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Water pumping for irrigation in a southern Moroccan oasis

from
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Abstract
Due to the shortage of irrigation water in the traditional system "khettaras[4]" caused by the drought, the farmers of the Jorf area[5] have began to pump the underground water either with collective or individual facilities. Currently, the Jorf area counts more than 240 pumping stations including 4 which belong to cooperatives.

A study was conducted in 2001 with the aim of diagnosing this new type of pumping in this area. A technical and economical assessment of the pumping was done after a survey that concerned more than 50 pumping stations.

After a description of the traditional irrigation system of khettaras, 3 main pumping stations types were identified. Their equipments were studied : engines and motors, pumps, energy, accessories. The way of maintenance and the conception of these pumping stations were criticized.

Using data from the survey, an economical assessment was conducted. Several options were compared. The estimate of the pumping cost according to the total manometric head TMH showed that the use of butane gas mixed with gasoil is less expensive than the use of pure gasoil, but generates more breakdowns of the engine and that an appropriate electrical installation is more economic than diesel engine powered one. Energy saving possibilities was also identified and can be used by the farmers to improve their energy efficiency while pumping water for irrigation.

The maintenance quality and the follow-up of a pumping station affect its performances and therefore the cost of pumping. It is important to provide farmers with technical advice to help them making right decisions. Their organisation in cooperatives and associations facilitate extension activities.

Key words :
Oasis, water pumping, maintenance, energy, cost, cooperative

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[4] underground irrigation system used in the south part of Morocco
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1. Introduction

Until the early seventies, irrigation was practiced in Tafilalet oasis along the ziz river using traditional systems such as seguias and khettaras. The water scarcity caused by the climate change has constrained farmers to adopt new means to mobilize water for irrigation. Wells were then sinked and equipped with pumping stations for both individual and collective use. In the prefecture of Tafilalet there are more than 600 private wells, 60 common pumping stations among witch 40 are managed by cooperatives and 570 khettaras. The technology of pumping stations is relatively new for farmers in this region.

The objective of this study is to get knowledge about pumping stations and the manner in witch they are used. Results can allow significant improvements especially in reducing costs and saving energy.

A survey was conducted in the Jorf district (ca. 100 km south of Errachidia). The major questions to be answered were related to technical, organisational and economical aspects :

- Identification of the households
- Technical characterization of the pumping stations
- Necessary data to compute the cost of pumped water
- Organizational aspects in the case of cooperatives

A databank was initiated to facilitate data treatment.

2. Objective

The objective of this study is diagnosing this new type of pumping in the area. On the basis of a survey that concerned more than 50 pumping stations, a technical and economical assessment of the pumping was done.

3. Material and methods

The study was conducted in the district of Jorf, prefecture of Errachidia, Southeast of Morocco. After a brief description of the site and the traditional irrigation system, the procedure and the results of the survey are presented and discussed.

Characterisation of the site

The climate of *Tafilalet* is semi-arid to arid. The annual rainfall varies between 50 and 250mm and irregularly distributed. Oasis soils are loamy to silt-clay, regenerating from alluvial deposits caused by river floods used for irrigation during the past centuries. The date palm is the basis of life and agricultural activity in the district. Cultivated land is generally located along river banks, in narrow strips in the mountains area and in larger tracts in the oases. The main cultivated crop species are : date palm, olive and apple trees (mountainous), cereals, alfalfa, vegetables and *henna*. Three agro-ecological zones can be distinguished each one is characterized by a particular production system :

- Mountain zone : irrigation derives from perennial waters mobilized using diversion dams. Livestock grazing area, alfalfa and cereals are the main crops cultivated in a two-level crop system in association with olive and *rosaceous* fruit species.
- Intermediate zone : In the hills and valleys at the foot of mountains, it is characterised by an intensive three-level cropping system with date palms as the upper level, olive trees as intermediate one and cereals, forages, legumes and vegetables as the lower level. River floods and springs are used in irrigation.
- Plain zone : Water for irrigation comes from river floods, pumping, *khettaras*, perennial streams and springs and *Hassan Addakhil* dam. A two-level cropping system is dominant with date palm trees and underneath cereals, alfalfa and vegetable crops. Animal husbandry is dominated by *D'man* sheep raised for both milk and meat production.

