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Fayoum pilot project for the reuse of drainage water for irrigation

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The Fayoum territory is one of the depressions in the limestone plateau of the western Egyptian desert. It lies about 85 km southwest of Cairo (see **Figure 1***), and it stretches over an area of about 400,000 feddans (1 feddan = 1.04 acres). It is a closed basin with an altitude ranging from 24 meters above sea level to 53 meters below sea level on the bed of Lake Qaroun which lies in the north and whose surface area is approximately 3,100 km^2. The present cultivable area is 315,000 feddans. Irrigation water is delivered from the Nile through Bahr Youssef canal and Bahr Hassan Wassef while the excess and drainage water discharges into Lake Qaroun (69%) and Wadi Rayan depression (31%).*

Irrigation water is constantly in short supply in certain parts of the Fayoum. As a result some arable lands lay fallow in summer and other areas are irrigated. This leads to low average agricultural productivity levels in the area.

The overall efficiency of irrigation water use is relatively high compared to water use in the Delta. Nevertheless, the absolute amount of drainage water that is actually drained into Lake Qaroun is too high, causing a rise of the lake levels to unacceptable limits.

To improve the uniformity of irrigation water supply, reuse of drainage water should be initiated. This would contribute to lowering Lake Qaroun levels and providing additional water as supplementary irrigation for existing lands and developing available water for the surrounding expansion areas.

This report is designed to shed some light on such problems and to explain some of the well-suited solutions. The research on which it is based was done under the umbrella of a project study (1985-1987) which was carried out jointly by the Drainage Research Institute (DRI) and the Mediterranean Agronomic Institute of Bari supported by the International Center for Advanced Mediterranean Agronomic Studies (CIHEAM), as part of an Egyptian-Italian project.

An area of about 10,000 feddans was chosen for the project, with a nearby area of 6,000 feddans which might be potentially developed as a result of this study.

A working team from both the Egyptian and Italian sides was formed with specific tasks to study: hydrological, agronomic, pedological and socio-economical studies.

I - Objectives of the project

1. To promote the utilization of drainage water for reclaiming new lands and supplying water to old areas which suffer from inadequate irrigation, with a minimum effect on agricultural land productivity.

2. To identify techniques to supply water at the tail ends of canals with enough irrigation water throughout the year and to enable enlargement of arable lands which are uncultivated due to soil characteristics or water shortages.

3. To develop recommendations for suitable cropping patterns that can be adopted according to the quality of drainage water and the properties of the soil.

4. To determine the degree of tolerance of different crops to saline water.

5. To do an economic evaluation of using drainage water for agriculture.

II - General aspects of the project

The pilot area project consists of about 10,000 feddans located in Ibshwai District, one of the five districts of the Fayoum Governorate. **Figure 2** illustrates the location of the project area with its boundaries. The area is irrigated from the final section of the Bahr El Nazla canal and it discharges its surplus water directly into Lake Qaroun through several minor drains.

From preliminary field investigations, it was found that the pilot area suffers from the rise of the groundwater table, and its northern part is flooded by the saline water of Lake Qaroun. At the same time, the area suffers from severe shortage of irrigation water, specially in summer. These facts explain the necessity of reusing drainage water for irrigation.

A study programme has been worked out in order to evaluate the possibility of reusing drainage water for agriculture not only within the project area, but also for an expansion area of 6,000 feddans, allowing for cultivating new areas and providing crop rotations. For extensive field investigations and studies, an experimental field (2.5 feddans) was selected (see **Figure 2**).

III - Hydrological studies

The topographical and hydrological boundaries of the Fayoum Governorate are very distinct. The desert around the depression rises from the irrigated land, except in the northwest where Lake Qaroun lies.

The direction of land inclination starts from Lahoun (+ 25 MSL) to Lake Qaroun (-43 MSL). **Figure 3** illustrates the steep inclination between Fayoum city and Lake Qaroun. This explains the water flow in the canals and the drains by gravity. Lake Qaroun is also the final delivery of 65% of the drainage.

The hydrological constraints in Fayoum are:

a) the inadequaccy and the unevenness of the distribution of irrigation water; and

b) the excess or scarcity of drainage water in different periods of the year, which causes water and salt unbalance in Lake Qaroun.

