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# Technical perspectives of irrigation efficiency improvement in the oasis systems - cases of southern Tunisia

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**Abstract.** The irrigated area in Tunisia covers around 400,000 ha (8% of the total suitable agricultural lands). Under periodical water shortage conditions an expertise in water management was acquired. Several research works, focused on the main aspects of irrigation, allowed a real advance in promoting water use efficiency. However, the situation is still rather precarious in the southern part of the country. Oases heavily depend on the availability of underground water resources. Due to water resources scarcity and deficit, the irrigation efficiency in these regions is a key element for their development. Since the PDES (Water Master Plan of the South) in 1979, the irrigation scheme has been subject to several works, to cope with the oasis expansion. The rehabilitation works aimed to overcome water losses within the distribution network. The most works were those undertaken within the framework of APIOS project (Project of irrigated area improvement in Southern Tunisia oases). Indeed, the concerned area concerned covers 23000 ha in the provinces of Gabes, Gafsa, Kebilli and Tozeur. Since 1996, the rehabilitation works, still in progress, have been already completed in 90 out of 153 (58,82%) initially-scheduled oases. Nevertheless, a continuous decrease in fossil underground water resources and their quality deterioration under intensive pumping threaten the weak ecological equilibrium of those regions. On the other hand, surface irrigation remains the main irrigation method widely used within parcels. Research review showed that farmers are still practicing over-irrigation, high amounts of water are applied and lost over the root zone, also through earth ditches. Such behaviours hamper the rational water use. Also, risks of shallow water table rise and soil salinization become permanent. Under such conditions of water management, the sustainability of these ecosystems is definitely compromised. In this regard, the improvement of water distribution efficiency has to be followed by a complementary research work, aiming to enhance irrigation efficiency within farmer's parcels. The introduction of different improved surface irrigation methods should be implemented. Their adaptation to irrigation technical conditions that prevail within the oasis (water quality, water flows and available charge) has to be validated. This couldn't be reliable without further involvement of farmers and their commitment to modernize irrigation practices but they are still reluctant despite the government subsidies and encouragements for water-saving equipments within parcels.

**Keywords.** Efficiency – Oasis – Irrigation – Improvement – Sustainability – Tunisia.

## **Perspectives techniques de l'amélioration de l'efficacité de l'irrigation dans les systèmes oasiens – cas du Sud de la Tunisie**

**Résumé.** En Tunisie, la surface irriguée couvre environ 400.000 ha (8% de la surface agricole utile). Dans un contexte de pénurie d'eau périodique, une expérience significative a été acquise en matière de gestion de l'eau. De nombreuses recherches, portant sur les principaux aspects de l'irrigation, ont permis de faire des pas en avant dans la promotion de l'efficacité d'utilisation de l'eau. Toutefois, la situation reste encore assez précaire dans le sud du pays. Les oasis dépendent considérablement de la disponibilité de ressources en eau souterraine. Vu l'insuffisance des ressources en eau et le déficit hydrique, l'efficacité de l'irrigation dans ces régions représente un élément fondamental pour leur développement. Depuis le lancement du PDES (Plan directeur de l'eau du Sud) en 1979, plusieurs travaux ont été entrepris dans le périmètre irrigué pour faire face à l'expansion des oasis. Les travaux de réhabilitation ont eu pour objectif la réduction des pertes d'eau sur le réseau de distribution. La plupart des travaux ont été réalisés dans le cadre du projet APIOS (Amélioration de Périmètres Irrigués dans les oasis du Sud tunisien). La zone intéressée couvre 23.000 ha dans les provinces de Gabes, Gafsa, Kebilli et Tozeur. A partir de 1996, les travaux de réhabilitation, encore en cours, ont déjà été achevés dans 90 des 153 (58,82%) oasis visées initialement. Cependant, une réduction continue des ressources en eau souterraine fossile et la détérioration de la qualité à cause des pompages intensifs constituent une menace pour l'équilibre écologique fragile de ces régions. Par ailleurs, l'irrigation de surface demeure la principale méthode d'irrigation, largement répandue dans les parcelles. Les

