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Crop yields, watertable depth, and soil salinity in the Nile Delta, Egypt

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Introduction

Under the auspices of the Advisory Panel for Land Drainage in Egypt (see article ILRI Annual Report 1982), the Drainage Research Institute (DRI) in Cairo, has conducted various studies in the past five years. One of these studies was the economic evaluation of subsurface drainage. A Crash Program was started in 1979 to acquire a rough quantitative insight into the effect of such drainage on agricultural production in the Nile Delta. Since high watertables and soil salinities are the two main factors to be affected by drainage, they formed the basis of the study. Another important component was the assessment of agricultural production, it being the yardstick by which farmers measure the effect of drainage. Data were also collected on farm management.

The Crash Program was conducted in the Nile Delta, in the agricultural areas of three sets of twin villages, one 'with' drainage, and the other 'without' (see Figure 1). These village areas were so selected that they are representative of large tracts of agricultural lands in the Nile Delta. In each village, twenty-five farmers were selected at random.

The Program placed emphasis on the five main crops in the Delta: wheat and berseem, which are two important winter crops, and cotton, maize, and rice, which are the main crops in the summer season.
The production of maize, rice, berseem, and wheat was assessed by means of crop cuttings. Data on cotton production were obtained from the village cooperatives, to which the farmers must sell all of their cotton crop, and where a record is kept of each farmer's production.

The watertables were measured daily in piezometers installed in the selected plots. Soil salinities were measured in the laboratory from soil samples taken from the plots at harvest date.

The results of the Crash Program, which became a Regular Program in 1982, were reported in technical reports of DRI and were bundled in a final report. This article will discuss the physical relationships between crop yields, watertable depth, and soil salinity, based on data derived from these reports.