Land tenure is characterized by small holders (micro-farms). Average farm size is almost 1 ha divided in 3 plots. 90% of the farmers own less than 5 ha. Private ownership represents 95% of land tenure. The remaining 5% belongs to the religious holdings, *Habous*. As shown in table 1, crop production consists mainly of cereals, fruits and forages.

Tab. 1 : Main crop production in Tafilalet (average 1989-94)

crops	average cultivated area	average production [tons]
Cereals	40,000 ha	300,000
Vegetables	1,900 ha	37,000
Beans	1,600 ha	2,400
Henna	650 ha	1,700
Alfalfa	9,000 ha	580,000
Date palms	1.25 M. trees	27,000
Olive trees	1.0 M. trees	13,000
Apple trees	0.4 M. trees	6,000

The livestock is composed of 620 000 cheep, 450 000 goats, 30 000 cattle and 10 000 dromedaries.

Description of the** Khettara **system

The khettara (Fig. 1) is a drain gallery that begins by a well usually sinked near mountain areas where water is available in the aquifer but distant from cultivable soil. Water moves by gravity from this well through the gallery (underground tunnel) to an oasis where cropping is possible.

At the origin well, the depth of water level may be at 20 m. The length of the Khettaras can reach 20 km. To maintain the gallery, wells were sinked each 10 to 15 m. At oasis level, the average flow of the khettara varies between 10 and 15 l/s.

Every khettara is managed by an elected *Cheikh* who is responsible for the maintenance of the gallery and of the distribution of water to the farmers.

The interaction between khettaras and modern pumping is not known. The Tafilalet Agency of Irrigation and Agricultural Development is trying to maintain the last khettaras in work. This task is very labour demanding.

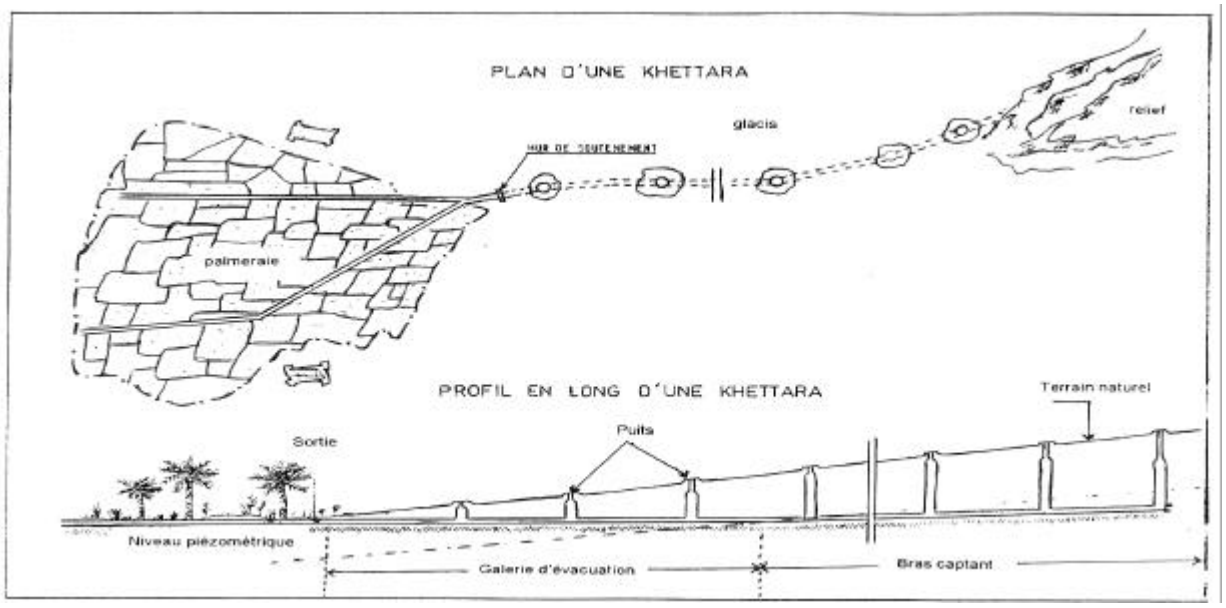

Fig. 1 : Design of a *Khettara*

Procedure of the survey

A questionnaire was prepared and tested before going to farmers. It consists of four parts :

