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PROJECT TECHNICAL REPORT #5

# ECONOMIC COSTS OF WATER SHORTAGES ALONG BRANCH CANALS

by

Shinnawi Abdel Atty El Shinnawi, Melvin D. Skold
and Mohamed Lofti Nasr

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# ECONOMIC COSTS OF WATER SHORTAGES ALONG BRANCH CANALS

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Colorado State University
Engineering Research Center
Ft. Collins, Colorado 80523
USA

Consortium for International Development
5151 E. Broadway, Ste., 1500
Tucson, Arizona 85711 USA

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## ABSTRACT

A survey of farmers served by the El Hammami canal reveals substantial differences in water availability and cropping practices, depending on farmers location along the canal. Among farmers in the upper one-third of the canal, 15 of 18 indicated water was available according to schedule at least 3/4 of the time. Farmers on the lower one-third reach of the canal said water availability is a problem most of the time. Lower-end farmers have compensated for less water availability by investments in pumps and wells, planting lower valued crops, expecting lower yields on common crops, and increasing farm size. The paper proceeds to demonstrate the potential benefits from water reallocations.

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## INTRODUCTION

One of the problems identified by the Eqyptian Water Use Project (EWUP) personnel is that of water shortages at the tail ends of certain branch canals. A report by EWUP engineers indicates a decrease in water delivery to branch canals at reaches successively more distant from the Mansuriya intake. Decreases in water availability along branch canals were also observed; farmers at the tail of branch canals were not being delivered as much water as those at the beginning of branch canals. The authors make a concluding comment: "The most remote areas may receive only one-fourth as much water as those at the beginning of the canal system."[1] Specific observations have been made of severe water shortages during the summer season at the lower end of the El-Shimi canal located in the El-Hammami Project site (Figure 1). Important economic costs are likely to be associated with these water shortages, both to farmers and to Egyptian agricultural economy. The purpose of this report is to present some observed differences in farms and farming practices resulting from varied amounts of water available and to make some economic evaluations of these differences.

The El Shimi branch serves an area of about 600 feddans. Estimates are that up to 200 feddans are affected by inadequate amounts of available water.[2] Thus, the amount of land affected represents a significant proportion of the total area. The area studied includes the El Shimi branch and neighboring canals in the Mansuriya area. Figure 1 locates the canals along which farmer enumerations were completed. Analysts of the Egyptian irrigation water delivery system do not see the problem represented by the El Shimi branch canal to be an isolated occurrence. Rather, water shortages at the ends of branch canals are widespread throughout the nation. A recently completed agricultural mechanization report holds that water shortages are a very important problem to farmers throughout

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[1] Wolfe, John, Farouk Shahin, and M. Saif Issa, "Preliminary Evaluation of Mansuriya Canal System, Giza Governorate, Egypt." Egypt Water Use and Management Project, Technical Report No. 3, Cairo, 1979.

[2] El Shinnawi Abdel Atty and M. E. Quenemoen, "The Problem of Water Delivery at the Tail of the El Shimi Branch Canal," Egypt Water Use and Management Project, Internal Report, December, 1976, p. 21.

Egypt. In a survey of farmers, 87 percent indicated that insufficient water was a problem.[3] This report does not evaluate the extent of the problem. It does consider the effects of water shortages along canals such as the El Shimi branch and proposes a more thorough investigation of the water shortage problem.

A detailed description of how water is delivered to farmers in the Mansuriya District is reported by Dr. Mona El Kady.[4] In the El Hammami region water is delivered on a four-days on, eight-days off rotation. According to Dr. El Kady, this system encourages more frequent irrigations than is necessary to meet the crops water requirements. The frequent irrigations lead to a tendency for over-irrigation, at least so far as water is available. Over-irrigation by farmers near the head of branch canals likely contribute to water shortages for farmers near the lower ends of branch canals. Farmers in the area affected by water shortages adjust to the water situation in a number of ways:

(1) First, without action to reduce water shortages, land is left idle,

(2) or if planted to crops, poor yields result.

(3) Purchased inputs such as seed, fertilizer, and chemicals may be wasted (or not used) and the time and effort of farmers may be lost.

(4) Alternatively, crops may be planted which are less than optimal but are more tolerant of water shortages or require less water.

(5) Finally, farmers may have adjusted by finding other means to supply water to the land such as investments in wells and pumps or pumping from drains.

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[3] ERA 2000, Inc., "Further Mechanization of Egyptian Agriculture," Gaithersburg, MD., April, 1979.

[4] El Kady, Mona, Wayne Clyma, and Mahmoud Abu-Zeid, "On-Farm Irrigation Practices in Mansuriya District, Egypt." Egypt Water Use and Management Project, Technical Report No. 4, 1980.

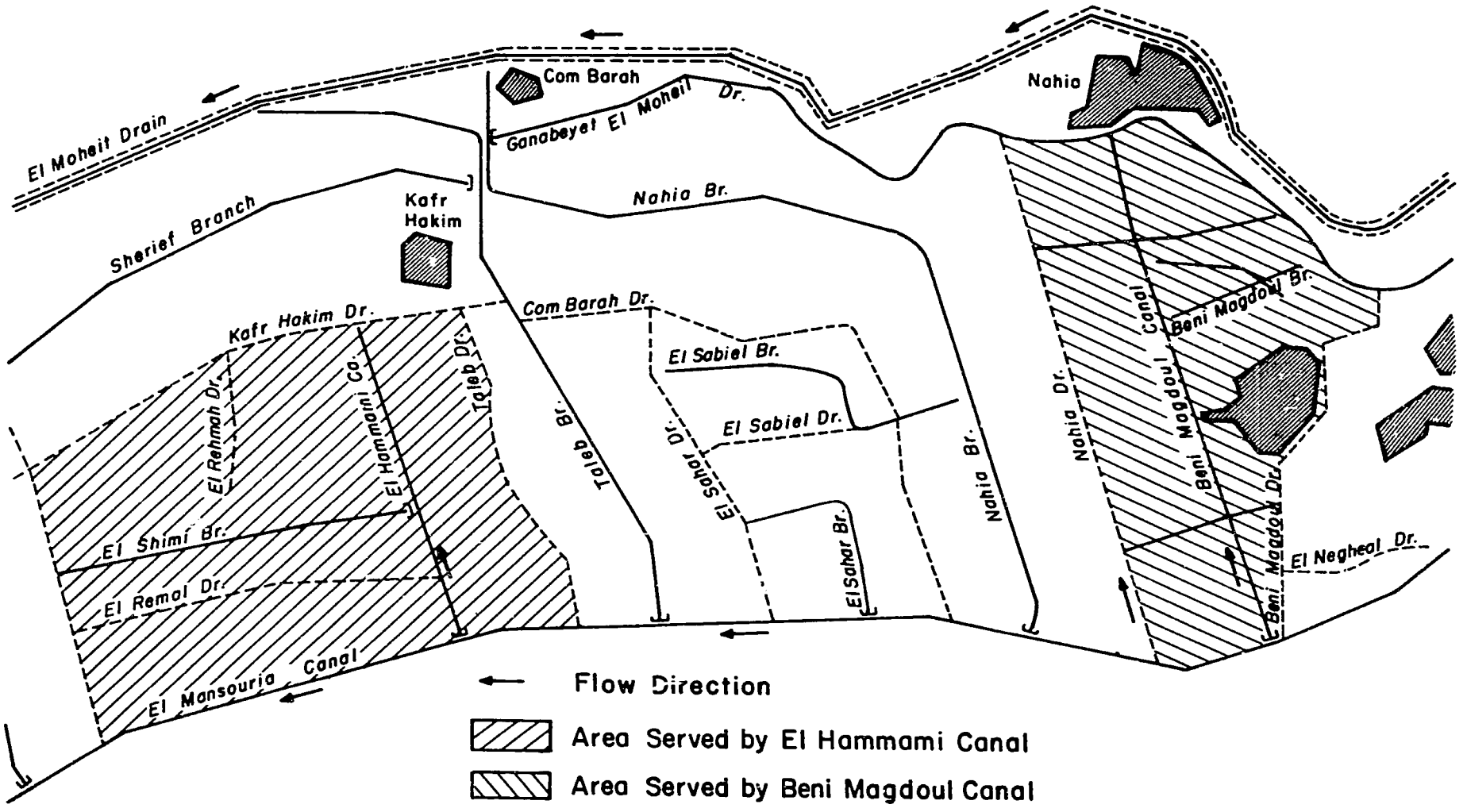


Figure 1. General Layout and Boundaries of the Beni Magdul and El Hammami Water Courses

This report examines each of these adjustment hypotheses. it is expected that water shortages also affect land values. Inadequate water greatly lowers the potential productivity of the land this is reflected in a lower land value.

## RESEARCH PROCEDURE

To estimate which, if any, of the above adjustments are occurring along branch canals in the Mansuriya canal system data was obtained from farmer interviews during the 1979 summer season. Farmer interviews were conducted during the summer of 1979 by the Egyptian authors of this report. The interview questionnaire is included as Appendix A to this report. Farms were grouped along a given branch canal into upper one-third, middle one-third, and lower one-third depending on their location relative to the canal beginning and end. Only farmers in the upper and lower groups were interviewed. A total of 38 farmers were interviewed; 20 of these farmers have their land at the end of branch canals and data were obtained from 18 farmers at the upper reaches of branch canals.

The data are summarized by farmers located at the upper reaches of canals and those whose farms were located at the lower end of canals. Comparisions between the "upper-end" farmers and "lower-end" farmers will be the basis of our analysis. In this way, we will be able to show the practices which are being followed by all farmers and those changes which are associated with water availability.

The data are summarized here to reflect the adjustments which these farmers have made or are making to perceived water-short situations. We first present the summaries of these data and in a final section some inferences about the economic costs associated with water shortages are presented.

## RESULTS OF THE SURVEY

The questionnaire provided information about the way in which Egyptian farmers have adjusted or are adjusting to water shortages. The data collected provide information about most of the possible adjustment suggested in the introduction. These will be considered in turn. In addition, some other observations about farmer adjustments as revealed by the questionnaires will be offered.

Water Availability

First, we must answer the question as to whether there is a difference in canal water availability between upper-end farmers and lower-end farmers. Table 1 presents some information about the availability of canal water to farmers during the summer crop season. Farmers were asked about the proportion of time for which water availability is a problem. The question, as stated, may imply that the timing of water availability is the only problem. Because of the way which water is delivered, if water is not available according to schedule, the quantity of water delivered is also inadequate.[5] Responses from farmers, which indicate water is not available according to schedule, reveal that canal water is not available during the four-days on portion of the rotation. Appendix Table A-1 and A-2 provide detailed information about how farmers at the lower end and upper end of branch canals, respectively, respond to this question.