Consequently, the purpose of this study was to identify the important hydrological and hydrogeological aspects of the project area within the governorate in order to improve the irrigation conditions, taking into account all factors affecting the water balance of the area.

1. Hydrologigal determinations

A - Irrigation

Irrigation water for Fayoum is diverted from the Nile at Lahoun to two main canals, Bahr Youssef (55 m^3/sec.), and Bahr Hassan Wassef (42 m3/sec.). The latter supplies two main canals, Bahr El Gharaq (17m^3/sec.) and Bahr El Nazla (25 m^3/sec.). The Bahr El Nazla canal serves the pilot area project (10,000 feddans).

The main Fayoum delivery system is operated 24 hours/day, continuous supply seven days a week. There are three kinds of division weirs called Ta'adil 36, Ta'adil 54 and Ta'adil 69, excluding the measuring weirs in the main canals. The present water duties range from 12 to 24 m^3/feddan with an average value of 18 m^3/feddan.

B - Drainage

The total annual drainage water for the Fayoum is about 660 million cubic meters. About 69% of the drainage water flows from three main catchment areas to Lake Qaroun (**Figure 4**), and 31% to the Wadi El Rayan depression through an open channel (Wadi Rayan drain), and an 8 km long tunnel through the desert ridges.

The pilot area project is drained by two small drains which discharge their water directly to Lake Qaroun, Ihrit drain and Mosharak drain.

The experimental field (2.5 feddans) takes its water from the Ihrit drain for the reuse of drainage water to study the effect of using high salinity water on crop yields.

It was found that using part of the Wadi El Rayan drain water to augment the irrigation supply of the pilot project area and the proposed expansion area (6,000 feddans) is the suitable solution for the shortage of irrigation water within the area. Consequently, the water level of Lake Qaroun will be decreased by diverging more of the drainage water towards the Wadi El Rayan depression.

C - Lake Qaroun

The average surface area of Lake Qaroun is about 250 km^2 and its volume is about 1100 MCM. Evaporation from the lake is reduced due to the steady increase of its water salinity ($\simeq$38 gr./lit.).

Over the period 1973-1984, the lake level rose by an average of 4.2 cm/year (**Figure 5**). This was caused by an excess of lake inflow over lake evaporation. A decrease of lake inflow can be achieved by improving the overall irrigation efficiency in winter, and the reuse of drainage water in agriculture.

D - Ground water

Seven deep wells were installed at a 30 meter depth. The location of these wells is shown in **Figure 2** and the obtained soil profiles are shown in **Figure 7**. From the well drilling study, it is clear that there is no significant effect of Wadi El Rayan groundwater on Lake Qaroun or on the agricultural land, although perched groundwater exists in some locations.

E - Climate

A new advanced meteorological station was installed at El Mokhtalat (**Figure 2**). Meteorologial data recorded at Fayoum town and Shakshouk at Lake Qaroun were also used.

The measurements provide the mean temperature (22° C), the mean relative humidity (55%), the annual rainfall (11 mm) and the annual evaporation (2,010 mm).

2. Crop water use

Preliminary investigations revealed that the maximum cultivable area is about 86% of the total area of the pilot area project, and the fallow land is about 14%.

For more investigations, the mathematical model "Fayoum Water and Salt Balance" which had been developed by the Egyptian Dutch project, was applied for the computation of crop area percentage of the total cultivable area, and was also used for the design of the optimal crop patterns on the basis of the available water supplied to the area.

Moreover, the monthly unit crop water use (CWU) for different crops with respect to the unit crop pattern was developed, from the following formula:

$$CWV = UC . KC . ET$$

where:

CWV is the consumptive use/month/crop,

KC is the crop water factor/crop, and

ET is the monthly potential evapotranspiration.

The results are illustrated in **Table 1**.

3. Reuse of drainage water

From the previous investigations, it is obvious that the reuse of drainage water for irrigation should be started wherever possible to improve the uniformity of irrigation water delivery in the Fayoum. This will contribute to lower Lake Qaroun's water level, provide additional water as supplemental irrigation for existing lands which suffer from water shortages, and also develop the excess of available water through reshuffling for the surrounding expansion areas.