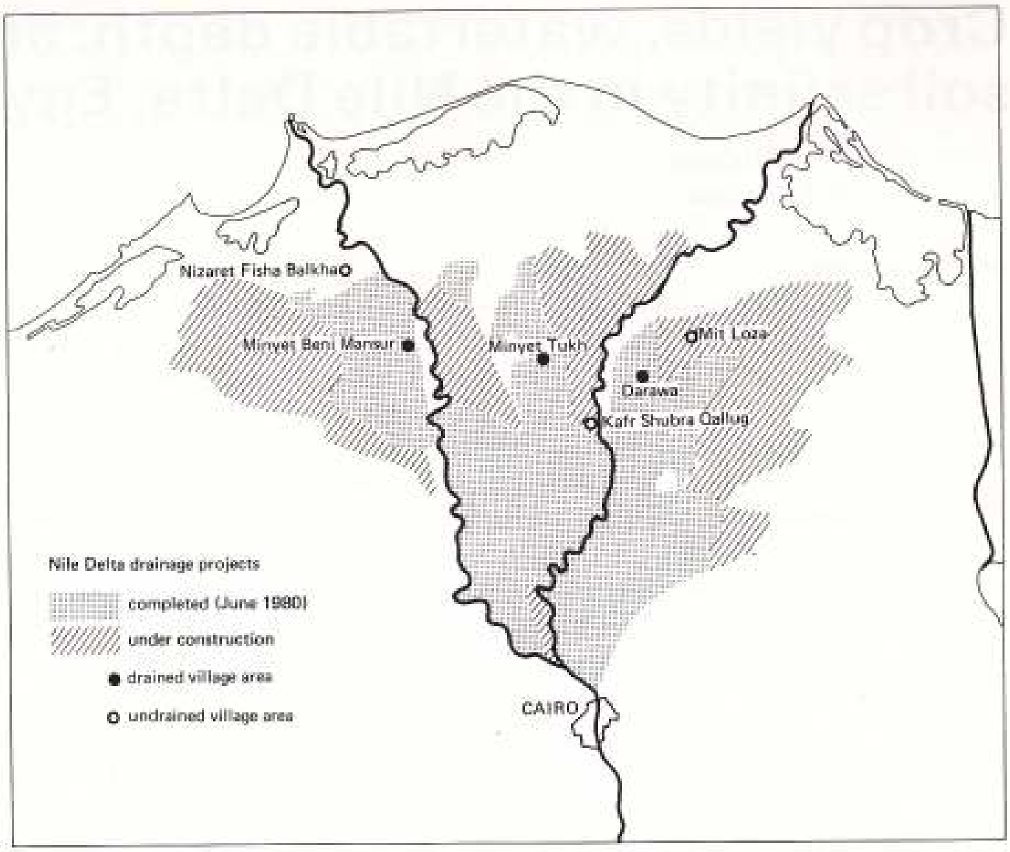

Figure 1. Location of Nile Delta drainage projects and the study areas of the economic evaluation

Salt-affected soils: brown spots in berseem in the undrained village of Nizaret Fisha Balkha

Watertable depth and crop yields

Cotton

Cotton is the most important Egyptian crop; it occupies about a third of all arable land in the summer season. Being the major export crop, it is a source of foreign exchange.

Cotton is planted from the end of March to the beginning of April; picking starts in September. There are usually two pickings. Figure 2 shows the relationship between the cotton yield and the average watertable depth during the growing season. Indicated in the figure are the upper envelope (maximum yields), central tendency (average yields), and the lower envelope (minimum yields).

These reveal that an average watertable depth in the range of 90 to 140 cm has no influence on the cotton yields. As soon as the average watertable is less than 80 to 90 cm, the cotton yields decrease. Lowering the watertable depth from 60 to 90 cm would improve the cotton production, on average, by 600 kg/feddan (1 feddan = 0.4202 ha).

The undrained village area of Mit Loza has severe drainage problems; all its plots have a watertable less than 90 cm. In contrast, the undrained village area of Kafr Shubra Qallug has only minor drainage problems. The drained village areas of Darawa and Minyet Tukh have no drainage problems.

Wheat

Wheat is the major winter cereal. It is planted from the end of November to the beginning of December and is harvested in May.

The average watertable depth during the growing season is plotted against the grain yield in Figure 3. This plot indicates that wheat yields are not influenced by watertable depths of more than 40 cm below soil surface. More yield observations at watertable depths of less than 40 cm are needed to determine the critical depth
.
A comparison of Figures 2 and 3 shows that watertables in winter (Figure3) are shallower than in summer (Figure 2). (See Table l.)
This is due to different climatic conditions and irrigation practices.

Table 1. Average watertable depth (cm)

Village area	Winter (wheat)	Summer (cotton)
Mit Loza	60	75
Kafr Shubra Qallug	90	120

