the chart 13.

Despite this correction, there still exists substantial water savings to be achieved through a significant improvement of the water productivity.

2ND PART

SYNTHESIS OF THE RESULTS OF THE THREE REPORTS

The implementation of the projection of the needs for water during the next decades in the considered Saharan regions is not easy, considering the multitude of the factors, which should be taken into account, especially for the horizon of relatively remote projections. Numerous rough approaches were therefore necessary in the accomplished works according to the situations and the available data. Furthermore, in the absence of a common methodology, the reports have come to results, which cannot be easily compared.

- At the level of methodology, the three authors based their work on the population growth on one hand, and in certain cases on the national strategic objectives relating to the development of the target regions, on the other.

- At the information level, the availability of the necessary data to the projections of the needs for water, could not be secured in the same way, in the three areas, and each author was obliged to adopt assumptions and standards that are deemed to be adaptable to the national situations.

- At the strategic level, there exists, between the reports, obvious differences in the clarity of the perspectives, for the long-term development, as far as the target zones in the three countries are concerned.

Faced to these multiple constraints, the authors have adopted then a generalized standard approach in most of the cases for all the zones, although they are quite different.

Chart 13. Comparison of the data which served
For the calculation of the needs

Data / Country	Population growth rate	Household standard	Industrial standard	Touristic standard	Agricultural standards	
					Technical	Extension in terms of surface
Algeria	High	Very high	Absence of standard	Non expressed needs	Very high	Very high > 100%
Libya	High	Very high	Absence of standard	Non expressed needs	Low	Very high > 100%
Tunisia	Very high	Appropriate	Absence of standard	High standard	High	Low 20%

The foregoing has resulted in expressing rather maximum "needs" (overestimated in the assumption called weak assumption) and not "correct" needs, considering the limits of water supply and an optimisation of the exploitation of this source.

The chart 14 sums up all the elements, considered in the projections, as well as the reached results.

Chart 14. Summary Chart of the standards and water needs

Basic data and needs	**ALGERIA**	**LIBYA**	**TUNISIA**
Population growth rate	2.2 %	2.8 %	3 %
Total population in 2000	2,631,272	995,000	376,206
2010	3,395,943	1,319,000	-
2016	-	-	603.701
2020	4,333,688	1,750,000	N.A
2030	5,346,249	2,320,000	N.A
Household water endowment per inhabitant	100 to 200 l/d/ha including the industrial needs	180 l/d/inhabitant	65 l/d/inhabitant
Household needs per year Mm^3/year			
In 2000	483 Mm^3 (including losses)	57 Mm^3	8,925
2010	610 Mm^3	96 Mm^3	-
2016	-	-	14,32
2020	756 Mm^3	128 Mm^3	14,94
2030	908 to 1025 Mm^3	170 Mm^3	-
Touristic endowment l/d/bed	N. E.*	N. E.*	700l/j/lit
Touristic occupation rate	N. E*	N. E*	70 %
Number of beds in 2000	N. E.*	N. E.*	54.320
2010	N. E*	N. E*	89.200
2016	N. E*	N. E.*	107.800
2020	N. E.*	N. E*	-
2030	N. E*	N. E*	-
Needs for water in tourism sector Mm^3/year	N. E.*	N. E.*	
In 2000	N. E*	N. E*	9,6
2010	N. E.*	N. E.*	-
2016	N. E*	N. E*	19,2
2020	N. E.*	N. E.*	-
2030	N. E*	N. E*	-
Industrial needs for water l/s	Included in the household water volume	N. E*	320
Industrial needs in terms of volume Mm^3/year			
in 2000	280	5.1	10,25
2010	-	6.6	10,25
2016	-	-	10,25
2020	-	8.8	10,25
2030	440	11.6	10,25
ERR mm/year		Piche	
	N. E*	Ghadames 5183	Tozeur 2100
	N. E*	Nalut 3182	Kebili 2100