A study of several proposals for the reuse of drainage water criteria has been made for returning reasonable quality drainage water to irrigation canals by pumping about 10 m/sec. out of the Wadi El Rayan drain or out of both the Wadi and Wadi El Rayan drains.

Detailed investigations were carried out to determine the most promising projects for the mixing locations in the area under consideration. Two proposals were initiated with the objective of:

– supplementing the irrigation water to the tail end of Bahr El Nazla (an area of 20,000 feddans);

where the water supply has always been in shortage;

– mixing the high quality of drainage water of the Wadi El Rayan drain (700-1,000 p.p.m.) with the flow of Bahr El Nazla;

– providing dependable water supply for reclamation of new areas (6,000 feddans).

a) The first proposal

Pumping water from the Wadi El Rayan drain to the El Nazla drain at their point of intersection. Pumping water discharge of 10 m/sec. with a salinity of 800 p.p.m. and a static head of 3.58 m. The total cost is LE 3 million.

b) The second proposal

Mixing irrigation water with Bahr El Nazla by means of an open channel 6 km long at a cost of LE 3.5 million.

The two proposals have the combined benefit of improving water supply and controlling the water levels of Lake Qaroun. The financial study of the two proposals showed a high feasibility, as inferred from the high value of return obtained (IRR = 78.6%) for the case of pumping and 63% for the case of construction of the canal. There will also be an increase of income per cultivated feddan for the rural family.

IV - Soil studies

A semi detailed soil survey was carried out in the project area. It found that the layers of the soil profile have different textures ranging from clay, clay loam, silt, silt clay, sand clay and sandy foam to sand. Clay content ranges from zero to 50%. Calcium carbonate (9–23%) is present in all layers. Clay or loam is predominant in the area and large areas of sandy soils are also present.

1. Salinity

Some saline areas, differing in size, are present all over the project area. Soil salinity is particularly high near Lake Qaroun, where large areas are flooded by saline lake water.

V - The experimental plot study

An experimental area of 2.5 feddans was established to study the use of drainage water for irrigation of common crops in the areas such as wheat, maize, cotton, sunflower, tomato and vegetables.

The area was divided into 12 plots. Drainage water from the drain is pumped to twin tanks which are connected to a third mixing tank (2 m). Mixing water took place in volumes each time with different properties. Irrigation water is delivered to the plots through a main pipe line with each counter at the head of the plots. 45 lysimeters were also installed directly on the ground.

Due to soil problems in the first season, the experimental area was provided with a tile drainage network and leached with gypsum at a rate of 2 t/feddan.

Six plots were used for cultivating one crop and the other six for another crop.

Six different irrigation water treatments were used:

i) fresh water from sowing to harvesting,

ii) fresh water in the first period and drainage water after,

iii) fresh water in the first period and mixed water after (50% fresh and 50% drainage),

iv) mixed water (50% fresh and 50% drainage) during the whole period,

v) drainage water only from sowing to harvesting,

vi) irrigation water as used by the neighbouring farms.

1. Effects of water quality on soils

From investigations of the salinity development over a depth of 2.0 m, it was clear that the plots with initial soil salinity higher than 4 mmhos/cm, all treatments even those irrigated with drainage water (1,700 ppm) showed soil desalinization. Soil salinity increased and accumulated in the plots which had initial soil salinity less than 4 mmhos/cm.

2. Agronomic studies

To provide crop rotations of salt tolerant species and varieties, a study was made for all seasons.

Figure 7 shows the cropping pattern for both the plots and lysimeters. Chemical analysis of irrigation, drainage and mixed water was made as shown in **Table 2**.

The results indicated that wheat crops can tolerate salinity of irrigation water up to 1,700 ppm without any reduction in yield. Cotton yields were higher by using fresh water during the whole period of growth. With all other treatments, however, there was no difference in yield.