In Table 1, it is seen that most farmers at the upper end of branch canals say water is available on schedule at least three-fourths of the time. Fifteen of eighteen respondents at the upper end indicate water is available three times out of four while only six of twenty respondents at the lower end of the branch canals report water is available with such scheduled reliability. The largest number of farmers at the lower end of branch canals report water is available only one-fourth of the time. Thus, there is a marked difference between upper-end and lower-end farmers. Farmers at the lower reaches of branch canals experience inadequate water deliveries much more frequently than farmers in the upper reaches of these branch canals.

The report cited earlier, indicated that night irrigation may be practiced by farmers for which daytime water deliveries are a problem.[6] Irrigation is sometimes possible at night because upper-end farmers may not be irrigating and water becomes available at the lower reaches of canals. Differences in night irrigation between upper-end and lower-end groups are not evident here. Thirteen of eighteen upper-end farmers and fourteen of twenty lower-end farmers do at least some irrigating at night.

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[5] El Kady, op. cit.

[6] op. cit., Wolfe, et al.

Table 1. Availability of Canal Water to Farmers Along Branch Canals During the Summer Season by Location.

| Frequency of Canal Water Availability/ Night Irrigation | Location Along Branch Canal: Upper One-Third | Lower One-Third |
|---|---|---|
| | (number of farmers) | |
| Usually on time | 3 | 4 |
| About 3/4 of time | 12 | 2 |
| About 1/2 of time | 3 | 5 |
| About 1/4 of time | -- | 8 |
| Never on time | -- | 2 |
| Practice night irrigation | 13 | 14 |

Table 2 reports on the frequency with which water availability is a problem during the winter season. Appendix Tables A-3 and A-4 provide a more detailed treatment. All of the upper-end farmers stated that water is always available on schedule during the winter season. Among the 20 lower-end farmers only 11 indicate winter canal water availability was no problem. Six lower-end farmers said canal water was available about three-fourths of the time and the remaining three farmers are distributed among the three more serious water shortage groups.

Water availability appears to be a problem primarily during the summer season, but it is not confined entirely to that time of the year. Given that water availability is a problem and one which affects lower-end farmers more severely than upper-end farmers, it is useful to examine the differences in farming operation between these groups.

Access to Pumps

Because canal water is not available as scheduled, many farmers have gained access to diesel-powered pumps to apply water to their crops. These pumps either have been purchased or the use of a pump is rented. Table 3 divides the upper-end and lower-end farmers into three groups: those who rent pumps, those who own pumps, and those with no pump. (See corresponding Tables A-5 and A-6.)

Farmers obtaining access to pumps corresponds closely to the intensity of water availability problem. At the upper-end of branch canals, where water availability is not so severe a problem, only 2 of 18 farmers use pumps. These two farmers rent pumps (and then only for a few days each summer).

Among lower-end farmers, 13 of 20 either rent or own pumps. One farmer owns and rents. Seven have no access to pumps. Of those with access to pumps, 8 rent and 6 own the pumps.

Differences in water availability to farmers along branch canals have resulted in some farmers being forced to provide other means to obtain water for their crops. The use of pumps is much more common among lower-end farmers than among farmers near the upper-end of branch canals. Thus, farmers at the lower-end of branch canals are incurring a cost to secure water that is not required of farmers near the start of branch canals. More will be said of these costs later, but the costs include the cost of renting a pump or the ownership and use costs of owned pumps. In addition, farmers have often invested in a well to provide the water needed for the pumps.

Table 2. Availability of Canal Water to Farmers Along Branch Canals During the Winter Season by Location

| Frequency of Canal Water Availability | Location Along Branch Canal: | |
|---|---|---|
| | Upper One-Third | Lower One-Third |
| | (number of farmers) | |
| Usually on time | 18 | 11 |
| About 3/4 on time | -- | 6 |
| About 1/2 of time | -- | 1 |
| About 1/4 of time | -- | 1 |
| Never on time | -- | 1 |

Table 3. Access to Pumps by Farmers Along Branch Canals, by Location

| Access to Pump | Location Along Branch Canal: | |
|---|---|---|
| | Upper End | Lower End |
| | (number of farmers) | |
| Rents a pump | 2 | 8 |
| Owns a pump | -- | 6* |
| No pump | 16 | 7 |

*One farmer both owns and rents.

Since farmers at the lower-end of branch canals fall into two groups according to access to pumps, it is now important to recognize differences between these two groups. The following dicussions of farmer adjustments to lack of water availability will continue to call attention to differences between upper-end and lower-end farmers, and will also compare those at the lower-end with access to pumps to those at the lower-end with no pumps.

Farm Size Differences

A difference between upper-end and lower-end farmers which was not expected at the inititation of the study was a difference in farm size. However, tabulation of the data revealed some important differences in this score too. Table 4 shows how the farms interviewed vary in size according to location along a branch canal. At the upper-end, farms averaged 1.38 feddans in size. At the lower-end the average farm size is more than twice as great, 3.69 feddans. Important differences can also be observed between lower-end farmers who have access to pumps and those who do not. Farmers with no access to pumps tend to be rather small, averaging only 1.45 feddans. Lower-end farmers with access to pumps average 4.66 feddans. Among all those with access to pumps, farmers who own pumps average 7.42 feddans and those who rent pumps are less than one-half that size, 2.73 feddans.

Two different interpretations can be made of these differences. First, in that lower-end farms tend to be larger may indicate that because of water shortages at the lower-ends of branch canals, farmers have been forced to expand the amount of land farmed to provide a satisfactory level of living for themselves and their families. Lack of sufficient water requires more extensive type of farming using fewer nonland inputs per unit of land. Net returns per unit of land are lower and more land is needed to provide adequate levels of income. Thus, if this interpretation is valid, a part of the adjustment to lack of a reliable supply of water is an expanded land base.

A second interpretation is that larger land holdings are the result of efforts to spread the fixed costs of altenative water sources (wells and pumps) over more land. Notice that lower-end farmers without pumps are of about the same average size (2.45 feddans) as upper-end farms (1.38 feddans). Farmers who rent pumps are about twice that size. But, farmers who have invested in pumps average 7.42 feddans. The larger land holding has enabled them to justify the investment in a pump.

Table 4. Average Farm Size by Location and by Access to Pumps

| Farms Group | Average Number of Feddans of Land |
|---|---|
| All Upper End | 1.38 |
| All Lower End | 3.69 |
| All with pump access | 4.91 |
| Pump renters | 2.72 |
| Pump owners | 7.42 |
| No pumps | 1.43 |

While farmers who obtained an alternative source of water by renting or purchasing a pump bear an additional cost of water that most upper-end farmers do no incur, some lower-end farmers do not have pumps and must rely on the availability of water from canals. These farms are both small and lack a reliable source of water.

Cropping Intensity

It was mentioned above that lower-end farms, especially those without alternative water sources, may tend to be operated more extensively. That is, farmers use fewer non-water inputs per unit of land in response to the absence of a reliable source of water. Further, they may select crops with lower water requirements, delay planting, and use less water and associated inputs per unit of land. Changes in cropping intensity associated with water shortage can be manifested in several ways. First, the amount of idle land would be expected to be greater on canal-end farms than is pesent on farms at the upper reaches of canals. Also, the number of crops per feddan per year may be less on canal-end farms. Farmers with water shortages are likely to practice less intercropping and multiple cropping. Further, the selection of crops used may be different. Water shortages would lead to growing fewer high value crops and selecting crops which are capable of withstanding some water-stress may be more common. Finally, the crop yields obtained per feddan are expected to be smaller on the farms near the canal ends.

Table 5 shows the summer season cropping patterns of farmers. Maize tends to be the dominant crop for all farmers, occupying between 50 and 60 percent of the land. Upper-end farmers and lower-end farmers with pumps grow about the same proportions of maize in their cropping patterns. However, lower-end farmers without pumps grow a much larger proportion of maize relative to vegetables and other crops.

Upper-end farmers have a slightly greater percentage of vegetables than lower-end farmers with pumps. Likely, since lower-end farmers with pumps are much larger than upper-end farmers, labor availability may limit the amounts of vegetables (which are relatively more labor intensive) grown on these lower-end farms. Lower-end farmers without pumps have only about one-half the amount of land committed to vegetables as the comparable sized farms near the upper-end of branch canals. In Appendix Table A-7, it is seen that maize is the ony summer crop for five of the seven lower-end farms with pumps. This cropping pattern is

Table 5. Summer Season Cropping Patterns of Farmers by Location and Water Availability

| Crop | Location Along Branch Canal: Upper* End | Lower End: All Farms | Lower End: With Pumps | Lower End: Without Pumps |
|---|---|---|---|---|
| | (feddans of crop ÷ feddans of land)x100 | | | |
| Maize | 53 | 60 | 55 | 86 |
| Vegetables | 42 | 31 | 33 | 21 |
| Other | 19 | 10 | 11 | 7 |

*Totals may add to greater than 100 because of the practice of intercropping.

not unique to them (See Tables A-8 to A-10), but most farmers who have access to pumps grow some vegetables during the summer season.

During the winter season there is a closer correspondence in cropping patterns between farms of similar size, Table 6. That is, upper-end farmers and lower-end farmers without pumps are more alike in their cropping patterns. Berseem claims most of the land, 70 and 77 percent, respectively. These two groups of farms with about 1.4 feddans of land have about the same amount of wheat as well. The lower-end farms do grow more hot peppers in the winter than the upper-end farmers. Correspondingly, the upper-end farms have more other crops; flax, eggplant, leak, parsley, and garden rocket being some of the more common other crops.

The cropping patterns of the much larger lower-end farmers with pumps differ markedly from the smaller farms. A much smaller proportion of total land is committed to berseem. Likely, they do not need to devote such a high percentage of their land to forage production for livestock. They are able to grow more wheat and tomatoes as cash crops than the smaller farms.