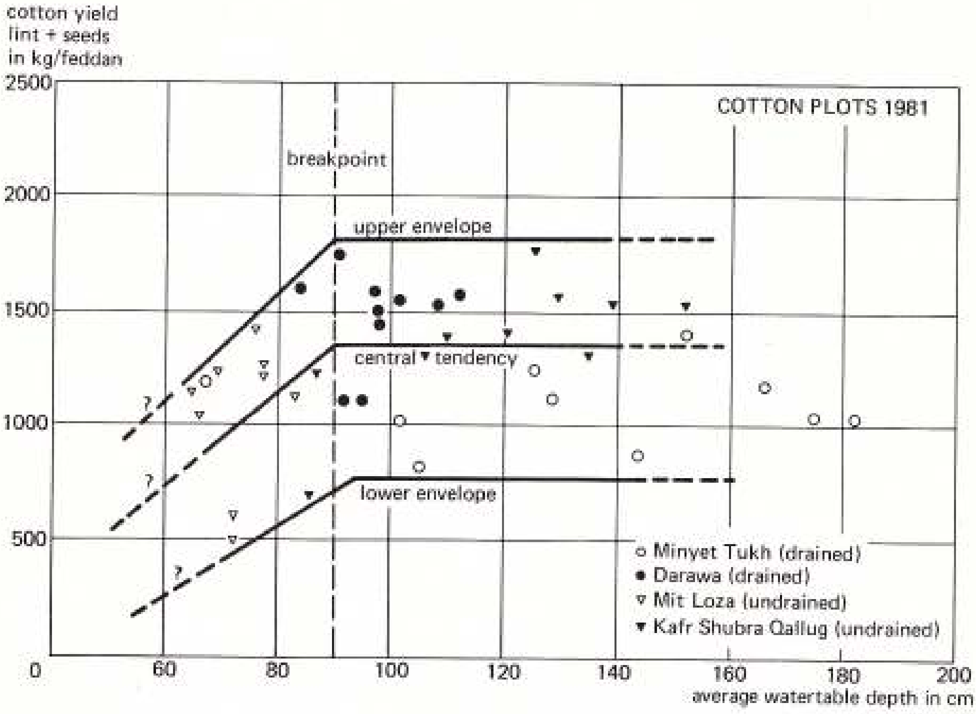

Figure 2. Relation between cotton yield and the average watertable depth during the growing season

Measuring the watertable in a field of young cotton

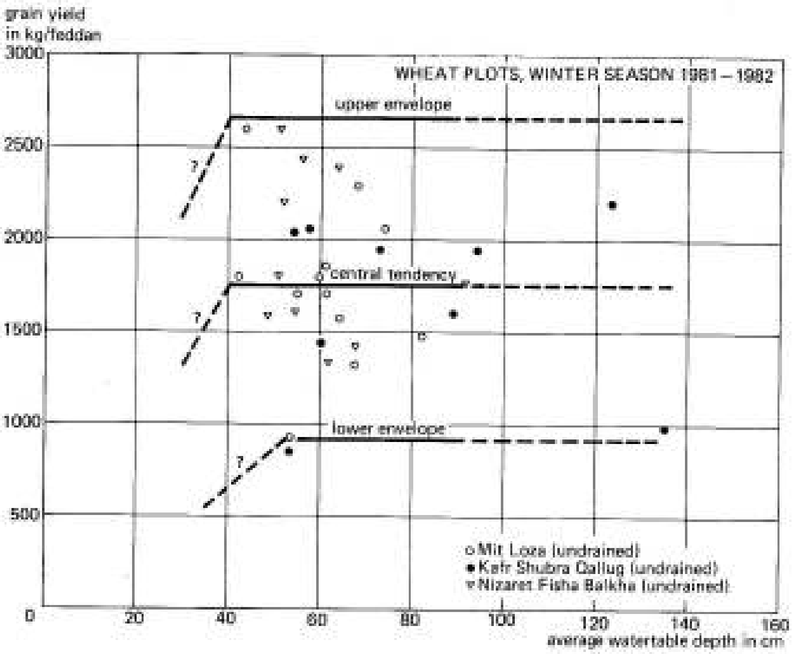

Figure 3. Relation between wheat yield and the average watertable depth during the growing season

Soil salinity and crop yields

Berseem (Egyptian clover- Trifolium alexandrinum)

Berseem is grown as short- season clover and as long-season clover. Both are planted from mid-September to November. Short-season clover, after one or two cuts, is ploughed under prior to planting cotton in March. It serves the dual purposes of fodder for livestock and soil conditioner. Long-season clover is kept for four cuts until May and no cotton crop follows. About 10 to 15% of the long-season clover is left after the third cut for seed setting. Seed is harvested in June.

Figure 4 shows the relation between the total berseem production (dry matter) of four cuts and the average soil salinity during the growing season. The central tendency is that yields decrease at salinity levels of more than 2 to 3 mmho/cm. The salinity level at initial yield decline is called breakpoint, threshold value, or critical value. For the higher yields of berseem, the breakpoint seems to differ from the breakpoint at minimum yields. This is possibly due to other limiting factors at lower yield levels influencing the critical value of ECex which factors are not present at higher yield levels. On average, at an ECM value of 2.5 up to 4, the total production decreases from 5,650 to 4,650 kg/feddan. This means roughly about 650 kg/feddan when the soil salinity increases by l mmho/cm.