It was concluded that:

– irrigation with saline water decreased the soil salinity as long as salt concentration of the water is less than that of the soil. This means that with using drainage or mixed water having salt concentrations of 1,300 or 1,700 ppm the soil salinity decreased if it was higher than 4 mmhos (2,560 ppm). On the other hand, using the same water quality in soils having salt concentration less than 4 mmhos, salts will accumulate. Gypsum application at a rate of 2 tons/feddan, with installation of tile drainage network decreased ESJP value by about 30%;

– wheat could tolerate salinity of irrigation water up to 1,700 ppm where soil salinity was greater than 4 mmhos without appreciable decrease in the yield but was affected by ESP higher than 13.

On the other hand, maize was very sensitive to soil salinity higher than 2.5 mmhos.

VI - Conclusions and recommendations

The constraints to irrigated agriculture development in Fayoum are identified as:

a) inadequacy and unevenness in the distribution of irrigation water; and

b) lack of cropping patterns and associated rotations adopted to an adequate irrigation system capacity.

These constraints can be corrected by developing the existing resources and inputs through improved water management, including water supply, by reuse of drainage water for irrigation and crop rotation.

The pilot project area is the most seriously affected by shortage of irrigation water during the summer period.

In order to evaluate drainage water reuse, a joint study was undertaken. The main objective was to study the possibility for reusing drainage water for irrigation in the pilot area (10,000 feddans) and in an expansion area (6,000 feddans). For intensive studies, an experimental field of 2.5 feddans was selected.

Different fields of study were identified, including hydrological, geopedological, agronomic and socio-economic studies. The following are the conclusions and recommendations:

1. Under the existing cropping pattern, there is a water shortage during the summer season due to peak demand of irrigation water supply.

2. Changing the cropping pattern, by introducing new crop rotations, would be capable by itself of solving the problems of peak demand, without considerably affecting Lake Qaroun water level.

3. Installation of gate regulators on main and secondary canals and other measurements are needed to control water supply.

4. Reuse of drainage water is important to increase the overall system efficiency and for developing new areas. However, the requirements to maintain Lake Qaroun water levels and the problem of increasing salt concentration must be taken into account.

5. Detailed investigation of the reuse of Wadi El Rayan drain water by mixing with water of Bahr El Nazla were carried out. They resulted in two alternative proposals. The first proposal is for constructing a pumping station to lift water (10 m/sec.) directly from the Wadi El Rayan drain to Bahr El Nazla at a cost of LE 3 million. The proposal is to feed Bahr El Nazla from the Wadi El Rayan drain by gravity through a 6 km open

channel at a cost of about LE 3.5 million. More detailed studies are needed for the correct choice.

6. From the field experiment plots, it was found that: irrigation with saline water decreased the soil salinity as long as salt concentration water is less than that of the soil. When using drainage water (1,700 ppm) or mixed water (1,300 ppm), the soil salinity decreased if it was higher than 4 mmhos/cm. Using the same water quality in soils having salt concentration less than 4 mmhos/cm leads to the accumulation of salts.

7. Wheat crops tolerated salinity in irrigation water up to 1,700 ppm where soil salinity was greater than 4 mmhos without appreciable decreases in the yield.

Maize was very sensitive to soil salinity higher than 2.5 mmhos/cm where the effect of water salinity could not be observed.

References

El Guindy, S., 1986. *Literature Study on the Effect of Salinity on Different Crop Production.*

Fayoum Pilot Project for Re-use of Drainage Water for Agriculture. Joint Egyptian-Italian report (1987). Cairo: Drainage Research Institute, WRC.

Fayoum Water and Salt Balance. Joint Egyptian-Dutch report (1986). Cairo: Drainage Research Institute, WRC.