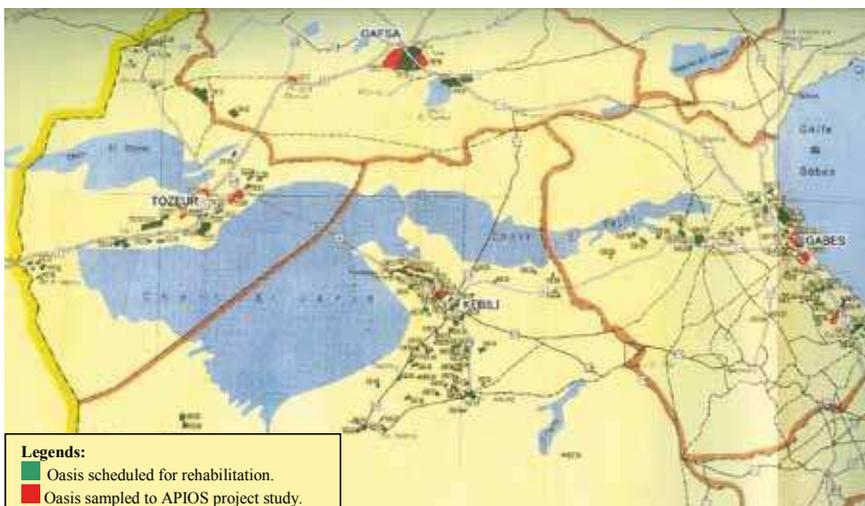
*résultats de ces recherches ont montré que les exploitants pratiquent encore une irrigation excédentaire et que de grandes quantités d'eau sont apportées et perdues dans la rhizosphère, aussi à travers les fossés. Tout cela ne fait qu'entraver l'utilisation raisonnée de l'eau. Egalement, la remontée de la nappe superficielle et la salinisation du sol deviennent un risque permanent. Dans ces conditions de gestion de l'eau, la durabilité de ces écosystèmes est compromise. Parallèlement, l'amélioration de l'efficacité de la distribution de l'eau doit être soutenue par une recherche visant à accroître l'efficacité de l'irrigation à l'échelle de la parcelle. Il serait nécessaire d'introduire différents équipements pour améliorer l'irrigation de surface. L'adaptation aux conditions techniques de l'irrigation qui prédominent dans les oasis (qualité de l'eau, flux de l'eau et charge disponible) doit être validée. Pour atteindre un tel but, il faudrait promouvoir la participation des exploitants et leur engagement dans la modernisation des pratiques d'irrigation. En effet, les exploitants sont encore réticents, malgré les subventions du gouvernement et les mesures d'incitation pour l'acquisition d'équipements permettant des économies d'eau à l'échelle de la parcelle.*

**Mots-clés.** *Efficience – Oasis – Irrigation - Amélioration – Durabilité -Tunisie.*

## I – Introduction

Over the centuries, the existence of the southern Tunisia oases (see Fig. 1) has always been conditioned by the availability of water resources and by the irrigation techniques deployed. De Hass (2002) defined the oases as agricultural sites in arid environments where agriculture is normally not possible without irrigation. Created at first, around natural sources, the Tunisian oases observed a real mutation in their landscape. Thanks to the development of drilling techniques, the very deep drillings replaced natural sources which dried up under the growing water demand that became progressively unable to overcome to the irrigated area extension.

Since the 1980s, within the framework of the Master Plan of Southern Water (PDES), the irrigation knew an important development. After the rehabilitation of the hydraulic infrastructures within the old traditional oases, the commitment of the authorities was focused on the enhancement of the irrigation efficiency. Several research works undertaken in these regions showed an alarming balance on the water management in the oases. Significant water losses were still occurring in the parcels where the competent authorities' efforts should be focused on farmers. This article is focused on the perspectives of irrigation efficiency improvement within parcels where the experience feedback often showed that, besides the technical aspects, the extension and awareness building on the water saving are a crucial tool that has to be certainly intensified.



**Figure 1.** Localization of Southern Tunisia Oasis (adapted from SAPI, 2005).

## II – Water management issue in the oases

The major underground water resources, supplying the southern Tunisia oasis, are not renewable. It gathers the North-Western Sahara Aquifer System (NWSAS), this basin covers an area of 1 million km<sup>2</sup> located in the western part of North Africa, about 80,000 km<sup>2</sup> in Tunisia, 700,000 km<sup>2</sup> in Algeria, and 250,000 km<sup>2</sup> in Libya. In Southern Tunisia, water of the SASS is used through the Continental Intercalary (CI) and the Complex Terminal (CT) aquifers. The depth varies between 60 and 2800 m for the CI and from 100 to 300 m for the CT.