		Miusrata 2090	
	N. E*	Hun 3921	Gabès 1700
Selected culture			
Dates	N. E*	N. E*	0.7
Dates + Arbo	N. E*	N. E*	0.7
Dates + garden culture	N. E*	N. E*	0.7
Dates + Arbo + garden culture	N. E*	N. E*	0.6
Arbo	N. E*	N. E*	0.5
Network efficiency	N. E*	0.68	0.54
Gross needs per ha m3/ha			
			Tozeur 27200 including 12512 of losses
	Big Development (BD) 0.5l/s/ha	12,275	Kebili 27200 including 12512 of losses
	Small Development (SD) : 0.9l/s/ha		Tataouine 19400 including 8900 of losses
	-		Gabès 18800 including 12000 of losses
Irrigated area in 2000	100,000	44,000	25,200 ha
Authorized area in 2000	-	-	18,400 ha
Illicit area in 2000	-	-	6,800 ha
Irrigated area in 2016	-	-	25,200
In 2020	-	77,000	25,200
2030	160,000 to 220,000	103,000	30,000
Water needs for total irrigated area Mm^3	Strong Assumption		
In 2000	69.8	540	448
2010	92	716	-
2016	-	-	396
2020	125	950	375
2030	162	1260	?
Total needs for water (drinking water, touristic, industrial, agricultural) Mm^3/an			
In 2000	2207	602	469
2010	2886	819	-
2016	2901	-	438
2020	3942	1087	406
2030	5109	1442	?

N.E = Not expressed*

This chart calls for the following comments in relation to the needs of the various sectors:

1 –Assessment of the needs for household water

1.1- Population growth rate

The population growth was worked out based on very high growth rates for the three countries. However, there are big differences between the demographic conditions in the target zones, in the three countries.

For Algeria, the adopted regressive rates are reasonable considering the expected social evolution. However, the fact of including the peripherical population in the study zone, in the prospections of the needs for water, makes up an over assessment source of these needs.

Concerning Libya, applying the rate of 2.8 % for all the decades is also a source of over assessment of the needs for water, knowing that a regression of this rate is expected in these regions where the starting of a demographic transition could be confirmed during the next decades.

In Tunisia, the latest intermediate census of the population (1999) brought out for the period 1994-1999, an average national growth rate of 1.45 %. For the Southwest, this rate is only 1.15 % and for the Southeast, it is 1.33 % (INS 1999). For the Tunisian South, this rate is therefore inferior to the half of the rate taken into account in the report (3 %), which allows us to review downwards and in a significant way the sizes of the populations on the considered horizons, and consequently their needs for water. It is however relevant to point out that for this country, the average standard for household water, namely 65l/d/inhabitant, is the lowest among the three countries, but it is reasonable and could be adopted for the projections of the water needs of the households in the other countries.

1.2 - AEP standards

For Libya and Algeria, the needs per capita, reaching 200l/day, look obviously very high if one considers the context of these regions. The present rates in the big urban centres in these three countries are below these standards. An endowment per capita of 65l/d/inhabitant, as adopted by the report about Tunisia, increased to 80 l/d/inhabitant, in order to take into account the municipal needs, can be considered as appropriate in a context of scarcity of the water resources. Thus, the expressed needs could be reduced to reasonable levels, without causing a harsh constraint for the normal living conditions in the arid regions.

Starting from these considerations, the needs for water could be fixed at their "fair value" and be fully satisfied in the future. This "fair value" is not necessarily the same value as the one suitable for the other eco-regions, suffering in lower proportions from the scarcity of the good quality water.

2 – The needs for water in the tourism sector

These needs are not expressed in the reports relating to the Saharan zones in Algeria and Libya. They are however strongly felt in Tunisia with an increasing number of beds. The selected standard of 700l/d/bed, properly used in other touristic contexts, deserves to be sensitively reduced in the Sahara regions, through implementing concomitant measures relating to the installation of water distribution equipment (taps) and calling the tourists' awareness to the issue of water saving.

One should point out, besides, that the needs of this sector in the Tunisian South amount only to about 20 million cubic meters and not to 200 million as mentioned in the report, following a calculation error. Thus these needs remain less than 5 % of the total needs.