Table 1: Selected reference evapotranspiration: Average ETO (Period: 1960 - 1976)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1. Berseem-Long	38.33	58.06	95.56	41.99	19.12	0.00	0.00	0.00	0.00	11.57	32.96	32.02	349.40
2. Berseem-Short	20.97	22.58	12.74	0.00	0.00	0.00	0.00	0.00	0.00	5.14	18.31	16.82	96.56
3. Wheat-Barley	43.24	62.90	95.56	61.99	16.99	0.00	0.00	0.00	0.00	0.00	30.76	42.69	354.14
4. Beans	4.42	6.05	10.95	7.75	0.00	0.00	0.00	0.00	0.00	0.00	4.81	3.83	37.86
5. Onions	11.47	18.14	29.86	30.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.85	94.46
6. Legumes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Vegetable-Winter	26.21	36.29	59.72	0.00	0.00	0.00	0.00	0.00	0.00	17.85	27.47	22.64	190.18
8. Other crop-Winter	13.76	16.93	27.87	18.08	24.78	0.00	0.00	0.00	0.00	0.00	9.61	11.32	122.36
9. Cotton	0.00	0.00	8.63	55.96	115.07	144.96	157.25	141.96	79.88	23.21	0.00	0.00	726.92
10. Rice	0.00	0.00	0.00	0.00	37.18	40.89	41.73	39.31	26.33	10.17	0.00	0.00	195.61
11. Maize-Summer	0.00	0.00	0.00	0.00	17.70	37.17	39.31	35.49	17.56	3.21	0.00	0.00	150.64
12. Sorghum	0.00	0.00	0.00	0.00	14.16	133.81	159.67	170.35	84.27	20.56	0.00	0.00	532.83
13. Sesame-Groundnut	0.00	0.00	0.00	0.26	4.72	9.29	10.28	9.28	5.27	0.00	0.00	0.00	39.10
14. Sunflower	0.00	0.00	7.96	15.50	26.55	27.38	27.22	16.38	0.00	0.00	0.00	0.00	121.49
15. Vegetable-Summer	0.00	0.00	4.78	41.33	75.53	79.30	77.41	15.72	0.00	0.00	0.00	0.00	294.07
16. Other crops-Summer	0.00	0.00	0.00	0.00	9.44	14.87	16.93	15.29	12.29	8.57	0.00	0.00	77.39
17. Maize-Nili	0.00	0.00	0.00	0.00	0.00	0.00	36.29	117.94	136.94	111.38	27.47	0.00	430.01
18. Vegetable-Nili	0.00	0.00	0.00	0.00	0.00	0.00	6.53	26.21	26.33	29.99	24.72	12.22	126.01
19. Citrus	13.76	16.93	31.85	41.33	56.65	63.19	61.69	55.69	42.13	34.27	19.23	13.52	450.31
20. Fruits	13.76	19.35	33.84	46.49	70.81	89.21	87.09	72.07	52.67	38.56	21.97	13.50	569.41
21. Sub tot. cropped	185.91	257.24	419.33	360.82	488.72	640.56	721.41	715.70	483.67	314.48	217.32	173.40	4 958.76
22. Fallow lands	8.52	10.48	7.83	11.88	109.76	71.84	36.77	10.05	17.54	51.62	13.73	8.54	358.60
23. Total area	194.43	267.72	427.16	392.70	598.49	712.43	758.18	725.74	501.22	366.10	231.05	182.14	5.317.36

Type of analysis	French water	Drainage water	Mixed water	Water used by farmers
EC	400 ppm	1700 ppm	1200 ppm	400 ppm
SAR	5	18	22	5