Under intensive pumping and overexploitation, the continuous decrease in the piezometric level has led to the complete drying up of natural sources. Water became gradually more expensive due to the rise of pumping costs, and to the deterioration of water quality (i.e. water salinity from CT reached 6 g/l in Douz Eastern Kebili). Furthermore, the multiplication of illegal wells (see Fig 2) accentuated this phenomenon.

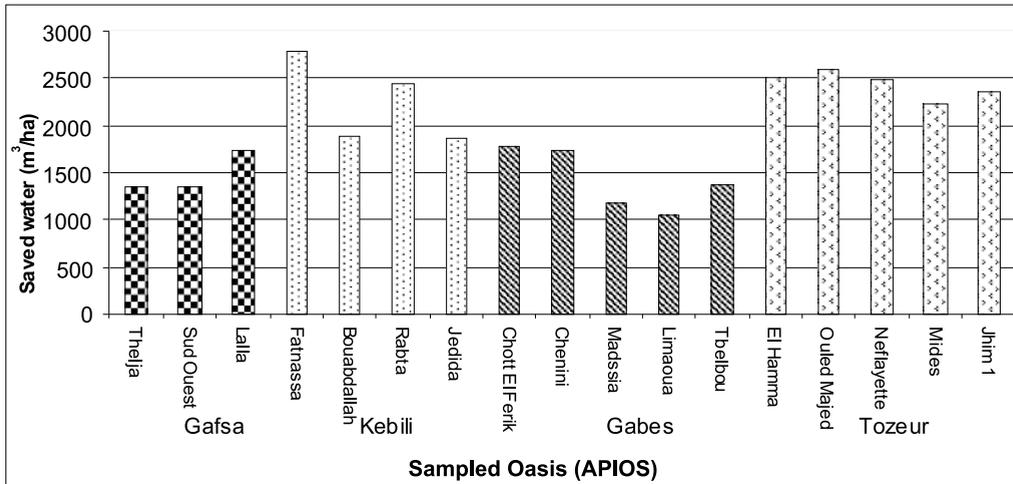


Figure 2. Illegal drilling supplying private oasis in Kebili (photo Till Loeper).

## III – Efficiency improvement within farmers' parcels

To optimize irrigation water supply in these regions, the APIOS project feasibility study considered the crop water requirements following four different empirical methods (Pan class-A; Penman; Blaney Criddle; Espinar). The modified Penman method under FAO recommendations was finally adopted but there are no important differences observed between the four methods for the southern governorates (Gabes, kebili, Gafsa, Tozeur). Therefore, crop water requirements within the oasis systems were valued to 1025-1510 mm/year in Gafsa, 1150-1669 mm/year in Tozeur, 1170-1670 mm/year in Kebili and 820-1240 mm in Gabes (SAPI, 2005). Based on these estimations, the rehabilitation works that aimed to enhance distribution efficiency within the Southern Tunisia oasis allowed 25 to 30% saving of water losses within the rehabilitated oases.

The irrigation interval was shortened by 3 to 2 weeks (SAPI, 2005). Therefore, the inventory of 17 sampled oases that observed rehabilitation works led on the distribution network revealed a total saved water amount around 7,500,000 m<sup>3</sup> (see Fig. 3). The crop intensity was enhanced from 143 to 164%, the crop yield was improved by 35% for palm dates, 36% for olives.



**Figure 3. Impact of irrigation network rehabilitation on the delivered water amounts in southern Tunisia (Adapted from SAPI, 2005).**

Despite the rehabilitation works undertaken, water shortage persists in the summer season when the network distribution capacity reaches its limits; on the other hand, the extracted water volumes still exceed the real water requirements, and such over-irrigation supplies groundwater table that rises to rather unacceptable levels (Prinz *et al.*, 2005).

Nevertheless, water consumption in farmer's parcels remains very high and their productivity does not show any significant improvement. Traditional irrigation method remains the main hindrance to the irrigation efficiency improvement in the field; this subject revealed an obvious need for irrigation modernization.

Mechergui and Van Vuren (1998) showed for the case of *Rahmat* oasis in Kebili that many inconsistencies occurred during irrigation. In the absence of any specific recommended method, each parcel managed the water in its own way. Some farmers did not any levelling inside the parcel which leads to considerable water loss. Whilst the required dose was 50 mm, observed irrigation amounts were 100 to 300 mm and more.