Wheat

Figure 5 presents the relationship between soil salinity and the grain yield Of wheat in the winter season 1981-1982 in the undrained village areas Nizaret Fisha Balkha and Kafr Shubra Qallug. There is a breakpoint at the ECex

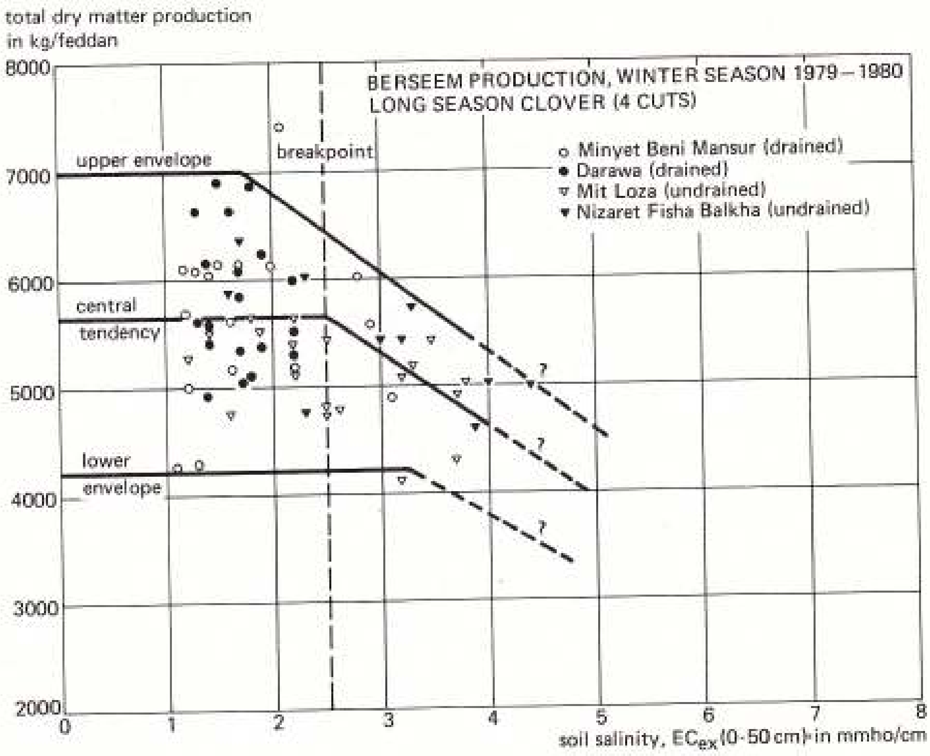

Figure 4. Relation between berseem yield and soil salinity during the growing season

Crop cutting of wheat to assess crop production, and soil sampling to determine salinity

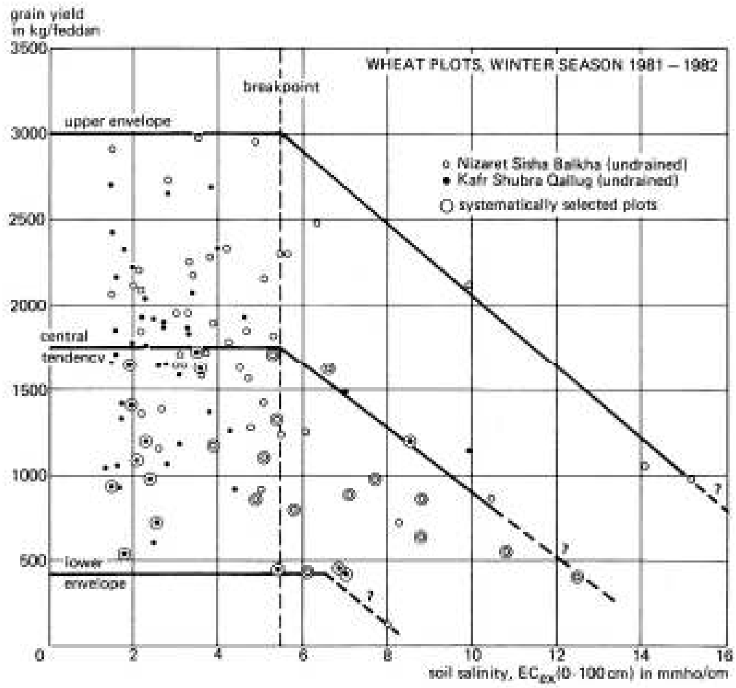

Figure 5. Relation between wheat yield and soil salinity at harvest date

value of about 5.5 to 6.5. The grain yields do not react to changes in ECex values below the breakpoint. In the range from ECec = 5.5 to 10.5 mmho/cm, an increase in soil salinity of l mmho/cm means that the yields decline by roughly 200 kg/feddan.