3 –The needs for water in the industrial sector

These needs are relatively less important compared to the total needs but they vary considerably from one country to the other (440 Mm^3 for Algeria, 12 Mm^3 for la Libya and 10 Mm^3 for Tunisia by the end of 2030).

The produced figures are global estimates, without justifying the present consumptions and the grounds for their increase in future. They were increased by 30 % up to the end of 2020 in Tunisia and doubled in Algeria and Libya up to the end of 2030.

In the absence of more information on the national strategies for the development of the industry in these zones, it is not up to the point to issue an appreciation about the put forward projections.

4 – Needs for irrigation water

The present water consumption in the irrigation field dominates to a large extent the consumptions in other usage fields and, in the future, these needs shall still remain for a long time at the front with more than 80 % of the total needs. The relevance of the projections for these needs in the long run will depend then, to a large extent, on the optimisation degree of the endowments according to the economic, social and environmental criteria. From this point of view, the standard approaches, almost generalized to the whole of the zones and cultures, brought forward clashing results, showing obvious excess.

It is true that the reports were not asked to discuss the national strategies in terms of system selection for the cultures and the agricultural production at stake, as a priority. However, one should in this synthesis, point out the big water consuming activities that are not very productive and which cause, above that, damages to the soils (such as Stalinization and congestion). This is the case for example of the development and extension of the irrigated cereal cultivation under pivot "Company's Cereal cultivation". This calls for the vigilance of the plan makers in order to identify the best production systems and the most appropriate speculations for the zones at stake.

Besides, among the wasting items of the water included in certain projections, one can quote the water losses in the transportation and distribution networks. Indeed, for Libya, we can suppose that in the set up projections, these losses are reduced to the minimum from the beginning, considering the endowment per hectare, which is of 12275 m^3 only (the lowest among the three countries). Likewise, for Tunisia, the projections show a regression of the agricultural needs through the decades, as a result of the control of these losses. On the contrary, in case of Algeria, the possibility to improve progressively the water efficiency during the next decades was not taken into account in the made projections.

Besides, the technical standards adopted in the calculation of the irrigation water needs made it that the results were superior to the experimental or practised values prevailing presently in the oases of the three countries. As an example, for the **Tunisian oases**, **the present demands** reach only **12000 to 14000 m^3/ha/year in the Jerid, 14000 to 17000 m^3/ha/year in Nefzaoua, instead of the 27000 m^3/ha adopted in the projections**.

We have here a lot of room for non-negligible water saving to be exploited, by considering the diversities of the situations, the local know how of the oases dwellers and the necessity to satisfy the needs to clear the salts that are loading, at various degrees, the concerned waters.

At this level, we notice that the three reports do not give attention to the problems inherent to the present quality of the water and to the high and obvious risks of its degradation, under the effect of the intensification of the overexploitation of these resources. Already in numerous localities in the three countries, this degradation is a well-established fact and its consequences on the quality of the lands and the yields are well known.

It is therefore necessary in the future to extend the greatest care to this quality aspect in the coming simulations, through integrating the impact of the intakes that are necessary to satisfy the increasing needs of these zones, on the water salinity.

5 – The total needs for water in the Saharan zones of the three countries

The Chart 15 sums up these needs in relation to the targeted populations as well as the needs per capita resulting there from. It calls the following remarks:

i- It is, by far, the Algerian Sahara space which requires the highest needs in terms of water volume. Libya comes in the second position with one third of the Algerian needs whereas the Tunisian zones come very far behind with less than 7 % of the total needs of the three countries.

ii- These differences come naturally fom the disproportionate sizes of the targeted populations in the three countries, on one hand, and the presently irrigated areas and their large extension in Libya and Algeria, on the other. For the Tunisian South, the total needs decrease through time as a result of the expected water saving brought along by the control of the water losses and the weak extension of the irrigated areas.

iii- Another noteworthy difference appears at the level of the needs per capita and their evolution in time:

- All the needs per capita in the Sahara zones of the three countries are certainly superior to the national present consumption per capita
- Libya keeps a stable need per capita around **600 m^3/year**
- Algeria's needs per capita range between **850 and 950 m^3/year** with an increasing tendency in case of a strong assumption
- As far as Tunisia is concerned, it starts with a need per capita of **1240 m^3/year** presently, which suffers, as the time passes by, from erosion, which brings it back, on the horizon of 2030 to **540 m^3/year**.

iv- The total needs of the Sahara zones, using the aquifer waters from the I.C.S. and the T.C. in the three countries, will reach in 2030 about **7,000 million M^3/year** for a total population of about 8.5 **million inhabitants**, namely an average need per capita for the whole of the region of **820 m^3/year/inhabitant**. Agriculture remains the biggest water consumer with a total irrigated surface covering **288,000 ha** in the case of **a weak assumption and 353,000 ha in the case of a strong assumption in 2030**.

Chart 15. Summary of the future needs for water in the zones exploiting the I.C.S.and the T.C. aquifers in Algeria (A), Libya (L) and Tunisia (T)

Year	Population x 1000				Total needs Mm3/year				Needs Per Capita m^3/year		
	A	L	T	Total	A	L	T	Total*	A	L	T
2000	2631.3	995	376.2	**4000**	2207	602	469	**3278**	**840**	**600**	**1240**
2010	3395.9	1319	505.6	**5220**	2617*/2901**	819	438	**4158**	**851**	**620**	**860**
2016	-	-	603.7	**-**	-	-	-	**-**	**-**	**-**	**-**
2020	4333.7	1750	680	**5700**	3490*/3952**	1087	406	**5445**	**910****	**620**	**650**
2030	5346.2	2320	750	**8416.2**	3879*/5109**	1442	406	**6957**	**950****	**620**	**540**

** In case of a weak assumption*
*** In case of a strong assumption*

If these results translate the national political guidelines in this respect, they would mean two important different tendencies in the objectives:

i- The reports on Algeria and Libya seem to recommend an exploitation without constraint of the available resources with an important extension of the irrigated agriculture, whose lifetime is questionable but it satisfies the immediate needs in the way of basic agricultural products and jobs and includes the risk of bearing prejudice to the aquifers at stake and the soils. From this angle, neither the economic viability nor the preservation of the natural resources seems to be taken into account. In a sense it is an « **extensification** » tendency.

ii- The report on Tunisia, despite a strong assumption of the population growth, seems to recommend rather the rehabilitation of the existing primers with some « **intensification** ».

But the three reports have overlooked, at various degrees, the vital necessity to save water. It would have been quite useful to develop in the three countries together with the strong assumptions, "very" weak assumptions" (offering, by large, more constraints than the assumptions called "weak" which were taken into consideration) for these needs in all the sectors. It would have allowed disposing of a wide range of simulation results of the impact of the pressure on the aquifers at stake and enabled each country to work out its strategic options for the future exploitation of these waters, with a full knowledge of the case.

In the same manner, it would allow to pave the way for a **transition from the development policy of the water availability towards a policy of a wise management of the demand** for this resource, based on the principles of the sustainable development which reconciles the economic efficiency, the satisfaction of the social needs and the preservation of the natural resources which, in this precise case, consists in extending, as long as possible, the exploitation life of these hydric "non renewable" resources.

Thus, beyond the water saving issue, which is after all quite possible to achieve in the different fields, developed earlier, the answers to the optimisation questions of the exploitation of the aquifers hydric resources in the I.C.S. and the T.C. in the zones of the North Western Sahara would lie in:

- The placing of the water issue at the centre of a global and integrated project for the socio-economic development of these zones, within the framework of national strategies providing for the selection of the functions of these zones at the economic, social and environmental levels, favouring the complementarity of the specificities, the aptitudes and the comparative advantages, among the different regions of each country, but also considering the shared responsibility between the three countries in order to better enhance the value of these waters.

- The urgency to raise a question about the place, the roles and the types of irrigated agricultures to be considered in these regions which suffer from multiple constraints, in view of the predominance of the needs of this sector for water.