In addition to the crop mix, another possible difference in farming operations associated with water availability is cropping intensity. Cropping intensity is defined as the total number of feddans of all crops divided by the total feddans of land farmed. Crops also vary as to their use of inputs per unit of land. Some crops, such as vegetables may require much more fertilizer, water, and labor per feddan than grain crops. Further, any given crop can be farmed with different levels of input intensity. Maize may be more sparsely seeded and receive less fertilizer in the anticipation of it having lower water requirements per feddan. From Table 7, the cropping intensities (crops/unit of land/year) of the various groups of farmers can be compared. (See Table A-11 and A-12 for more details.) The greatest intensity is found on upper-end farms. However, farms at the lower end with pumps also achieve cropping intensitites greater than 2.0.

Thus, as more water is available during the summer, farms tend to (a) grow more vegetables and (b) have less of the total available land committed to maize. But, during the winter season when water is more uniformly available, cropping patterns appear to be more influenced by size of farm than by location along a branch canal. Small farms have larger proportions of their land devoted to berseem than the larger, canal-end farms with access to pumps. On the other hand, the larger farms grow more wheat, tomatoes and other cash crops.

Table 6. Winter Season Cropping Patterns of Farmers by Location and Water Availability

| Crop | Location Along Branch Canal: Upper* End | Lower end: All Farms | Lower end: With Pumps | Lower end: Without Pumps |
|---|---|---|---|---|
| | (feddans of crop : feddans of land)x100 | | | |
| Berseem | 70 | 38 | 38 | 77 |
| Wheat | 7 | 25 | 28 | 7 |
| Tomatoes | 6 | 14 | 16 | -- |
| Hot Pepper | 1 | 15 | 14 | 16 |
| Other | 22 | 12 | 14 | -- |

*Totals may add to greater than 100 because of the practice of intercropping.

Table 7. Cropping Intensities of Farms by Location and Water Availability

| Season | Location Along Branch Canal: | | | |
|---|---|---|---|---|
| | Upper End | Lower End | | |
| | | All Farms | With Pumps | Without Pumps |
| Summer | 1.14 | 1.01 | 1.01 | 1.0 |
| Winter | 1.06 | 1.14 | 1.14 | 1.0 |
| Annual | 2.20 | 2.13 | 2.15 | 2.0 |

Cropping intensity, as measured by the ratio total feddans of crops to the total feddans of land, does not appear to be greatly influenced by size or by position along a branch canal. But, if the crop mix is considered, cropping intensity differences are more pronounced. Since vegetables (an input intensive crop) is associated with superior water availability, whether provided by the canal or by pump, a part of the increased cropping intensity is hidden in the choice of crops. The small farms without pumps near the end of branch canals choose to concentrate their efforts to growing maize during the summer season.

A further dimension of cropping intensity is that of expected production per feddan. Farmers were asked about their expected yields from crops. Comparable data were obtained for only one crop and these results are presented in Table 8. Important differences are shown in the farmers expected maize yield depending upon their circumstances for water availability. Upper-end farmers expect a maize yield of 11.2 ardabs* per feddan. Lower-end farmers with pumps have expected maize yeidls of 10.7 ardabs and lower-end farmers without pumps expect yields of only 6.7 ardabs. Thus, another measure of intensity, the amount of production per unit of land, is also associated with water availability. Crop yields are decreased as water becomes less available.

One might expect farmers at the lower-end with pumps to have yield expectations at least as great as those farmers at the upper-end. Three possbile explanations for their lower expected yields can be advanced. (a) Even with pumps lower-end farmers incur an additional cost for water. For economic reasons they may choose to apply less water per feddan of maize than do upper-end farmers. The added costs they are incurring (pumping costs) do not justify as much water applied per feddan of maize as is the case when these pumping costs are less. (b) The soils near the lower reaches of branch canals are more saline than those at the upper reaches.[7] Perhaps because of inadequate deliveries of water to flush these salts from the soil, higher levels of salts have accumulated and these salts are deleterious to yields of most crops. (c) Further, water pumped from the ground or from drains may be of lower quality than canal water.

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* An ardab is a volume measure which varies in weight depending on the commodity measured; an ardab of maize is 140 kilograms or about 308 pounds.

[7] Dotzanko, A.D., M. Zanati, A.A. Abdel-Wahed, and A.M. Keleg, "Preliminary Soil Survey Report for the Beni-Magdul and El-Hammami Areas." Egypt Water Use and Management Project, Technical Report No. 2, 1979.

Table 8. Expected Maize Yields on Farms by Location and Water Availability

| Farmer Group | Expected Maize Yield/Feddan |
|---|---|
| | (ardabs) |
| Upper end | 10.6 |
| Lower end: | |
| with pumps | 8.9 |
| without pumps | 6.7 |

Another measure of cropping intensity is the amount or extent of idle land. Farmers were asked how much or for how long they may leave land idle. Response to this question was rather limited, but 5 lower-end farmers indicated that they leave some land idle for a period of about one month. Two others indicated that they often delay planting of crops because of the lack of available water. Leaving land idle tends to be associated with farmers without access to pumps.

Anticipated Changes

The survey results presented thus far, are measurements of how water availability is affecting farming operations. Differences in the organization and operation of upper-end and lower-end farms have been observed. We next turn to more "what if" kinds of issues. That is, if water were available according to schedule, how would cropping patterns, cropping intensities and expected yields change. Data on "what farmers would do if questions" are more qualitative than those data presented above, but the provide some additional information. The responses are detailed in Table A-13.

When asked how they would respond to water being available more on schedule during the summer, 12 lower-end farmers indicated that they would grow more vegetables, 5 would keep the same crops (two of these volunteered they would expect a higher yield) 2 would grow more maize and 2 would grow more of other crops.

The better delivery of water relative to the water rotation schedule and crop water requirements during the winter season is also reinforced in these data. During the winter season most farmers would maintain the same crops.

The differences observed between upper-end and lower-end farmers and between those with and without alternative water sources are supported by these indicated changes in improved water delivery. The amounts of summer vegetables are being limited by available water; more maize is grown than would be if the water situation were changed. Lower-end farmers without alternative water sources also expect lower maize yields because of the problems associated with water availability; several farmers indicated they would expect a higher yield if more water were available.

Given the adjustments farmers have made or are making to their cirucumstances of water delivery, it is appropriate to consider the potential benefits from actions to improve the distribution of water along branch canals.

The following section discusses some of the potential benefits. The necessary data to demonstrate the benefits from alternative water distributions are not readily available. The data on which the following discussions are based do serve to illustrate the costs and benefits to improved water distribution. The material presented also illustrates the potential importance on the problem to the agricultural economy of Egypt.

Implications of Water Delivery Problems

The information presented above illustrates that differences are present between upper-end and lower-end farmers along branch canals. These differences are associated with the delivery of irrigation water. The availability of irrigation water according to schedule is important to (a) the income potentials of individual farmers and (b) to the area or district, measured as the extent to which agricultural output potentials are being reached. (c) Further, the problem has national significance to the government of Egypt and the agricultural sectors ability to contribute to national economic development goals.

Farmer Income

Farmers at the lower end of branch canals may be adversely affected by one or more ways. First, they may incur additional costs to supply water to their farms. Investments in pumps and wells and/or expenditures for pump rentals are being incurred by some farmers. Second, their cropping patterns are affected. Farmers are forced to choose crops which are relatively less sensitive to moisture stress and must forego the opportunity to produce vegetables (in the Mansuriya district) with greater income earning potentials. Finally, even for the same crop mix, lower-end farmers cannot achieve the same yields per unit of land as their peers at the upper-end.

Table 9 shows the amount of investment in pumps and wells reported by the farmers who responded. Total investments vary from L.E. 400 to L.E. 2,300; investment per feddan ranges from about L.E. 89 to L.E. 250.

Three of the farmers who own pumps also have wells; one of these farmers has two wells. Two others pump from a drain. The source of water for the remaining farmer is not known. One farmer indicated that he jointly owns the pump with two other farmers.

Farmer number 2 rents his pump so that it serves about 25 feddans in addition to the 3 feddans he owns. His rental income on the pump is about L.E. 0.75 per hour; total annual income from pump rental is about L.E. 675.

Table 9. Investments in Alternative Water Sources Reported by Lower-End Farmers Who Own Pumps

| Farmer[a] Number | Investment | Land Farmed | Investment per Feddan |
|---|---|---|---|
| | (L.E.) | (feddans) | (L.E.) |
| 1 | 2,000 | 17 | 117.65 |
| 2 | 700 | 3 | 233.33 |
| 3 | 400 | 2.5 | 160 |
| 5 | 1,500 | 6 | 250 |
| 6 | 400 | 4.5 | 88.89 |
| 15 | 2,300 | 11.5 | 200 |
| Average | 1,217 | 7.4 | 164.45 |

[a]Farmer numbers here correspond to those identified in Tables A-1 through A-13.

Farmer number 6, who jointly owns his pump with two others, also rents the pump to others. The pump serves 13.5 feddans for the three owners and is rented to provide water to another 4 feddans. The rental cinome is L.E. 0.60 per hour or about L.E. 60 per year. Thus, farmers who own pumps may be spreading the fixed costs of these pumps by providing either water or a pump for rent to this neighbors.

In addition to these investments, which must be amortized over several years, farmers must pay the operating costs for using these pumps. Upper-end farmers also have water lifting costs; however,the data obtained for this study are not sufficient to compare the costs of lifting water between upper-end and lower-end farmers. Reports are in preparation by other EWUP economists which examine the costs of lifting water by alternative means.[8] Appendix B-1 and B-2 provide some investment and operating cost data as reported by two farmers included in this study. This study was not designed to provide sufficient information about differences in water lifting costs between upper-end and lower-end farmers to make comparisons.

Other farmers rent pumps to offset canal water delivery shortfalls. Table 10 summarizes the average rental cost obtained from those who reported. Pump rental rates vary a great amount, from L.E. 0.50 per hour to L.E. 1.00 per hour. The average rental rate is L.E. 0.67. Likely, these variations are associated with size and flow rate but the data obtained do not include such measurements.

Farmers who neither own or rent pumps, and perhaps some who rent pumps only for certain crops or irrigations, have different kinds of costs. Their cost are opportunity costs of income foregone. It was shown earlier that the cropping patterns favor maize at the expense of vegetables. Further, expected maize yields are much lower than those expected by upper-end farmers and by lower-end farmers with pumps.

First, consider the differences in income per feddan from vegetables versus maize. The EWUP Enterprise Cost Sutdies estimate the net return above all costs

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[8] Quenemoen, M.E. and Shinnawi Abdel Atty El Shinnawi, "An Economic Analysis of Water Lifting With a Diesel Pump for a Farm at El Hammami." A Paper presented at the UNESCO Training Conference on Irrigation Development. Egypt Water Use and Management Project, 1979.