Figure 1:The Fayoum Depression

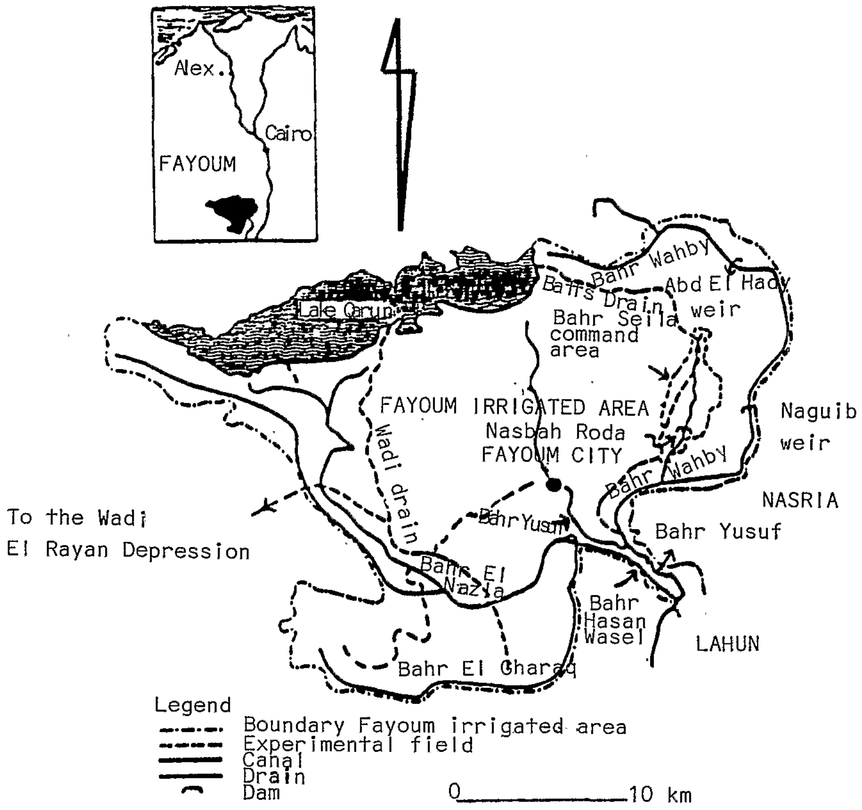


Figure 2: Location of project area

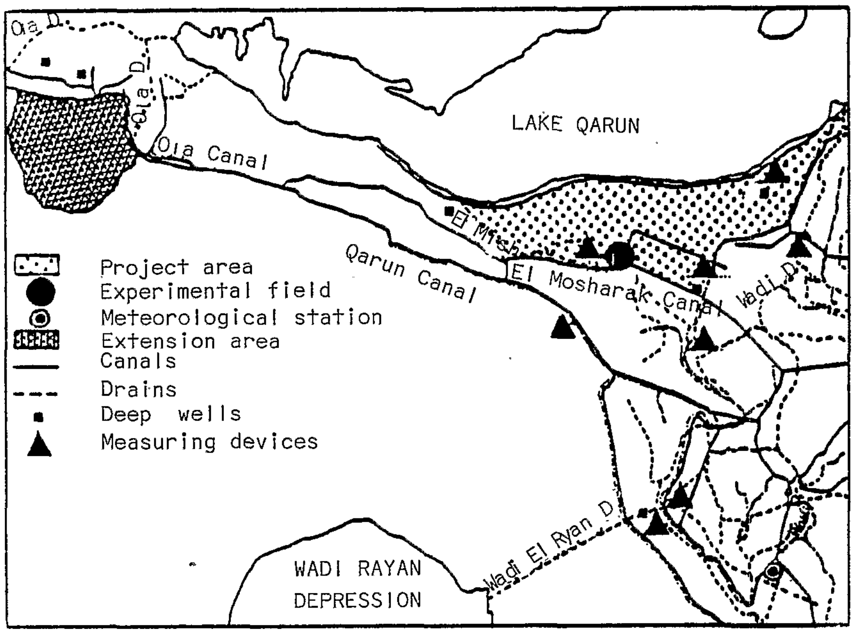