Indeed, within the framework of a multiple subject and regional refelxion, it is important to:

- Draw the conclusions from the present Sahara agriculture which is faced with numerous local, national and international stakes,

- Redefine the irrigated agriculture to be developed in future in these zones, while considering the tendency for scarcity in the water resource, the competition of the other

sectors, the necessity to create jobs, to feed the local populations and to protect the environment against all forms of degradation.

Considering the experience of the three countries in the "Saharan irrigated agriculture" which was exclusively an "oasian agriculture" but which was extended thereafter to new irrigated perimeters in greenhouses or "in the open", it seems that the extension of the irrigation over extensive perimeters, even under pivot, which is not performing at the economic and environmental levels, has no future.

On the contrary, a new type of agriculture inspired from the oasian experience concentrated on the best natural sites (weather, soil, water quality) on an intensive basis, targeting agricultural products and agri-food activities with high added value, with as motto not "the water saving" but the increase of its productivity supported permanently by an appropriate scientific research and a vulgarisation system at hand, can be considered and implemented while taking into account:

- The high risk for the water degradation and its impact on the lands,
- The spacing of the needs and the risks, in accordance with the development of the various sectors, consuming water,
- The evolution of the development costs of the resource and its viability.

GENERAL CONCLUSION

General Conclusion

Starting from a fundamental data, namely the ad eternum non availability of the water resource in the North Western Sahara (Drying up of the springs and certain drillings at a first stage, the progressive disappearance of the artesianism at a second stage and the increasingly deep pumping and the deterioration of the water quality at a third stage,) the first principle which should guide any development in the North Western Saharan regions in the three countries at stake, would be to extend the life of the exploitable parts in the I.C.S. and T.C. aquifers, as long as possible. The improvement of the productivity of this resource, in the widest meaning of the wording, should make up the permanent concern of the plan makers.

It is within the framework of a sound management of the "common resource" with a "shared responsibility" complying with the future needs in a fair and strict way, but without any excess, that the future of the water in the considered zones should be contemplated.

The three reports on Algeria, Libya and Tunisia have forecast the needs for water in these zones, during the forthcoming decades, based on "unconstraining" assumptions even in case of the assumptions called weak, based on:

- High growth rates for the populations, which do not, or do to a very small extent, take account of the starting, already under way, of a demographic transition.

- Technical standards and needs per capita for each sector, which are over assessed if we consider the eco-region context and the tendency towards the scarcity of the resource and the increase of its production cost.

- An extension of the irrigated areas in Algeria and Libya, which do not take into account the technological progress margins to be made now and more substantially in the future in the irrigated agriculture field.

The foregoing has entailed global needs per capita that are however relatively low in relation to the threshold of 1000 M^3/inhabitant/year, but which are superior to the national average present endowments in the three countries. There would be in 2030 in the whole of these zones 8.416 million inhabitants who would need 7000 million M3 of water each year.

Concerning the most water consuming sectors, two different strategies seem to emerge from these projections:

- The first one, developed by the reports on Algeria and Libya, adopted a maximum extension of the irrigated perimeters in order to satisfy the obviously increasing needs, in terms of agricultural products and jobs, but apparently without focusing on the improvement of the water productivity in this sector or bothering about the ecological impacts. This would be an « **extensification** » strategy.

- The second one, which the report on Tunisia covers, favours especially the rehabilitation of presently irrigated areas, without a significant extension, with in addition, the targets to control water losses and increase the viability of this source. This would be a concentration and « **intensification** » strategy.

The high needs expressed in these reports, especially those brought along by the strong assumptions, will surely allow to force the simulations for the behaviour of the aquifers to

reveal the tendencies and the risks of such an overexploitation but could hide the real limit range of a wise exploitation of this resource, through integrating the technological and especially agronomic jumps which are surely achievable in the near future, as well as water savings which could be secured by:

- The reduction of the losses in the transportation and distribution networks,
- The improvement of water efficiency per each plot of land while considering the needs for salt clearance,
- The adoption of new technological packages,
- The control and the development of substitution energies for the desalination of low quality waters and the automatization of the irrigation.