Table 10. Pump Rental Costs Paid by Lower-End Farmers Reporting

| Farmer Number | Rental Cost per Hour |
|---|---|
| | (L.E.) |
| 3 | 0.60 |
| 7 | 0.80 |
| 8 | 0.80 |
| 9 | 0.50 |
| 12 | 0.50 |
| 19 | 1.00 |
| 20 | .50 |

for cabbage in the El Hammami area are L.E. 351.36 feddan.[9] In the same area, the net return above all costs for eggplant is L.E. 227.62 per feddan.[10] And for tomatoes in the Beni-Magdul area, per feddan net returns above all costs are estimated at L.E. 52.54.[11] Currently available data do not permit direct comparisons to maize in the Mansuriya district. However, enterprise costs and returns have been made for maize in the Abu-Raya area of the Kafr El Sheikh Governorate. The yields reported in this estimate are 13 ardabs, slightly greater than the 10.6 ardabs yield expected by Mansuriya district farmers. Net return per feddan of maize above all costs is reported as L.E. 7.19.[12] It appears that net returns above all costs are considerably higher for vegetables than for maize. Income sacrifices per feddan may range from L.E. 46, comparing maize to tomatoes, to L.E. 344 when comparing maize to cabbage.*

Even if maize is produced, the opportunity cost of foregone income is great. Gross returns per feddan from maize yielding 10.6 ardab and priced at L.E. 8 per ardab is L.E. 84.8. The gross returns per feddan associated with the 6.7 ardab maize expected by lower-end farmers without pumps is L.E. 53.6. A difference of L.E. 31.2 in expected gross returns per feddan of maize exists between these two groups.

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*These analyses hold true for individual farmers only; if all farmers increased vegetable production, additional supplies would cause prices to decrease and the net income differences to narrow.

[9] El Shinnawi and Farouk Abdel Al, "Crop Enterprise Cost Study, Cabbage at El Hammami Area." Egypt Water Use and Management Project, 1979.

[10] El Shannawi and Farouk Abdel Al, "Crop Enterprise Cost Study, Eggplant at El Hammami Area." Egypt Water Use and Management Project, 1979.

[11] Lofti, Nasr and Farouk Abdel Al, "Crop Enterprise Cost Study, Tomatoes at Beni-Magdul Area." Egypt Water Use and Management Project, 1978.

[12] Quenemoen, M.E., Yusef Yusef and Gamal Ayad, "Crop Enterprise Cost Study Maize at Abu-Raya." Egypt Water Use and Management Project, 1978.

Production losses along branch canals.

Differences in water costs and net income per feddan between farmers with adequate irrigation water and those with water shortages can be sizable. Here, it will be shown that for a given amount of water delivered to the head of a branch canal, total production can be increased by improving the distribution of water along the branch. That is, a greater total output can be reached by providing more water to lower-end farmers, even if this requires reducing water use of upper-end farmers.* Thus, if water use efficiency is measured as the amount of (or value of) agricultural ouput per unit of water, an improvement in water use efficiency would occur by providing a more uniform distribution of water along all branch canals. The potential benefits from a more uniform distribution are different depending on whether or not adequate amounts of water are being available at the head of branch canals to meet the crop water requirements for all land served by the canal. Here we assume adequate water is available at the head of the branch canal. The potential gains from improved water distribution then depend on the case if (a) upper-end farmers are using excessive amounts of water and thereby prevent the water from being delivered to lower-end users, or (b) upper-end farmers are not using water excessively, but the water is being lost by seepages, weed growth, etc., from the branch canals. Water use efficiency cannot be considered in isolation from other input use. Suppose in either case that adequate amounts of all other inputs are available and are varied in correct proportions to the amount of water applied. Figure 2 and 3 illustrate these two cases.

Figure 2 is based on a production response function for corn (maize) at Davis, California.[13] As for Egypt, little or no growing season precipitation occurred in the experiments on which the function is based. The functional relationship between water (W) in acre-inches, pounds of nitrogen (N) fertilizer, and pounds of maize production (M) per acre is:

$$(1) \quad M = 3294.4 + 367.2W + .52N - 7.06W^2 + .0038N^2 - .0458WN$$

---

*If lower-end water shortages are caused by losses in the branch canal from seepage, weed growth, etc., reallocations may not be necessary. Upper-end irrigations would not be affected by measures to reduce in-canal losses which would provide more water to lower-end farmers.

[13] Heady, E.O. and R.W. Hexem. Water Production Functions for Irrigated Agriculture. Iowa State University Press, Ames, Iowa. 1978. P. 92.

Since it is assumed the levels of all other inputs but water are given, setting N=100 the production response equation reduces to:

$$(2) \quad M = 3852.4 + 366.7W - 7.05W^2$$

The maximum per acre yield occurs when 25.97 acre-inches of water are applied resulting in a yield of 8.614 pounds of maize per acre. converting these measurements to cubic meters ($m^3$) per feddan and ardabs of maize, the maximum yield occurs when 2,770.8$m^3$ of water is applied and a yield of 29.03 ardabs of maize is reached. This yield is more than double the greatest of yields observed among the farmers sampled in this survey. The response function is fit to data from a controlled experiment and the cultural practices applied in California are different from those used in Egypt. The functional relationship given in equation 2 is adjusted for both the experimental and cultural practice effects and the following equation results:*

$$(3) \quad Y = 1926.2 + 183.4W - 3.53W^2$$

With equation 3, yields still reach a maximum at 2770.8$m^3$ of water; the maximum yield is 14.5 ardabs per feddan. Such is consistent with the survey data and other reports of maize yields in Egypt.[14]

In Figure 2 we assume that upper-end farmers are not using excessive amounts of water. Shown along the water response curves for maize, are points corresponding to the possible water application rates for upper-end and lower-end farmers. First, Point A on the curve locates where lower-end farmers without pumps may be operating; they may be receiving only one-fourth the amount of water as upper-end farmers.[15] Point C locates where upper-end farmers may be operating; they are applying water at the level which maximizes their yields.

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*Equation 3 is derived as Y = 1/2 (equation 2)

[14] Fitch, J.B., A.A. Goueli, and M. El Gabely, "The Cropping System for Maize in Egypt, Survey Findings and Implications for Policy in Egypt," Workshop on Improved Farming Systems for the Nile Valley. Ministry of Agriculture and UNDP/FAO. Cairo. 1979.

[15] op. cit., Wolfe, et al.

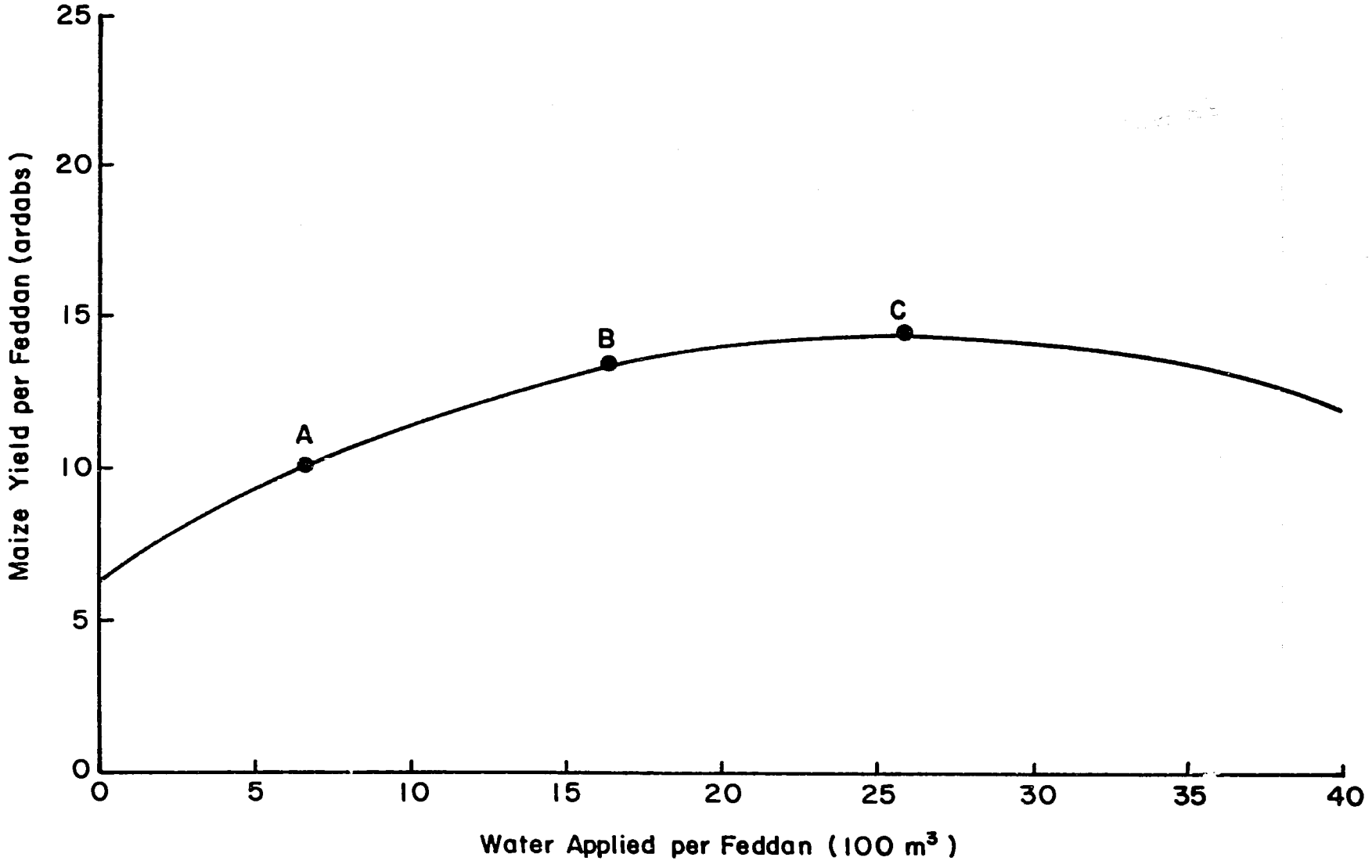


Figure 2. Water Response Curve for Maize; Upper-End Farmers Not Using Water Excessively

At A about 700 cubic meters of water are applied and at C, about four times as much or 2,800 cubic meters are applied. In equation 3 the maximum yield for 14.5 ardabs is reached with about 2,600m$^3$ of water per feddan. From equation 3 the estimated yield reduction resulting from reducing water application by, say, 500m$^3$ can be estimated. If W-2, 100m$^3$, maize yields would be reduced by 0.30 ardab. If that 500m$^3$ were made available to lower-end farmers, water applications could be increased from 650m$^3$ per feddan (Point A) to 1,250m$^3$ per feddan and an additional yield of about 2.37 ardab would be forthcoming. A gain of 2.37 - .30 = 2.07 ardab of maize would be obtained on each feddan following this reallocation. Such redistributions could continue until the marginal increment in yield per unit of water is equated for the upper-end and lower-end farmers such as would occur at Point B. At B, the output of 2 feddans would be only 24.5 ardabs (10.0 + 14.5). This distribtuion of the same amount of water, a total of 3,250 cubic meters for 2 feddans, would yield about 9 percent more maize.