In 1970, the CRUESI (Research Center in Use of Saline Water to Irrigation) research works had been the initiator in the matter; several studies targeted the improvement of water management within parcels efficiency. Determination of crop water requirements (e.g. *Alfalfa*) under oases climate had been undertaken using lysimeters notably in experimental parcels of Helba in Tozeur. These works had been followed by many other and it was evident that even the research works led on the drainage topics had been faced to take into account the irrigation aspects. The relation between them both is being often close in such complex environment.

For the case of Ibn Chabbat Oasis in Tozeur, Goussi (1996) studied the contribution of excess water providing from private wells to the rise of the water table, which led to permanent risks of water logging and soil salinization. Ounis (1999) demonstrated the impact of drainage deficiency on the crop yield and putted in evidence the inadequacy of the leaching fraction during irrigation. Such conditions led to positive salt balance and a chronic water logging, cultures damages had

been observable especially at the downstream part of the oasis due to a low slope. Kacem (1990) put in evidence a significant flow between parcels during irrigation, the cumulative water surplus coming towards parcels near to the lower part oasis, where alarming water logging signals became evident.

Louhichi (1999) showed for the case of Gabes oasis, that terminal irrigation network settlement (until 400 m) allows to economize 14344 m<sup>3</sup>/year. The average total cost is 523 DT, which equals to 0,036 DT/m<sup>3</sup>. Whereas the unitary mobilization cost is 0,091 DT/m<sup>3</sup>, the difference between both becomes more significant, when the calculation takes into account several depreciation costs (storage facilities, exploitation fees). Total mobilization cost reaches then 0,416 DT/m<sup>3</sup> equalling 10 times the saved cost (0,036 DT/m<sup>3</sup>). This demonstrates that water economy is more efficient, if it passes through the water demand control. On the other hand, the actual method of water ratemaking commonly used within the oasis is fixed and the amount to pay (DT/ha) takes into account only the irrigated surface as standard. Sghaier (1995) claimed that such water rate marking doesn't valorise water irrigation. A rate marking policy covering the economic cost of water should be instituted. The water amount used every irrigation by farmers has to be the main standard of these watermarking policy.

The traditional irrigation method still widely used by farmers within the oasis (see Fig 4), this water over application leads to hamper water and brings out the shallow water table rise. Other consequences of such irrigation method could be an outflow between parcels. Risks of water logging become evident, particularly for parcels located downstream the oasis.



**Figure 4. Traditional irrigation method inside a farmer's parcel in Kebili oasis (Photo Nizar Omrani).**

The introduction of water-saving equipment in the oasis parcels remains rather limited. Low technical know-how of local farmers hampers their multiplication. Furthermore, some pre-conceived ideas inhibit the fully commitment of farmers to invest in such equipment. Most of them consider that *“as soon as the water enters the parcel, we cannot qualify the excess as losses; sooner or later it will be available to crops”*. Nevertheless, the Ministry of Agriculture, Direction

of water –saving in irrigated agriculture is making huge efforts to develop the irrigated sector (at national scale, the contribution of the irrigated sector is supposed to increase, at long term, from 32% to 50% of the total agricultural production). The water-saving programme applied to parcels has progressed since 1995. Several financial subsidies were granted to equip the irrigated schemes with modern and performing irrigation systems: 40%, 50% and 60% respectively for the large, medium and small farms (Hamdane, 2004). The situation is rather complicated in the Southern Tunisia oases where the traditional irrigation method is still the most common despite the above-cited government subsidies. The traditional methods prevailing in the parcels cause important water losses, especially along unlined feeder and when farmers widely overtake the irrigation period fixed by the calendar.

In this respect, the evaluation made during the faisability study for the APIOS project in 1996 revealed unlined feeder water losses higher in the newly created oases, where the soil is still very sandy and highly permeable (see Fig. 5). These losses had been estimated to average about 25% per 100 m length. Nevertheless, this rate is not proportional to the canal length. At the *Rahmat* oasis, Mechergui and Van Vuren (1998) measured canal losses of 30 to 60% over a length of 400 to 1000 m. The occurrence of such losses depends exclusively on the canal management by farmers.