For the future, it becomes obvious and urgent to manage the scarcity of the resources of good quality underground waters and the competition/tension between the usages in a "holistic" approach, integrating the economic, social and environmental dimensions. In this respect, the elaboration of a trend scenarii for the needs in this resource should be accompanied by the identification of the ecological and social impacts and their spacing, while considering that the human resources form, together with the natural resources, a complex entity working in a system governed by interactions which determine the quantity and quality evolution trend of the whole system.

Based on the foregoing, the exploration of the possible common future is naturally possible only through the identification of a convergence towards a regional consensus, on a strategy and coherent common objectives, especially in the irrigated agricultural field. At this level, three action levers can be considered:

- The management of the water at the level of the plot of land and the agricultural exploitation field, as long as the agricultural exploitation field remains the essential core for decision making as far as the technical, micro-economic and environmental issues are concerned.
- The management of the water between the different usages at the local, regional and national levels. It is at this level that the decisions, relating to the coordination, the integration and the general coherence of the water using through institutional and political measures, are made.
- Economic and financial measures favouring the production sectors, channels and systems, judged as priority for each country.

In this perspective, several investigation channels can be developed within a regional and multiple subject frameworks.

- A detailed analysis of the agricultural production systems in the considered zones in order to clarify their water consumptions, their productions and their present economic viability. This would allow the identification of the most performing channels and cultures liable to be reproduced and developed.
- An investigation about the chemical quality of the waters in the whole of the region and the implementation of a follow up system for the quality of these waters according to the draw down of the aquifer levels.
- A study of the perspectives of the technical, economic and social opportunities for the water transfer in both ways North – South and South – North, according to two scenarii:

- A scenario of "Natural Catastrophe" for "strategic" water shortage,
- A scenario of redeploying the irrigated cultures those are not appropriate to the desert zones (cereals for example).

- A study about the development perspective of the saving technologies, the perspectives of the recycling and the desalination of the water using the substitute energies available in the concerned zones.
- Identification of the research themes at the regional level about the future of the irrigated agriculture in the North Western Sahara, in the perspective of the scarcity of the good quality water resources.

ANNEX

The minimum usable standards in a scenario
For the calculation of "fair needs" for water

Needs for irrigation water in sub-desertic and desertic zones	17,000 m^3/ha (Including the clearance portion)
Needs for drinking water	80 l/jd/inhabitant
Needs for water in the tourism sector	350 l/bed/day

The incurred risks in relation to the degradation of the water quality

Space scale Time scale	Cultivated Plot	Agricultural Exploitation	Irrigated Perimeter	Hydro-pedological System
Short term (1-2 years)	Collapse of the yields according to the water salinity	Low yields, superficial salination of the soil		
Mid term (3-5 years)	Accumulation of salt in the soil and regression of the cultures	Generalized salination of the soil. Pauperisation of the population	Salination of the low zones of the perimeters	
Long term (10-30 years)	Abandonment of the sensitive cultures	Degradation of the soil proprieties Abandonment of the affected plots	Generalized salination of the perimeter	Raising and salination of the superficial sheets
Very long term > 30 years		Abandonment of the exploitation	Abandonment of the perimeter	Salination of the low zones that are ill drained

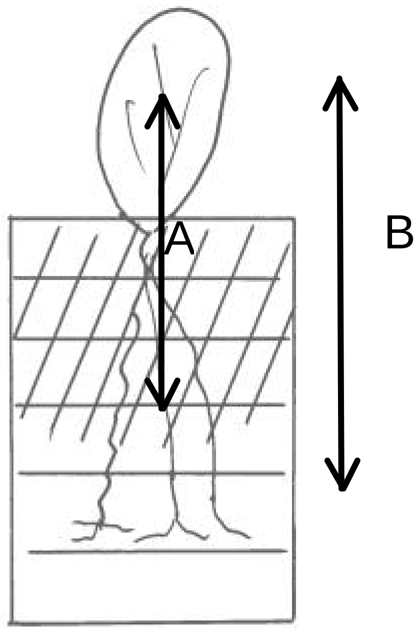
Sources: The future of the water – a new challenge for Tunisia (Avenir de l'eau: un nouveau challenge pour la Tunisie. I.T.S. TUNISIE 2002.)