1. Identification of the land holdings : seize, owner, situation, age of the station, main crops, ...
2. Equipment Characteristics :
    i. engine/motor : power, consumption, state, ...
    ii. pump : type, flow, state, ...
    iii. accessories : type, state, ...
3. Data for economical assessment : price for each component, maintenance, energy, ...
4. Organizational aspects of the cooperatives : personnel skills, water pricing, problems

In the Jorf district, there were only 4 cooperatives but 256 private stations. Thus it was dealed only with 50 individual stations chosen to be representative of the whole population. The active participation of farmers and extension agents has allowed making some measures related to water flow and water level in the wells.

A databank was initiated with ACCES program to facilitate the treatment. It consists of several parts each related to one part of the investigation. The statistical program STATITCF was also used to search relations between the studied parameters.

4. Results and discussion

The wells equipped as pumping stations were sinked between 1940 and 2001 with a major part after 1970. Three types of stations were identified :

- Diesel engine – centrifugal horizontal pump : 71% of the cases, small to middle seize (6-9hp), water level does not exceed 29m.
- Diesel engine – vertical axis pump : 19% of the studied stations, p.t.o shaft transmission for power that exceeds 28 hp.
- Electrical motor – vertical axis pump : 10% of the studied stations.

The soil consists on a superposition of clay and sand layers followed by limestone and rocks at about 20 to 30m. The aquifer is located in a thin surface layer (10 – 30m). The depth of the wells varies between 16 and 30m with an average of 24m. Their diameter is 2.1m in average (1.3-2.5m). The only one forage visited has a depth of 132m and a diameter of 0.4m. The water level is influenced by the annual precipitations. In April 2001, it varied from 7 to 29m with an average of 17.65m. 73% of the wells are partially or completely built with reinforced concrete or bricks.

64% of the stations have reservoir constructed with reinforced concrete where water is pumped. 36% of these reservoirs are cylindrical, the remaining are rectangular in shape. Their capacities vary between 0.8 and 45 with an average of 8.8 m^3.

13 marks were found in a population of 82[6] engines (Table 2). Two marks are the most used representing 20.7 and 48.8% of the engines.

Table 2 : Marks[7] of engines that equip the pumping stations

marques	effectifs	%
TAURUS	3	3,65
UNO	2	2,44
ASSAD	3	3,65
DEUTZ	2	2,44
DIPCO	1	1,22
LISTER	40	48.78
MARSHALL	17	20.73
NEMITSAS	1	1,22
PETER	4	4.88
RENAULT	2	2,44
ROTAX	2	2,44
SAME	4	4.88
ROVATTI	1	1,22
TOTAL	82	100,00

92.5% of the pumping stations use gasoil as energy. The electricity is not yet available in the area. For 2 stations, there is a combination of gasoil and domestic gas (butane). 4% only of the stations use electrical energy.

[6] some wells are equipped with more than one engine
[7] the commercial names are given only as technical data.

The power of the engines varies between 6.5 and 53 hp. The most representative are 8hp (19%), 10hp (12%), 12hp (9%) and 27hp (9%). The effective energy consumption was assessed to be :

- for engines (gasoil) : 0,75 – 4 l/h
- for engines that use gas and gasoil (gasoil) : 0,5 l/h (plus gas)
- for electric motors (electricity) : 7-12 kWh/h

5% of the engines have been bought second hand. Their maintenance is relatively expensive.

9 marks of pumps were identified. The 3 most used are :

- Rotax : 53.5%
- Rovatti : 17.7

77.8% of the used pumps are centrifugal pumps. The remaining are axial.
The oldest pumps were bought in 1970. The third of the visited stations are equipped with second hand pumps. The outlet pump diameter is 3 inch in 56%, 2.5 in 20% and 4 in 17% of the studied pumps. The measured water flow varies between 4 and 18 l/s. It depends on water level and well capacity.