Figure 3: A cross-section from Fayoum City to Lake Qaroun

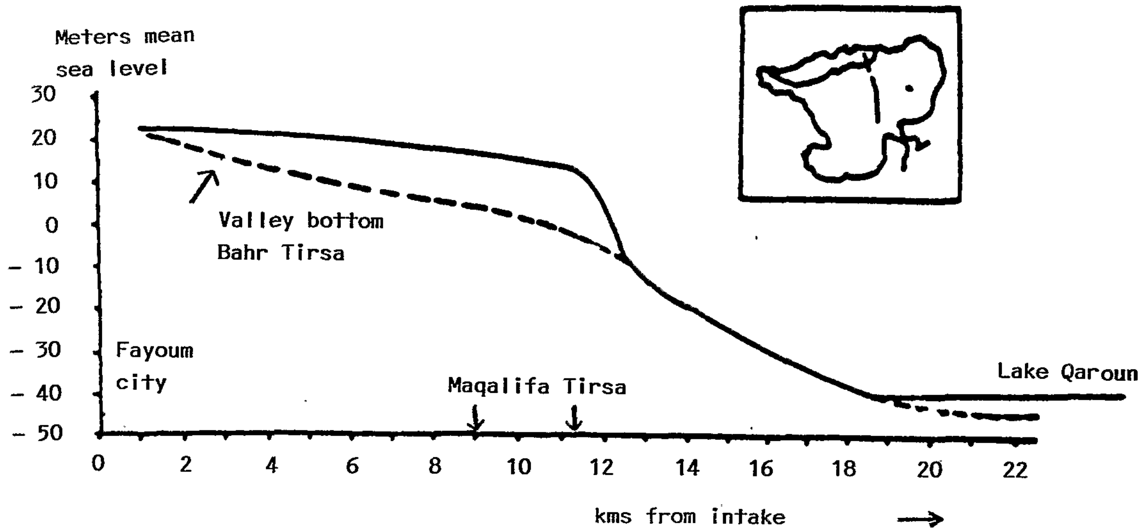
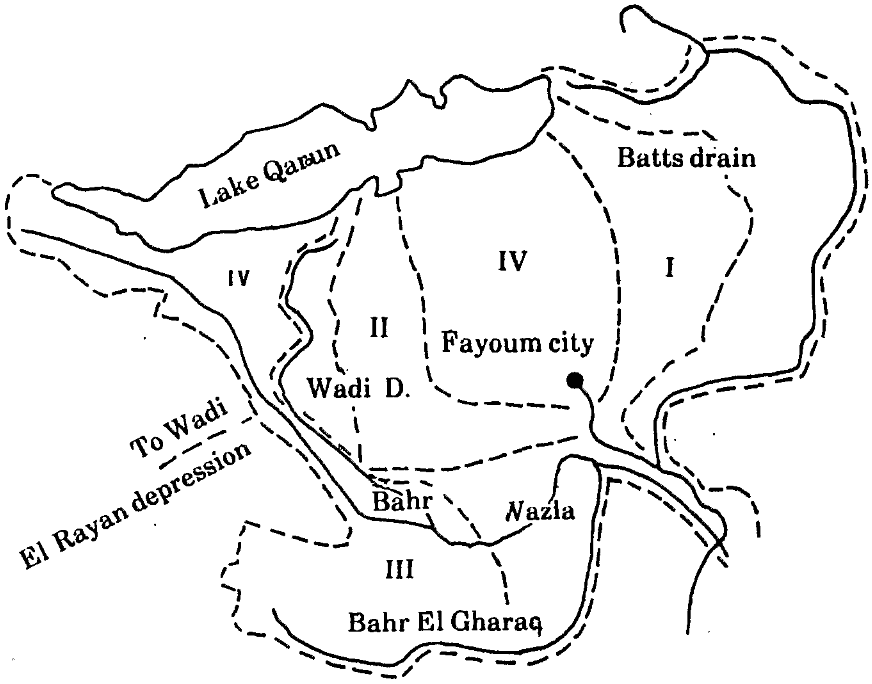