Effect of the salinity and the irrigation water volume on the yields of a tomato cultivation (source: CRUESI-TUNISIA)

Water salinity g/l Water volume	0.2	1.5	2.4	3.5
	Yield t/ha			
675 mm	44.4	43.2	26.8	13.1
1070 mm	68	66.1	40.8	34.5

Relation between the irrigation volume and the soil salination

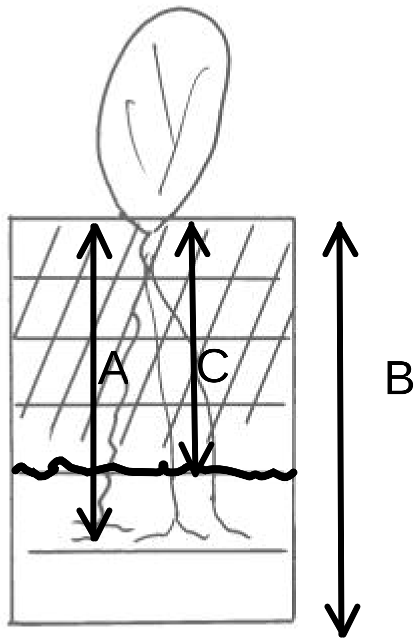
1. Profile of a cultivated soil



A = Depth of the rooting system

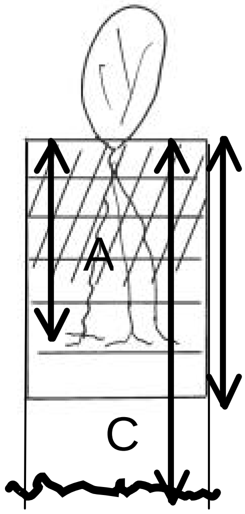
B = Total depth of the sound soil

2. Low irrigation dose (to cover the needs of the evapotranspiration only)



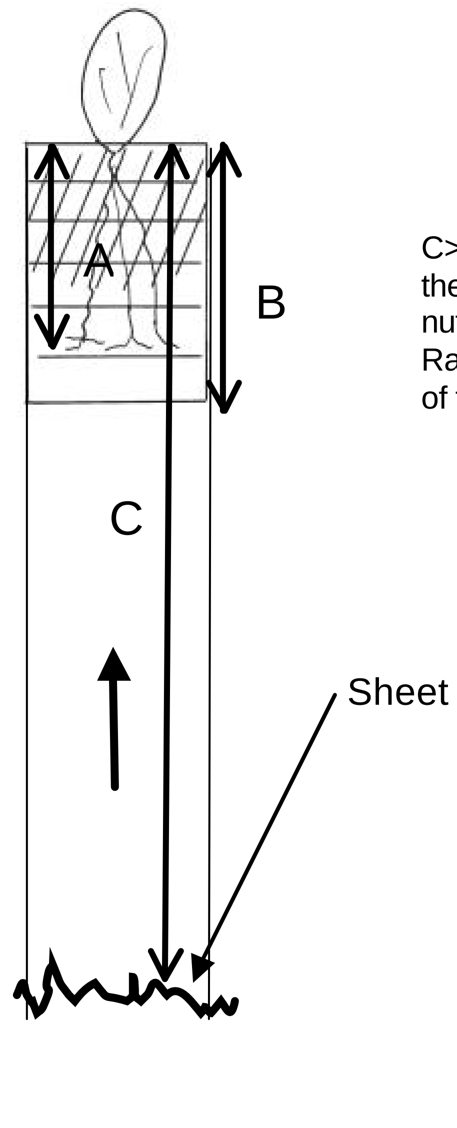
C = Depth of the soil humidification front by irrigation
C = A Accumulation of salt in the profile and forwarding of stocks from one year to another

3. Appropriate dose to cover the l'ERR needs + clearance portion (10 to 30 % of ERR)



C > A and B => Salt clearance and natural or artificial draining

4. Overdose = to cover the needs of ERR + clearance portion > to the draining capacity of the soil



C>>>B => Clearance of the salts and nutriments,
Raising and salination of the superficial sheet