Concerning the accessories, 3 remarks can be made :

- the transmission between engine and pump is always ensured by a driving,
- the duct is from steal in 88.1% of the cases. The remaining is from PVC,
- all the stations are equipped with a strainer.

Further more, no pumping station was equipped with safety and measurement means. This makes difficult the technical follow-up of the stations.

Assessment of the cost

To estimate the cost of the pumped water, some assumptions were done :

- amortization of buildings : 25 years
- amortization of materials : 10 years
- degressive amortization method
- data according to farmers and some measures
- the salary of the owner was not taken in account.

Table 3 shows the results witch allow us to make the following deductions :

- the cost of the pumped water each m depth varies from 0.19 to 1.19 MAD/m^3 with a standard deviation of 0.30 and a variation coefficient of 47.8%. The average of 0.63 MAD/m^3 is higher than that estimated for Errachidia in 1995 (0.30 MAD/m^3). The real practiced water price in the area is 20 to 32 DH/h according to the “demand-offer law”
- The unit price varies between 0.008 and 0.38 MAD/m^3/mHMT. The average is 0.021 MAD/m^3/mHMT with a variation coefficient of 40.8%.

Table 3 : Estimated cost of pumped water for 15 stations

Station	Energy	Annual cost MAD[8]	annual pumped volume m^3	**Cost** MAD/ m^3	HMT m	Cost MAD/m^3/ mHMT
1	gasoil	45377	38016	1,19	35,2	**0,034**
2	gasoil	77845	114048	0,68	26,4	**0,026**
3	gasoil	34408	106920	0,32	28,6	**0,011**
4	electricity	66406	213840	0,31	28,6	**0,011**
5	gasoil	58439	83160	0,70	26,4	**0,027**
6	gasoil	47168	42768	1,10	35,2	**0,031**
7	gasoil	21599	38016	0,57	24,2	**0,024**
8	gasoil	21847	61776	0,35	24,2	**0,014**
9	gasoil	45972	47520	0,97	29,7	**0,033**
10	gasoil	26602	44550	0,60	31,9	**0,019**
11	gasoil	16324	44550	0,37	31,9	**0,012**
12	gasoil	26947	35640	0,76	35,2	**0,022**
13	gasoil + butane	9249	49896	0,19	25,3	**0,008**
14	gasoil	19941	47520	0,42	29,7	**0,014**
15	gasoil	34485	35640	0,97	33	**0,029**

5. Conclusion

Due to frequent droughts, groundwater levels have fallen to levels more than 20 meters or more below the level existing 25 years ago. The problem is worsened by the run-off of the surface water and that of *khettaras*. The farmers have opted for groundwater pumping. Diesel pumps are the most used because electricity is not available.

This relatively recent mean to mobilize groundwater is necessary accompanied with some technical, economic and organizational problems. A local survey was conducted to assess the actual situation and make some improvement interventions for the future.

Globally, the design of the stations has not respected the needs of the land holding but a simple imitation of the neighbourhood. The Know-how of the visited farmers is only a result of their experience, they have had no education and training in this matter.

Diesel pumps represent more than 90% of the total equipment. Two of 13 engine marks dominate with more than 69%. The most frequent engine power are 8, 10, 12 and 27 hp. 2 of 9 pump marks represent 69,2% of the total. 77,8% of the pumps are centrifugal.

For the cost of pumped water, farmers pay much more for diesel in comparison to what they would be pay for electricity. Some farmers that use dual fuel (gasoil & natural gas) pay less than electricity but the engines must be adapted.

High maintenance costs were observed with oldest engines and pumps. These costs decrease with the frequency of maintaining operations. The situation can be improved when organizing

[8] 1 MAD # 0.1 Euro

farmers in cooperatives or association of water users even thought organization difficulties may exist in such coopertatives.

As possible interventions to improve this situation, the following measures can be retained :

- Improve policy and institutional support to advance efficient energy and water use,
- Enhance commercial management in rural power distribution in consonance with aquifer/watershed management,
- Plan, design and implement energy and water use efficiency programs through innovative institutional, financial and service delivery arrangements

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