If, however, the situation is a depicted in Figure 3, the potential gains from redistribution are even more significant. Here it is assumed that (a) adequate amounts of water are being delivered to the head of branch canals and that (b) upper-end farmers are using water destined for lower-end users. The upper-end farmers are, in fact, using so much water that it is deleterious to their yields.* That some farmers may be using water excessively was cited as a possibility in an earlier study.[16] This report found some indication that as water applications increase, total yields decrease. Such is the case at Point C. In Figure 3, a total of about 2,500m$^3$ is provided for each feddan of maize, an amount which approximates its consuptive use requirements. The distribution is not uniform, however, upper-end farmers claim 4,000m$^3$ of water leaving only 1,000m$^3$ for lower-end farmers. Points A and C depict the lower-end and upper-end farmers operations, respectively.

Lower-end farmers are using 1,000 cubic meters of water (1/4 the amount of upper-end users) and are obtaining a yield of about 11.5 ardabs per feddan. Upper-end farmers are using 4,000 cubic meters and get a yield of 12.0 ardabs.

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*Such water use practices appear irrational. They are rational, however, in that such input use practices often occur because of lack of knowledge, risk aversion, or are necessary to insure one's continued use of a resource.

[16] El Kady, op. cit., P. 54.

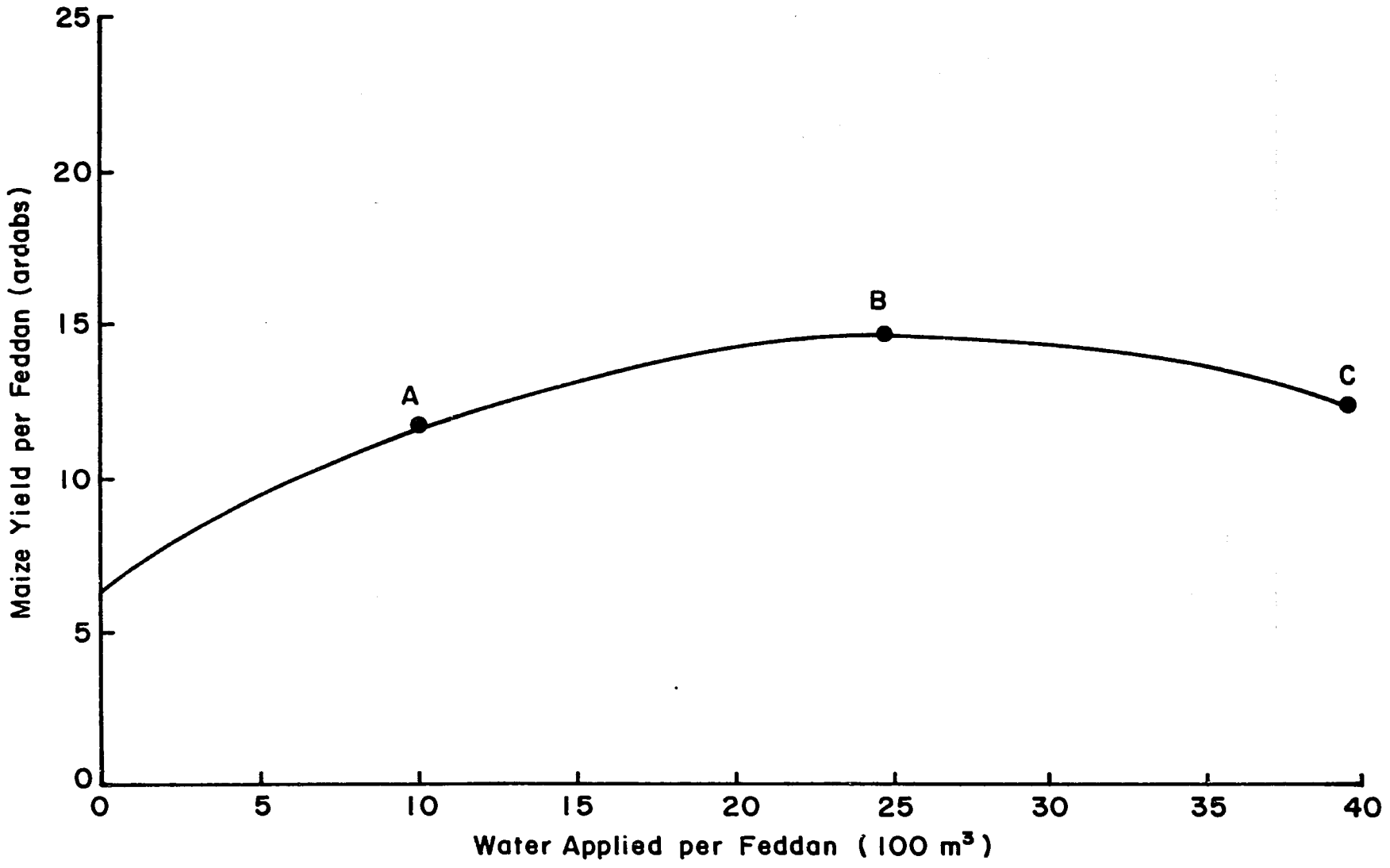


Figure 3. Water Response Curve for Maize; Upper-End Farmers Using Water Excessively

Now, redistribution of water from the upper-end to lower-end will benefit both groups. If 1,500 cubic meters are taken from each upper-end feddan, reducing the amount applied from 4,000m$^3$ to 2,500m$^3$, yields would increase from 12.0 ardabs to 14.5 ardabs. A corresponding increase in the amount of water delivered to maize on lower-end farms would increase the water used per feddan from 1,000 to 2,500m$^3$ and increase their yields from 11.5 to 14.5 ardabs. Dividing the water equally among upper-end and lower-end land, allowing 2,500m$^3$ for each feddan equates the yield increment per marginal unit of water. At this point (Point B in Figure 3) the yield would be 124.5 ardabs for both upper-end and lower-end lands. Thus, total output from 2 feddans, one located at the upper-end and the other at the lower-end, would increase from 11.5 + 12.0 = 23.5 ardabs to 29 ardabs. This is a 23 percent increase.

Depending on whether the situation in Figure 2 or Figure 3 prevails, potentials to increase water use efficiency and agricultural output along branch canals are present. Output of maize alone could increase from 9 to 23 percent. Likely, changes would also occur in the cropping patterns as lower-end farmers would grow more vegetables. Thus, the benefits demonstrated by Figure 2 and 3 are on the conservative side. The potentials to achieve improvements in water use efficiency are even greater than the illustrations reveal.

Aggregate Effects

Just as the efficiency of water use along a branch canal can be increased by improved distribution of water and these efficiency gains are relaized as a greater level of agricultural output, approximations can be made of the potential benefits to the agricultual output of the nation. Egypt has about 5.5 million feddans of land. In the Mansuriya area, lower-end farmers without access to alternative sources of water have about 86 percent of the land in maize during the summer season. Their peers with water have only about 54 percent of their land in maize. Conversely, vegetables make up only 21 percent of lower-end without water farmers' summer crops, while those with water have between 33 and 42 percent (say 37 percent) of their land in vegetables. One-third of the land is being operated below its potential. The Mansuriya district includes 27,745 feddans.[17] The lower-end farms produce only (27,745 ÷ 3 X .21) 1,942 feddans of vegetables while upper-end farms produce (27,745 ÷ 3 X .37) 3,422

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[17] op. cit. Wolfe, et. al.

feddans of vegetables. The difference in net farm income per feddan of vegetables and that of maize ranged from L.E. 46 to 344. Assuming a difference of L.E. 200, the income foregone from not producing vegetables in the Mansuriya district alone could amount to L.E. 296,000 per year. It is very possible, however, that the amount of vegetables grown is constrained by labor availability. Thus, extrapolation like those presented here should be interpreted with some reservations.

In addition, the net income per feddan of maize grown by lower-end farmers is below potential. Increases in gross income per feddan of maize could range from 9 to 23 percent. Gross income per feddan of maize is about 13 ardabs at L.E. 8 = L.E. 104. Assume maize would occupy only 54 percent of the summer land, as with farmer with adequate water, and 4,994 feddans of maize are below potential (27,745 feddans x 1/3 x .54). A 10 percent increase in gross income per feddan amounts to L.E. 51,938 (4,994 x .72); a 23 percent increase would increase gross farm income by L.E. 119,456.

Not all areas of Egypt possess the income potentials from vegetables as does the Mansuriya district. Nevertheless, these analyses illustrate the potential gains which can be achieved by improving the efficiency of water distribution and use. Further, such estimates of the benefits from improvements in water use efficiency can serve as a guide as to how much can be spend to improve the efficiency of water delivery and use. Such is the goal of the Egypt Water Use and Management Project.