The same phenomenon as in Figure 4 is observed: the breakpoint shifts somewhat to a higher soil salinity level at low yields.

In addition to the random samples, thirty extra wheat plots were selected systematically to get more data on crop production at high soil salinity levels. These data are encircled in Figure 5.

From the random samples, it appears that only 5% of the village area of Nizaret Fisha Balkha has salinity problems for wheat, and that the village area of Kafr Shubra Qallug has hardly any salinity problems for wheat.

Rice

The farmers grow the short-grain or Japonica type of rice, the predominant variety being Nahda. Rice nurseries are prepared in May and the rice is transplanted in June. The harvest starts mid-October.

Figure 6 shows the relation between the rice yield in the village Mit Loza and the top soil salinity. As in the earlier figures, a clear breakpoint is found: this time at a salinity level of ECex = 3.5 to 4.0 mmho/cm. Up to this level an average grain yield of 2,400 kg/feddan can be obtained. If the top soil salinity increases, yields decrease sharply. From ECex = 3.5 to 7.5 mmho/cm, the grain yield decreases about 1,000 kg/ feddan. This means that, if the soil

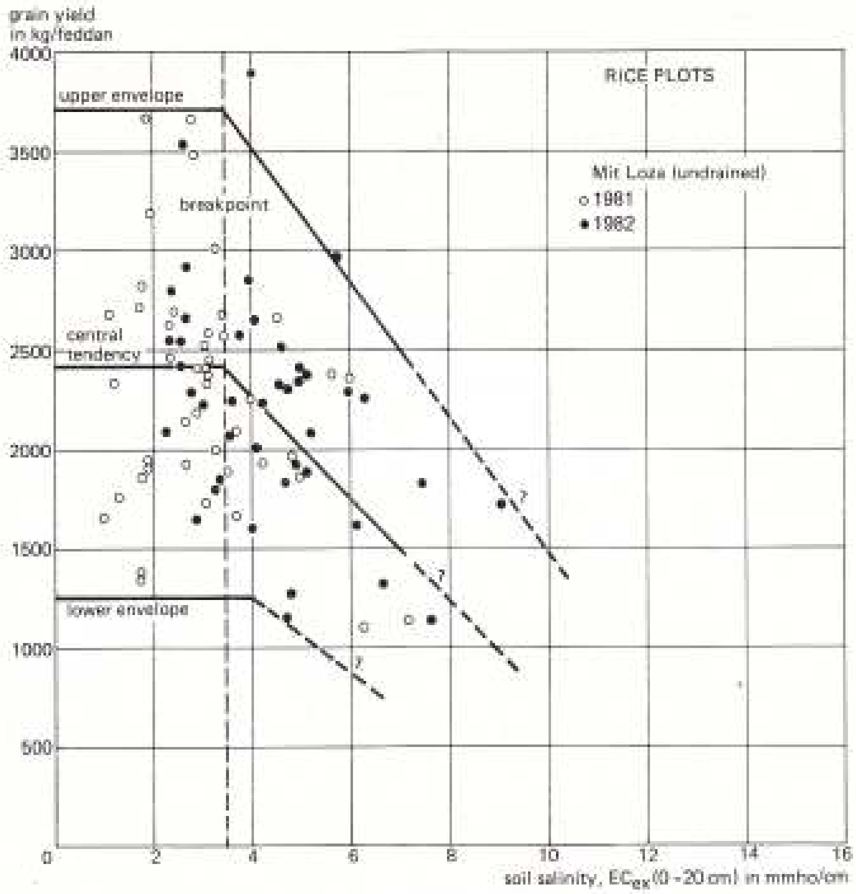

Figure 6. Relation between rice yield and soil salinity at harvest date

Crop cutting of rice to assess crop production

salinity increases one unit in this range, yields decline about 250 kg/feddan. The samples were taken at random, and if we look at the number of observation points, we can conclude that in Mit Loza the rice fields of about 40% of the area could be improved by salinity control.