Figure 4: Drainage catchments of Fayoum



I - Batts drain

II - Wadi drain

III - Wadi Rayan

IV - Minor drains

Figure 5: Average annual water levels of Lake Qaroun, 1900-1986

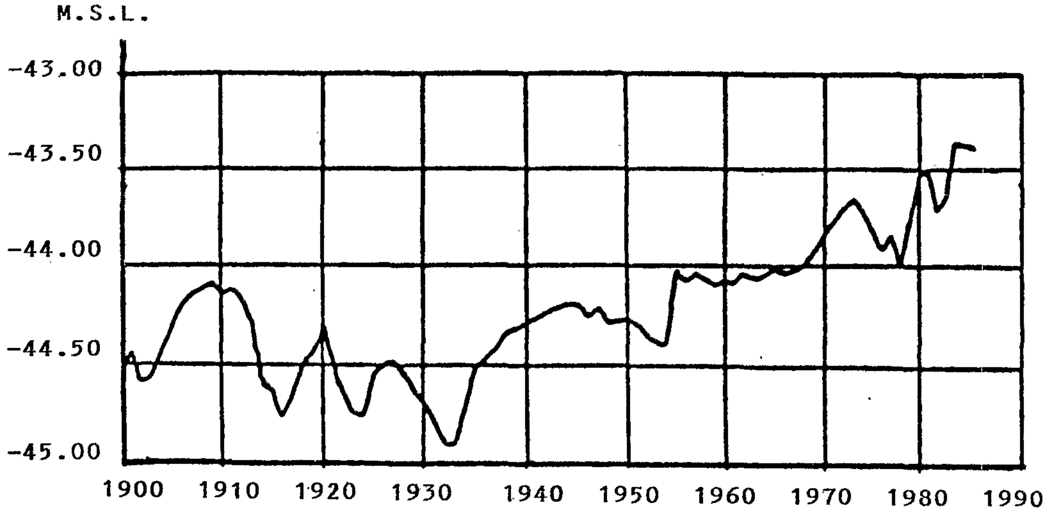


Figure 6: Measured discharges compared with crop water consumption

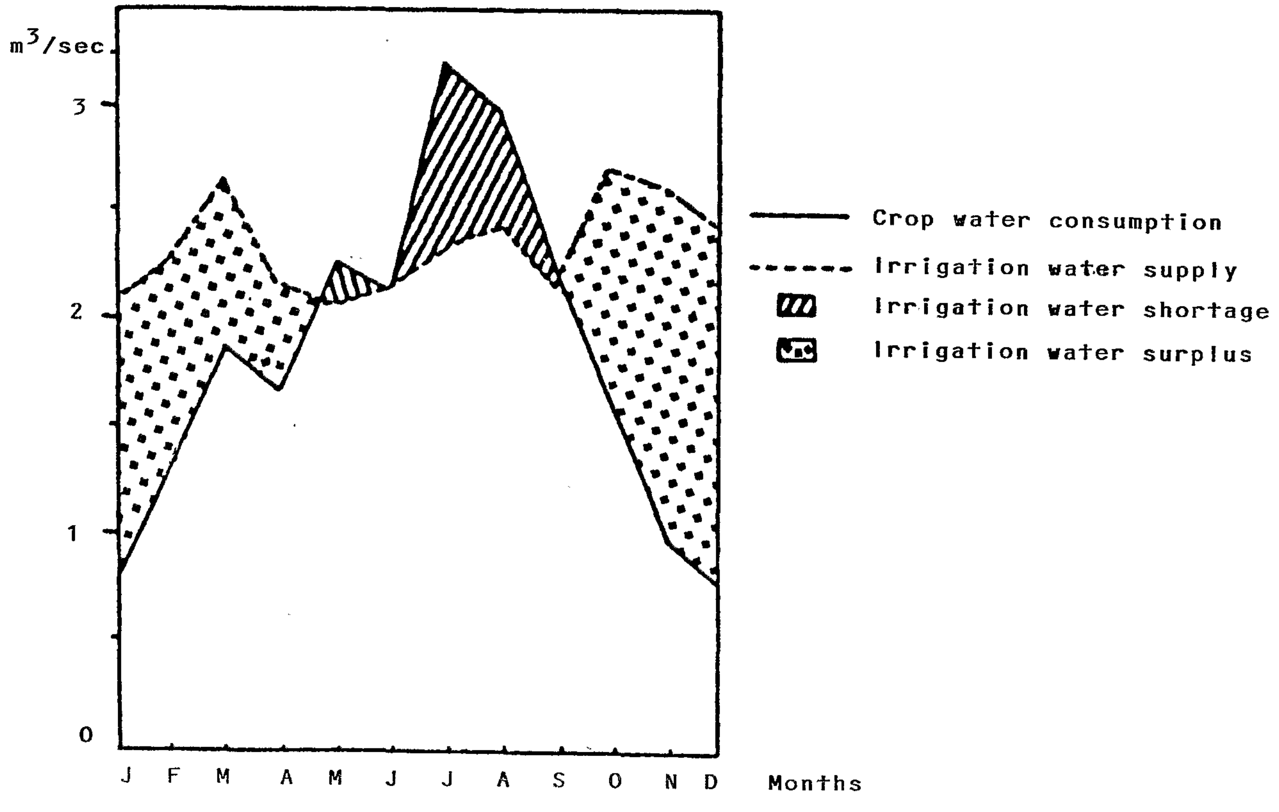


Figure 7: Cropping pattern for plots and lysimeters