# APPENDIX "A"

# APPENDIX A

## EGYPT WATER USE AND MANAGEMENT PROJECT
## (ECONOMICS TEAM)
## INTENSIVE (FARMER) SURVEY
## EVALUATION OF WATER SHORTAGES
## ON BRANCH CANALS

SITE AND GOVERNORATE: _____

1. Name _____ Age _____

2. Family Members: Wife _____

   Children: Age Sex

   _____ _____

   _____ _____

3. Location: Name of Canal _____

   Canal Start _____

   Canal End _____

4. Amount of land farmed: Number of Feddans _____

   Number of Feddans Owned _____

   Number of Feddans Rented _____

5. Livestock and Equipment Inventories:

   a.

| Livestock | No. | Age | Uses |
|---|---|---|---|
| Buffalo | _____ | _____ | _____ |
| Cattle | _____ | _____ | _____ |
| Donkeys | _____ | _____ | _____ |
| Goats | _____ | _____ | _____ |
| Sheep | _____ | _____ | _____ |
| Chickens | _____ | _____ | _____ |
| Other (Specify): | | | |
| _____ | _____ | _____ | _____ |

---

Data Prepared By: _____

Date: _____

a.

| Equipment | No. | Uses |
|---|---|---|
| Sakia | _____ | _____ |
| Tambour | _____ | _____ |
| Shadoof | _____ | _____ |
| Plow | _____ | _____ |
| Tractor | _____ | _____ |
| Planter | _____ | _____ |
| Diesel Pump | _____ | _____ |
| Electric Pump | _____ | _____ |

6. Source of Water; number of feddans served by:

| | |
|---|---|
| Canal Only | _____ |
| Canal & Drain | _____ |
| Canal & Well | _____ |
| Well Only | _____ |
| Other (specify) | _____ |

7. Crops Grown:

a.

| Summer Crops | No. of Feddans (expected) | Average Yield |
|---|---|---|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

b.

| Winter Crops | No. of Feddans | Average Yield (expected) |
|---|---|---|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

8. Water Rotation:

Summer: Days On _____ Days Off _____

Winter: Days On _____ Days Off _____

9. Canal Water Availability:

a. Summer Season

(1) Usually available on schedule _____

(2) Available as scheduled about 3 times out of 4 _____

(3) Available as scheduled about one-half the time _____

(4) Available as scheduled about one-fourth the time _____

(5) Never available as scheduled _____

(6) Is water available at night? _____
Explain: _____
_____

(7) Will you or do you irrigate at night?_____
Explain _____
_____

b. Winter Season

(1) Usually available on schedule _____

(2) Available as scheduled about 3 times out of 4 _____

(3) Available as scheduled about one half the time_____

(4) Available as scheduled about one-fourth the time _____

(5) Never available as scheduled _____

(6) Is water available at night? _____
Explain _____
_____

(7) Will you or do you irrigate at night? _____
Explain _____
_____

10. Changes in farming practices because of problems with water availability:

    a. Leave land idle _____ if so, number of feddans _____, for how many months/year _____

    b. Change crops grown from _____ to _____

    c. Develop an alternative water source from _____ to _____

11. If water was always available according to rotation, what crops would be grown?

| Summer Crops | No. of Feddans | Average Yield (expected) |
|---|---|---|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

| Winter Crops | No. of Feddans | Average Yield (expected) |
|---|---|---|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

12. Do you rent a pump? Yes____ No_____

13. Do you own a pump? Yes____ No_____

    a. If yes on 12 or 13, source of power:

    ____ Diesel

    ____ Electric

    ____ Other (Specify): _____

    b. Pump Characteristics:

    Motor size _____

    Investment Cost (if owned) _____

    Year Purchased (if owned) _____

    Rental Cost (if rented) _____

    c. Number of months per year in which the pump is used. _____

14. Reasons for using pump:

    a. Labor shortage _____

    b. Problem of feed for livestock used to turn sakia _____

    c. Can apply available canal water on a more timely basis _____

    d. Lower cost method of pumping water _____

    e. Used as an alternative to taking water from canal _____

    f. Other
    (specify): _____
    _____

15. Do you have a well to supply part of the wtaer used on your farm?

    Yes ___ No___

    a. If yes, year installed _____

       Investment cost _____

       Depth _____

    b. Number of months per year the well is used to supplement canal water_____

    c. Number of years in 10 the well will be needed to supplement canal water _____

16. Reason for investing in well:

    a. Better water _____

    b. Water is always availabe when needed_____

    c. Needed because of water shortages from canal during some months _____

    d. Other
    (specify): _____
    _____

17. Do you obtain some water used on your farm from sources other than the canal or well? Please explain _____
    _____

18. Is quality of water a problem at any of the sources available to you?
    _____
    _____
    _____

Farm Location Map

## CONVERSION FROM KERATES TO FEDDANS

| K. | F. | K. | F. | K. | F. |
|---|---|---|---|---|---|
| 1 | 0.04 | 9 | 0.38 | 17 | 0.71 |
| 2 | 0.08 | 10 | 0.42 | 18 | 0.75 |
| 3 | 0.13 | 11 | 0.46 | 19 | 0.79 |
| 4 | 0.17 | 12 | 0.50 | 20 | 0.83 |
| 5 | 0.21 | 13 | 0.54 | 21 | 0.88 |
| 6 | 0.25 | 14 | 0.58 | 22 | 0.92 |
| 7 | 0.29 | 15 | 0.63 | 23 | 0.96 |
| 8 | 0.33 | 16 | 0.67 | 24 | 1.00 |

Table A-1. Availability of Canal Water to Farmers at the Lower End of Branch Canals During Summer Season and Practice of Night Irrigation

| Farm Number | Canal Water is Available: Usually on Time | About 3/4 of the Time | About 1/2 of the Time | About 1/4 of the Time | Never on Time | Night Irrigation Yes | No |
|---|---|---|---|---|---|---|---|
| 1 | | | | | X | X | |
| 2 | | | | | X | | |
| 3 | | | | X | | | |
| 4 | | X | | | | | |
| 5 | | | | X | | X | |
| 6 | | | X | | | X | |
| 7 | | | | X | | X | |
| 8 | | | | X | | X | |
| 9 | | | | X | | X | |
| 10 | | X | | | | X | |
| 11 | | | X | | | X | |
| 12 | | | X | | | X | |
| 13 | | | X | | | | X |
| 14 | X | | | | | X | |
| 15 | | | | X | | | X |
| 16 | | | X | | | X | |
| 17 | X | | | | | X | |
| 18 | X | | | | | | X |
| 19 | | | | X | | X | |
| 20 | | | | X | | X | |
| Number | 3 | 2 | 5 | 8 | 2 | 14 | 3 |

Table A-2. Availability of Canal Water to Farmers at the Upper End of Branch Canals During the Summer Season and Practice of Night Irrigation

| Farm Number | Canal Water is Available: Usually on Time | About 3/4 of the Time | About 1/2 of the Time | About 1/4 of the Time | Never on Time | Night Irrigation Yes | Night Irrigation No |
|---|---|---|---|---|---|---|---|
| 1 | X | | | | | X(sometimes) | |
| 2 | X | | | | | X | |
| 3 | | | X | | | | X |
| 4 | | X | | | | X | |
| 5 | | X | | | | X | |
| 6 | | X | | | | X | |
| 7 | | X | | | | X | |
| 8 | | X | | | | | X |
| 9 | | X | | | | X | |
| 10 | | | X | | | X | |
| 11 | | | X | | | X | |
| 12 | | X | | | | X | |
| 13 | | X | | | | X | |
| 14 | | X | | | | | X |
| 15 | | X | | | | | X |
| 16 | | X | | | | X | |
| 17 | X | | | | | | X |
| 18 | | X | | | | X | |
| Number | 3 | 12 | 3 | | | 13 | 5 |

Table A-3. Availability of Canal Water to Farmers at the Lower End of Branch Canals During the Winter Season

| Farmer Number | Canal Water is Available: Usually on Time | About 3/4 of the Time | About 1/2 of the Time | About 1/4 of the Time | Never on Time |
|---|---|---|---|---|---|
| 1 | | | | | X |
| 2 | | | | X | |
| 3 | X | | | | |
| 4 | X | | | | |
| 5 | | X | | | |
| 6 | X | | | | |
| 7 | | X | | | |
| 8 | X | | | | |
| 9 | | | X | | |
| 10 | | X | | | |
| 11 | | X | | | |
| 12 | | X | | | |
| 13 | | X | | | |
| 14 | X | | | | |
| 15 | X | | | | |
| 16 | X | | | | |
| 17 | X | | | | |
| 18 | X | | | | |
| 19 | X | | | | |
| 20 | X | | | | |
| Number | 11 | 6 | 1 | 1 | 1 |

Table A-4. Availability of Canal Water at the Upper End of Branch Canals During the Winter Season

| Farmer Number | Canal Water is Available: Usually on Time | About 3/4 of the Time | About 1/2 of the Time | About 1/4 of the Time | Never on Time |
|---|---|---|---|---|---|
| 1 | X | | | | |
| 2 | X | | | | |
| 3 | X | | | | |
| 4 | X | | | | |
| 5 | X | | | | |
| 6 | X | | | | |
| 7 | X | | | | |
| 8 | X | | | | |
| 9 | X | | | | |
| 10 | X | | | | |
| 11 | X | | | | |
| 12 | X | | | | |
| 13 | X | | | | |
| 14 | X | | | | |
| 15 | X | | | | |
| 16 | X | | | | |
| 17 | X | | | | |
| 18 | X | | | | |
| Number | 18 | | | | |

Table A-5. Access to Irrigation Pumps by Farmers at the Lower End of Branch Canals

| Farm Number | Rent a Pump | Own a Pump | Months Pump Used |
|---|---|---|---|
| 1 | | X | 12 |
| 2 | | X | 10 |
| 3 | X | X | 3 |
| 4 | | | |
| 5 | | X | 12 |
| 6 | | X | 12 |
| 7 | X | | 3 |
| 8 | X | | 3-5 |
| 9 | X | | <1 |
| 10 | | | |
| 11 | X | | <1 |
| 12 | X | | <1 |
| 13 | | | |
| 14 | | | |
| 15 | | X | 7-8 |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | X | | <1 |
| 20 | X | | <1 |
| Number | 8 | 6 | --- |

Table A-6. Access to Irrigation Pumps by Farmers at the Upper End of Branch Canals

| Farm Number | Rent a Pump | Own a Pump | Months Pump Used |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | Yes | | 1 |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | Yes | | <1 |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |

Table A-7. Cropping Patterns of Farmers at Lower End of Branch Canals During Summer Season

| Farmer Number | Total Land | Maize (grain) | Maize (forage) | Vegetables | Other |
|---|---|---|---|---|---|
| | ---- no. of feddan ---- | | | | |
| 1 | 17 | 8 | 3 | 6 | |
| 2 | 3 | 1 | | 2 | |
| 3 | 2.5 | 1.25 | .6 | .6 | |
| 4 | 4.25 | 3.5 | .75 | 1.5 | |
| 5 | 6 | 2 | | | 2.5 |
| 6 | 4.5 | 2 | 1 | 1.5 | |
| 7 | 3.5 | 1 | 1 | 1.5 | |
| 8 | 1.33 | 1 | .33 | | |
| 9 | 1 | 1 | | | |
| 10 | 1 | 1 | | | |
| 11 | 1.5 | 1 | | .5 | |
| 12 | 4.5 | | 1.5 | 1.75 | 1.75 |
| 13 | .4 | .4 | | | |
| 14 | 1.4 | .8 | .6 | | |
| 15 | 11.5 | 4 | | 5 | 2.5 |
| 16 | .63 | .63 | | | |
| 17 | 1 | 1 | | | |
| 18 | 1.38 | | | .63 | .75 |
| 19 | 5 | 4 | .67 | .33 | |
| 20 | 2.5 | .83 | | 1.67 | |
| Total | 73.89 | 34.41 | 9.45 | 22.98 | 7.50 |
| Average | 3.69 | 1.72 | .47 | 1.15 | .38 |
| Percent | ---- | 47 | 13 | 31 | 10 |