Maize

Maize is the major coarse grain in Egypt and it is used extensively in bread for human consumption, especially in rural areas. It is planted from the end of May to mid-June and is harvested from mid-September to mid-October. The relation between the grain yields of maize in three villages e Kafr Shubra Qallug, Darawa, and Minyet Tukh - and the soil salinity is presented in Figure 7.

The breakpoint is found at an Eex = 3.0 to 4.0 mmho/cm, the average grain yield being approximately 1,800 kg/feddan in the range ECex = 0.3 mmho/cm. In the range ECex = 3 to 5.5 mmho/cm, yields decline from 1,800 to 1,350 kg/feddan. If the EC" value in this range decreases 1 mmho/cm, the grain yields of maize increase by 180 kg/feddan.

Cotton

Figure 8 presents the relation between soil salinity and cotton yield in the summer season of 1981. From this figure it can be seen that soil salinity exerts no influence on the yields in the range EC" = 0 to 7 mmho/cm. Lack of data beyond ECN = 7 mmho/cm makes it impossible to indicate the breakpoint.

Conclusions

The data collected under the Crash Program have allowed various conclusions to be drawn. For example, the data on the relation between watertable depth and crop yields show that cotton is more sensitive to high watertables than wheat; with average watertable depths of less than 90 cm during the growing season, cotton yields decline. Although no data on maize and berseem are available yet, literature data would seem to indicate that these crops are less sensitive to high watertables. It is therefore justitied to conclude that the design criteria presently used by the Egyptian Public Authority for Drainage Projects (EPADP) - i.e. that field drains be installed to lower the watertable to at least 1.0 m - provide an adequate watertable level for all crops grown.

For four of the five main crops grown in the Nile Delta, the Crash Program made it possible to derive the yield decreases at soil salinity levels exceeding the threshold value. This information is presented in Table 2, which shows that yields decrease roughly 10% per unit salinity increase.

The data in Table 2, if used correctly, can be very useful in planning future drainage projects. As a simplified example, let us take Figure 6, which shows that about 40% of the rice-growing area in Mit Loza has an average salinity level of roughly 5 mmho/cm and is thus suffering from salinity problems. The mean yield increase per mmho/cm salinity decrease is about 10% up to the threshold value of 3.5 mmho/cm. If salinity control measures could be