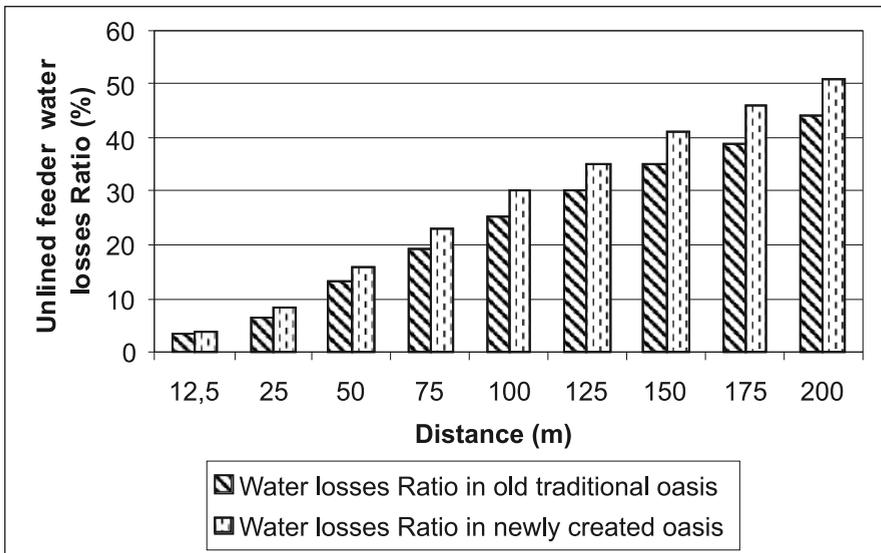


Figure 5. Evolution of water losses along unlined feeder in Southern Tunisia Oases (Adapted from SANYO, 1996).

Added to these losses, the operator drills that having significant repercussions on the water turn. The opening degree of the outlet isn't the same in each water turn. On the other hand, the operator decides of the opening degree of the outlet, that having significant repercussions on the water turn.

## 1. Technical Constraints

There are several constraints within the oasis systems. Water losses occur along the distribution system, starting from the pumping station until the parcels entrance. These losses affect especially connections between seguia transects where joints (Nardyl matter made) don't present a good resistance to high temperature and often break out inducing huge water losses. Due to such dysfunctions, the water flow becomes lower and contributes to increase water temperature

through the distribution network. The problem is more acute in the oases supplied by artesian wells on the CI. In the absence of suitable proportions of water mixture between CT and CI water, during electricity cuts, only high-temperature (60-70°C) CI water runs within the network, which obliges the farmers to let it directly runoff to drainage canals to avoid crop burning.

## 2. Oasis Extension

The oasis extension is one of the most important current challenges to face within the next coming decades. The multiplication of private parcels occurs always at the oasis periphery. Their water consumption is very high, as twice as that of the public irrigated area. This induces important water wastage and significant drainage water amounts. The water surplus provides the shallow water table that rises up and leads to water logging phenomena, all the more so the private extensions are mostly located downstream and do not benefit from sufficient differences in level, which allows a far distant drainage water evacuation. Also, salinization risks become very imminent in such water management conditions (see Fig. 6).



Figure 6. Accumulation of drainage water in the oasis depression (Photo: Dieter Prinz, 2006).

## IV – Conclusion

Oases in southern Tunisia are facing a very complex hydraulic situation, characterized by water shortage and by increasingly expensive irrigation water (continuous decrease in the piezometric levels of deep aquifers, pumping operations on the major CT drillings, CI water cooling). On the other hand, the expansion of irrigated area is moving towards the depressions and chotts, the contamination risks by salty drainage water become very imminent. An example is given by the regions of Hssay, Douz and Ziret Louhichi in kebili where the water salinity ranges between 4 and 6 g/l. The rehabilitation of the distribution network allowed saving about 7,500,000 m<sup>3</sup> as in the case of the seventeen oases sampled through the four governorates. The implementation of underground drainage systems also allowed a good drainage efficiency. Nevertheless, even after the improvement of the distribution network efficiency (25 to 30%), considerable water amounts are still lost within the parcels, the research carried out still reveals a low water application efficiency in the parcels, important water losses resulting from inappropriate soil and water management combined to a low farmers' commitment to modernize surface irrigation method

in their parcels. In the absence of any assessment of the social conditions prevailing within the southern oases, notably a permanent dialogue between competent irrigation authorities and farmers who are the main stakeholders in the water management, acting on a strictly technical aspect becomes insufficient to improve irrigation efficiency. It is therefore necessary to intensify awareness raising campaigns on water saving in the parcels. More farmers' categories should be targeted, particularly the owners of small-sized farms.

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