Table A-8. Cropping Patterns of Farmers at Upper End of Branch Canals During Summer Season

| Farmer Number | Total Land | Maize (grain) | Maize (forage) | Vegetables | Other Crops |
|---|---|---|---|---|---|
| | ---- no. of feddan ---- | | | | |
| 1 | 1.5 | 1.25 | | .38 | |
| 2 | 1.5 | 1.5 | | | |
| 3 | .3 | | | .3 | |
| 4 | 1.5 | .5 | .5 | .5 | .5 |
| 5 | 1.25 | 1.0 | | .5 | |
| 6 | .67 | | | | .67 |
| 7 | .83 | | | .83 | |
| 8 | .17 | | | .17 | |
| 9 | 2 | 1.0 | .25 | .5 | .5 |
| 10 | 2 | .75 | | 1.25 | |
| 11 | 2 | 2 | | | |
| 12 | 2.75 | 1 | | 1.0 | 1.25 |
| 13 | .63 | .29 | | .34 | |
| 14 | 3 | 1.5 | | 2.08 | |
| 15 | .33 | | | .33 | |
| 16 | 3 | 1.5 | | | 1.5 |
| 17 | .5 | .25 | | .75 | |
| 18 | .92 | | | 1.5 | .42 |
| Total | 24.85 | 12.54 | .75 | 10.43 | 4.84 |
| Average | 1.38 | .70 | .04 | .58 | .27 |
| Percent | ----- | 50 | 3 | 42 | 19 |

Table A-9. Cropping Patterns of Farmers at Lower End of Branch Canals During Winter Season

| Farmer Number | Total Land | Berseem | Wheat | Tomatoes | Hot Peppers | Other |
|---|---|---|---|---|---|---|
| | ----- no. of feddan ----- | | | | | |
| 1 | 17 | 5 | 10 | 8 | 2 | |
| 2 | 3 | 1 | 1 | | | 1 |
| 3 | 2.5 | 1.25 | 1.25 | | | |
| 4 | 4.25 | 3.5 | .75 | | | |
| 5 | 6 | 1 | .5 | .5 | 2 | 2 |
| 6 | 4.5 | 1 | 2 | | 1.5 | |
| 7 | 3.5 | 1 | 1 | 1 | 1 | .5 |
| 8 | 1.33 | .33 | | .5 | .5 | |
| 9 | 1 | .5 | .5 | | | |
| 10 | 1 | 1 | | | | |
| 11 | 2 | 1 | | | | 1 |
| 12 | 4.5 | 3 | 1.5 | | | |
| 13 | .4 | .4 | | | | |
| 14 | 1.4 | .6 | | | .8 | |
| 15 | 11.5 | 2.5 | | .5 | 2 | |
| 16 | .63 | .63 | | | | |
| 17 | 1 | 1 | | | | |
| 18 | 1.38 | .58 | | | .79 | |
| 19 | 5 | 2 | | | | 3 |
| 20 | 2.5 | .83 | | | .20 | 1.33 |
| Total | 74.39 | 28.12 | 18.5 | 10.5 | 10.79 | 8.83 |
| Average | 3.72 | 1.41 | .93 | .52 | .54 | .44 |
| Percent | ----- | 38 | 25 | 14 | 15 | 12 |

Table A-10. Cropping Patterns of Farmers at the Upper End of Branch Canals During the Winter Season

| Farmer Number | Total Land | Berseem | Wheat | Tomatoes | Hot Peppers | Other |
|---|---|---|---|---|---|---|
| | ----- no. of feddan ----- | | | | | |
| 1 | 1.5 | 1.25 | | | | .25 |
| 2 | 1.5 | 1.5 | | | | |
| 3 | .3 | .3 | | | | |
| 4 | 1.5 | 1.25 | | | .25 | |
| 5 | 1.25 | 1.25 | | | | |
| 6 | .67 | .67 | | | | |
| 7 | .83 | .83 | | | | |
| 8 | .17 | .17 | | | | |
| 9 | 2 | 1.5 | | 1.0 | | |
| 10 | 2 | 1.5 | | | | .5 |
| 11 | 2 | 1 | | | | 1 |
| 12 | 2.75 | 1.58 | .33 | | | .92 |
| 13 | .63 | .17 | | | | 1.38 |
| 14 | 3 | 1.5 | | .5 | | 1.0 |
| 15 | .33 | | | | | .33 |
| 16 | 3 | 1.5 | 1.5 | | | |
| 17 | .5 | .5 | | | | |
| 18 | .92 | .92 | | | | |
| Total | 24.85 | 17.39 | 1.83 | 1.5 | .25 | 5.38 |
| Average | 1.38 | .97 | .1 | .08 | .01 | .30 |
| Percent | ---- | 70 | 7 | 6 | 1 | 22 |

Table A-11. Cropping Intensity on Farms at Lower End of Branch Canals

| Farmer Number | Total Land | Total Summer Crops | Total Winter Crops | Crop Intensity Summer | Crop Intensity Winter | Total Crop Intensity |
|---|---|---|---|---|---|---|
| | --- no. of feddan --- | | | --- ratio --- | | |
| 1 | 17 | 17 | 25 | 1 | 1.47 | 2.47 |
| 2 | 3 | 3 | 3 | 1 | 1 | 2 |
| 3 | 2.5 | 2.5 | 2.5 | 1 | 1 | 2 |
| 4 | 4.25 | 4.25 | 4.25 | 1 | 1 | 2 |
| 5 | 6 | 6 | 6 | 1 | 1 | 2 |
| 6 | 4.5 | 4.5 | 4.5 | 1 | 1 | 2 |
| 7 | 3.5 | 3.5 | 4.5 | 1 | 1.29 | 2.28 |
| 8 | 1.33 | 1.33 | 1.33 | 1 | 1 | 2 |
| 9 | 1 | 1 | 1 | 1 | 1 | 2 |
| 10 | 1 | 1 | 1 | 1 | 1 | 2 |
| 11[a] | 1.5 | 1.5 | 2 | 1 | 1 | 2 |
| 12 | 4.5 | 5 | 4.5 | 1.11 | 1 | 2.11 |
| 13 | .4 | .4 | .4 | 1 | 1 | 2 |
| 14 | 1.4 | 1.4 | 1.4 | 1 | 1 | 2 |
| 15 | 11.5 | 11.5 | 11.5 | 1 | 1 | 2 |
| 16 | .63 | .63 | .63 | 1 | 1 | 2 |
| 17 | 1 | 1 | 1 | 1 | 1 | 2 |
| 18 | 1.38 | 1.38 | 1.38 | 1 | 1 | 2 |
| 19 | 5 | 5 | 5 | 1 | 1 | 1.23 |
| 20 | 2.5 | 2.5 | 2.36 | 1 | .94 | 1.94 |
| Total | 73.89 | 74.39 | 83.25 | 1.01 | 1.13 | 2.13 |

[a]Farmer farms .5 feddan more in winter than in summer

Table A-12. Cropping Intensity on Farms at the Upper End of Branch Canals

| Farmer Number | Total Land | Total Summer Crops | Total Winter Crops | Crop Intensity Summer | Crop Intensity Winter | Total Crop Intensity |
|---|---|---|---|---|---|---|
| | --- no. of feddan --- | | | --- ratio --- | | |
| 1 | 1.5 | 1.63 | 1.5 | 1.09 | 1 | 2.09 |
| 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 2 |
| 3 | .3 | .3 | .3 | 1 | 1 | 2 |
| 4 | 1.5 | 2.0 | 1.5 | 1.33 | 1 | 2.33 |
| 5 | 1.25 | 1.5 | 1.25 | 1.2 | 1 | 2.2 |
| 6 | .67 | .67 | .67 | 1 | 1 | 2 |
| 7 | .83 | .83 | .83 | 1 | 1 | 2 |
| 8 | .17 | .17 | .17 | 1 | 1 | 2 |
| 9 | 2 | 2.25 | 2.5 | 1.13 | 1.25 | 2.4 |
| 10 | 2 | 2 | 2 | 1 | 1 | 2 |
| 11 | 2 | 2 | 2 | 1 | 1 | 2 |
| 12 | 2.75 | 3.25 | 2.83 | 1.18 | 1.03 | 2.2 |
| 13 | .63 | .63 | 1.55 | 1 | 2.46 | 3.5 |
| 14 | 3 | 3.33 | 3 | 1.11 | 1 | 2.11 |
| 15 | .33 | .33 | .33 | 1 | 1 | 2 |
| 16 | 3 | 3 | 3 | 1 | 1 | 2 |
| 17 | .5 | 1.0 | .5 | 2 | 1 | 3 |
| 18 | .92 | 1.92 | .92 | 2.08 | 1 | 3.09 |
| Total | 24.85 | 28.31 | 26.35 | 1.14 | 1.06 | 2.20 |

Table A-13. Expected Changes in Summer and Winter Crops if Canal Water Delivery was Improved

| Farmer Number | Summer Crops Would Grow More | | | | Winter Crops Would Grow More | | | |
|---|---|---|---|---|---|---|---|---|
| | Same Crops | Maize | Vegetable | Other | Same Crops | Wheat | Vegetable | Other |
| 1 | X | | | | X | | | |
| 2 | | | X | | | | | |
| 3 | | | X | | | | X | |
| 4 | | | X | | X | | | |
| 5 | | | | X | X | | | X |
| 6 | | | X | | X | | | |
| 7 | | X | | X | X | | | X |
| 8 | | | X | | X | | | |
| 9 | | | X | | X | | | |
| 10 | | | X | | | | | |
| 11 | X | | | | | | | |
| 12 | | X | X | | | | | |
| 13 | | | X | | | | | |
| 14 | X | | | | X | | | |
| 15 | X | | | | X | | | |
| 16 | | | X | | | | X | |
| 17 | | | X | | | X | | |
| 18 | X | | | | X | | | |
| 19 | | | X | | X | | | |
| 20 | X | | | | X | | | |
| Total | 6 | 2 | 12 | 2 | 12 | 1 | 2 | 2 |