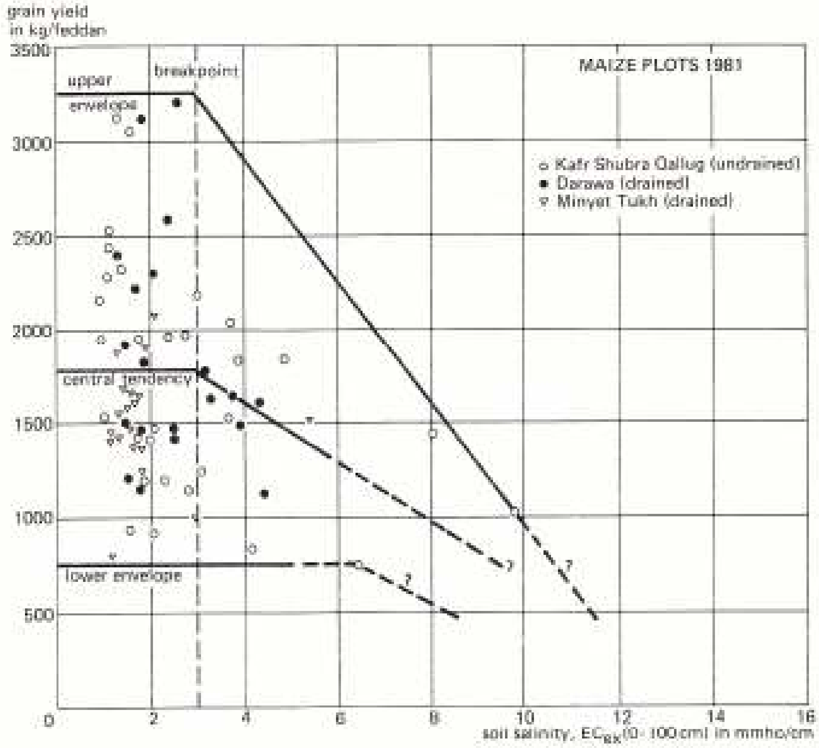

Figure 7. Relation between maize yield and soil salinity at harvest date

Crop cutting of berseem to assess crop production

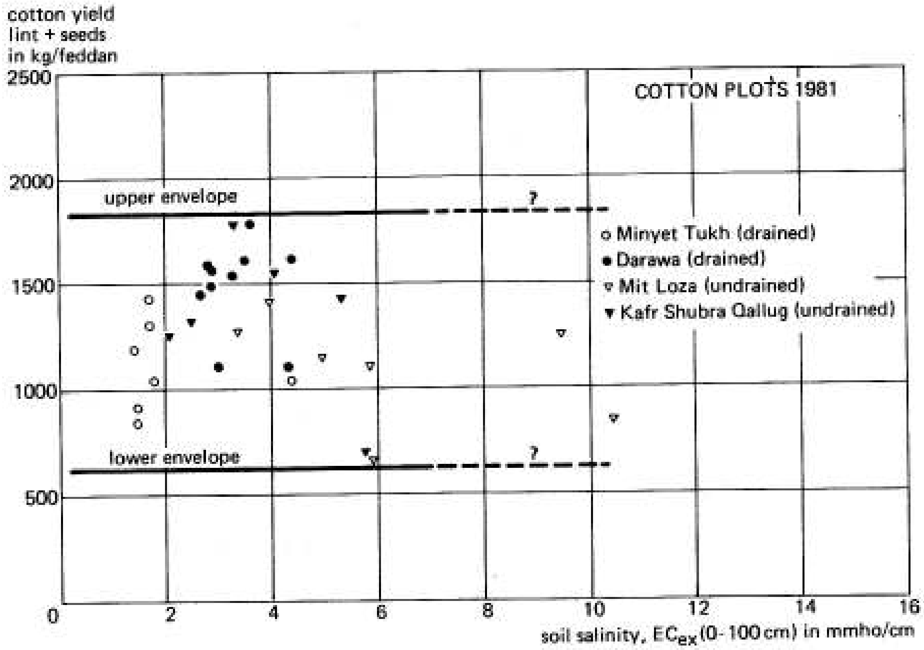

Figure 8. Relation between cotton yield and soil salinity

Table 2. Salinity threshold values and yield decreases

Crop	Average yields up to the threshold value kg/feddan	Threshold value EC_{ex} in mmho/cm	Soil salinity range in which yield decreases were determined in mmho/cm	Yield decrease per mmho/cm in kg/feddan
Berseem	5,650	2.5–3.0	2.5– 4.0	650
Maize	1,800	3.0–4.0	3.0– 5.5	180
Rice	2,400	3.5–4.0	3.5– 7.5	250
Wheat	1,750	5.5–6.5	5.5–10.5	200

taken only in the 40% of the area that requires them, the yield increase would be of the order of:

(5 - 3.5) x 10% = 15%.

The problem areas, however, cannot be singled out because they are scattered at random. Salinity control measures would therefore have to be taken for the entire rice-growing area. This means that the yield increase would not be 15%, but only 40% of l 5%, which is 6%. One can follow the same procedure for the other crops grown in the Mit Loza area, taking into account the area under each crop as a weighting factor.

In this way - by estimating possible yield increases in areas to be drained - one can obtain a sound basis for the priority-ranking of future drainage projects.