# APPENDIX "B-1"

# APPENDIX B-1

## The Cost of Lifting Water with a Stationary Horizontal Diesel Pump
Farmer Number 5

### Basic Information and Assumptions:

1. The Pump is Ruston - Made In England.
2. Size 6/6" Pump (9/10) Horse Power Motor.
3. Average Time To Irrigation One Feddan - 3 Hours Each Irrigation.
4. Number of Irrigations Per Year - 24 Times.
5. Average Lift is 1.5 Meters From a Major Drain.
6. Area Served Is 11 Feddans.
7. Initial Investment:

| | | |
|---|---|---|
| a. Pump and Motor (including installation) | LE | 1,2000 |
| b. Building and Two Intake Types | LE | 3000 |
| | LE | 1,5300 |

8. Expected Useful Life of Investment - 20 Years.
9. Interest Rate is 10 Percent.
10. Operating Expenses:

Diesel Fuel, 2.5 Liters Per Hours @ LE 0.25 Per Liter.
Oil, 0.37 Kg. Per Hour @ LE 0.450 Per Kg.(1
Grease, Annual Cost LE 8.0
Gaskets For Pump, Annual Cost LE 5.0.
Labor To Operate The Pump LE 0.05 Per Hour (This is the value of the farmer's time while operating the pump).
Maintenance and Repairs LE 50.0 Per Year.

### Annual Fixed Costs:

| | | |
|---|---|---|
| Depreciation LE 1,530 ÷ 20 Years | LE | 76.500 |
| Interest on Investment $\frac{1,530}{2}$ x .10 | LE | 76.500 |
| Total for 11 Feddans | LE | 153.000 |
| Average Per Feddan LE 153 ÷ 11 | LE | 13.910 |

---

(1 The oil consumption is high because this is a low speed pump oiled by a drop system.

Variable Cost Per Feddan:

| | | |
|---|---|---|
| Diesel Fuel, 2.5 Liters X 24 Irrigations X 3 Hours X LE 0.025 | LE | 4.500 |
| Oil, 0.375 KG. X 24 Irrigation X 3 Hours X LE 0.45 | LE | 12.150 |
| Grease, LE 8 + 11 | LE | 0.730 |
| Fibers, LE 5 + 11 | LE | 0.450 |
| Labor, 24 Irrigation X 3 Hours X LE 0.05 | LE | 3.600 |
| Maintenance and Repairs LE 50.0 + 11 | LE | 4.540 |
| Total Variable Cost Per Feddan | LE | 25.970 |
| Total Annual Fixed and Variable Cost Per Feddan | LE | 39.880 |

This total cost is somewhat higher than the ordinary estimated water lifting cost (LE 25-30), because the farmer was obliged to construct this pump to serve only 11 feddans. But, in fact the farmer rents his pump to lift the drainage water to his neighbors to irrigate about 6 more feddans.

| | | | |
|---|---|---|---|
| Added Return: | 6 Feddans X 10 Irrigation X 3 Hours X LE 0.70 Per Hour | LE | 126.000 |
| Added Costs: | Diesel Fuel, 2.5 Liters X 10 Irrigations X 3 hours X LE 0.025 | LE | 1.875 |
| | Oil, 0.375 Kg. X 10 Irrigation X 3 hours X LE 0.45 | LE | 5.062 |
| | Labor for Operating | LE | 1.500 |
| | Maintenance and Repairs | LE | 1.891 |
| | Grease and Gaskets | LE | 0.491 |
| | Total Added Cost | LE | 10.819 |

The net return is LE 126 - 10.819 = LE 115.181

The average return per feddan for his owned land is:

$$\frac{115}{11} = 10.45 \text{ per feddan}$$

Then the total annual fixed and variable cost per feddan becomes less (LE 39.88 - 10.45 = 29.43) which is approximately the usual cost of water lifting by a diesel pump.

# APPENDIX "B-2"

# APPENDIX B-2
## Farmer Number 15

Basic Information and Assumptions:

1. The Pump is a Diesel Shobra - Made at Helwan Factory.

2. Size 6/6" Pump - 11 Horse Power Engine.

3. Average Time to Irrigate 1 Feddan is 3 Hours.

4. Number of Irrigations Per Year is About 24.

5. Average Area Served by The Pump is Only 5 Feddans.

6. Average Lift is 2.5 Meters From a Well.

7. Initial Investment:

| | | |
|---|---|---|
| Pump and Motor | LE | 980 |
| Drilling the Well 37 m. X LE 6.0 | LE | 222 |
| Type is 37 m. X LE 8.5 | LE | 315 |
| Casing is 18 m. X LE 10 | LE | 180 |
| Intake Type 2 m. X LE 8.5 | LE | 17 |
| Discharge Type is 1 m. X LE 11 | LE | 11 |
| Construction Cost LE 45 (installation) | LE | 45 |
| Small Pump for Bringing Water At The Beginning, LE 11 | LE | 11 |
| Building an Installation is LE 400 | LE | 400 |
| It Occupies $16m^2$, LE 19 (LE 5000/Fed) | LE | 19 |
| The Total Fixed Cost | LE | 2200 |

8. Expected Useful Life of Investment is About 20 Years.

9. Interest Rate is About 10 Percent.

10. Operating Expenses:

Diesel Fuel, 1.7 Liters Per House @ LE 0.025/Liter
Oil, .05 Kg. Per Hour @ LE 0.350 Per Kg.
Grease Annual Cost LE 2.0
The Farmer Operates the Pump by Himself
Maintenance and Repairs, LE 20 Per Year

Annual Fixed Costs:

| | | |
|---|---|---|
| Depreciation LE 2200 + 20 years | LE | 110 |
| Interest on Investment $\frac{2200}{2} \times .10$ | LE | 110 |
| Total Annual Fixed Cost for 5 feddan | LE | 220 |
| Average Fixed Cost Per Feddan LE 220 + 5 | LE | 44 |

Variable Cost Per Feddan:

| | | |
|---|---|---|
| Diesel Fuel 1.7 Liters X 24 Irrigations X 3 Hours X LE 0.025 | LE | 3.06 |
| Oil .05 Kg. X 24 Irrigations X 3 Hours X 35 | LE | 1.26 |
| Grease LE 2 ÷ 5 Feddans LE | .40 | |
| Maintenance and Repairs LE 20 ÷ 5 | LE | 4.00 |
| Total Variable Cost Per Feddan | LE | 8.72 |
| Total Annual Fixed and Variable Cost Per Feddan | LE | 52.72 |

The dual figure shows us that the cost of pumping is about twice the ordinary cost. This means that the farmer will lose LE 23 - LE 29 per year when he obtains water from a well and pump.

# AMERICAN EQUIVALENTS OF EGYPTIAN ARABIC TERMS AND MEASURES COMMONLY USED IN IRRIGATION WORK

| LAND AREA | IN SQ METERS | IN ACRES | IN FEDDANS | IN HECTARES |
|---|---|---|---|---|
| 1 acre | 4,046.856 | 1.000 | 0.963 | 0.405 |
| 1 feddan | 4,200.833 | 1.038 | 1.000 | 0.420 |
| 1 hectare (ha) | 10,000.000 | 2.471 | 2.380 | 1.000 |
| 1 sq. kilometer | $100 \times 10^4$ | 247.105 | 238.048 | 100.000 |
| 1 sq. mile | $259 \times 10^6$ | 640.000 | 616.400 | 259.000 |

| WATER MEASUREMENTS | FEDDAN-CM | ACRE-FEET | ACRE-INCHES |
|---|---|---|---|
| 1 billion $m^3$ | 23,809,000.000 | 810,710.000 | |
| 1,000 $m^3$ | 23.809 | 0.811 | 9.728 |
| 1,000 $m^3$/Feddan (= 238 mm rainfall) | 23.809 | 0.781 | 9.372 |
| 420 $m^3$/Feddan (= 100 mm rainfall) | 10.00 | 0.328 | 3.936 |

| OTHER CONVERSTION | | METRIC | U.S. |
|---|---|---|---|
| 1 ardab | = | 198 liters | 5.62 bushels |
| 1 ardab/feddan | = | | 5.41 bushels/acre |
| 1 kg/feddan | = | | 2.12 lb/acre |
| 1 donkey load | = | 100 kg | |
| 1 camel load | = | 250 kg | |
| 1 donkey load of manure | = | 0.1 $m^3$ | |
| 1 camel load of manure | = | 0.25 $m^3$ | |

EGYPTIAN UNITS OF FIELD CROPS

| CROP | EG. UNIT | IN KG | IN LBS | IN BUSHELS |
|---|---|---|---|---|
| Lentils | ardeb | 160.0 | 352.42 | 5.87 |
| Clover | ardeb | 157.0 | 345.81 | 5.76 |
| Broadbeans | ardeb | 155.0 | 341.41 | 6.10 |
| Wheat | ardeb | 150.0 | 330.40 | 5.51 |
| Maize, Sorghum | ardeb | 140.0 | 308.37 | 5.51 |
| Barley | ardeb | 120.0 | 264.32 | 5.51 |
| Cottonseed | ardeb | 120.0 | 264.32 | 8.26 |
| Sesame | ardeb | 120.0 | 264.32 | |
| Groundnut | ardeb | 75.0 | 165.20 | 7.51 |
| Rice | dariba | 945.0 | 2081.50 | 46.26 |
| Chick-peas | ardeb | 150.0 | 330.40 | |
| Lupine | ardeb | 150.0 | 330.40 | |
| Linseed | ardeb | 122.0 | 268.72 | |
| Fenugreek | ardeb | 155.0 | 341.41 | |
| Cotton (unginned) | metric qintar | 157.5 | 346.92 | |
| Cotton (lint or ginned) | metric qintar | 50.0 | 110.13 | |

EGYPTIAN FARMING AND IRRIGATION TERMS

fara = branch
marwa = small distributer, irrigation ditch
masraf = field drain
mesqa = small canal feeding from 10 to 40 farms
qirat = cf. English "karat", A land measure of 1/24 feddan, 175.03 $m^2$
qaria = village
sahm = 1/24th of a qirat, 7.29 $m^2$
saqia = animal powered water wheel
sarf = drain (vb.), or drainage. See also masraf, (n.)

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