Technical Report # 17
UNDP-EGY/73/024

OLD NILE

MASTER PLAN FOR WATER RESOURCES DEVELOPMENT AND USE

CONSUMPTIVE USE OF WATER BY MAJOR FIELD CROPS IN EGYPT

March 1981

FOREWORD

This report is one of a series of technical reports prepared to document the work done by or for the first phase of the Master Plan for Water Resources Development and Use EGY 73/024. A complete list of the reports prepared in this series is given below.

Number	Title
1.	Water Planning : Methods and Three Alternative Plans.
2.	Water Demands.
3.	Water Supply.
4.	Groundwater.
5.	Regulation Studies.
6.	Project Information System.
7.	Water Quality.
8.	The Organization, Administration and Legal Framework for Water Planning.
9.	Water and Wastewater Studies Municipal and Industrial Sectors.
10.	Industrial Water Use and Wastewater Production.
11.	Water Management Capabilities of the Alluvial Aquifer System of the Nile Valley, Egypt.

3.35 Abdel-Rasool et al. (1971) found that seasonal evapotranspiration at Northern Delta (Sakha) ranged from 25.60 to 42.10 and 21.29 to 35.24 cms in 1968/69 and 1969/70 seasons, respectively. Seif-El-Yazal (1971) pointed out that the consumptive use values were found to be 32.5, 27.9 and 25.1 cms for 50%, 75% and 100% depletion in available soil moisture respectively.

3.36 Abd-El-Hafez (1976) showed that, at Sakha, the consumptive use was 35.80 cms in 1971/72 for Giza 155 wheat variety. In the second season at Mexipak wheat variety was planted and evapotranspiration was found to be 42.98 cms. Eid (1977) found that the consumptive use values at Giza were 34.10 and 35.75 for the Giza 156 and Mexipak varieties respectively. Abdel-Motalleb (1978) found that at Mallawi in Middle Egypt, evapotranspiration was 41.4 cms for Mexipak 69 wheat variety. El-Gibali and Badawi (1978) computed evapotranspiration rates for wheat using the Balney-Criddle formula and the values were found to be: 37.9, 40.5 and 42.1 cms for Lower, Middle and Upper Egypt respectively.

3.37 The consumptive use studies indicated that the values were 38.31, 47.54 and 52.27 cms for Lower, Middle and Upper Egypt respectively (table 8). It can be noticed from this table that the average daily use was 0.28, 0.29 and 0.33 cms for the regions respectively. The crop coefficients for wheat are 0.50, 0.72, 0.74, 0.76, 0.80, 0.58 and 0.42 for the months from November to May with an average value of 0.65.

TABLE 8

Consumptive Use for Wheat (cm)

Regions	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Seasonal
LOWER EGYPT								
Monthly rates	0.65	4.37	4.34	5.49	9.61	10.50	3.35	38.31
Daily rates	0.13	0.14	0.14	0.20	0.31	0.35	0.28	0.23
MIDDLE EGYPT								
Monthly rates	1.13	5.77	6.32	7.81	13.27	11.55	1.69	47.54
Daily rates	0.16	0.19	0.20	0.28	0.43	0.39	0.34	0.29
UPPER EGYPT								
Monthly rates	2.20	6.91	7.60	10.22	13.64	11.70		52.27
Daily rates	0.22	0.22	0.25	0.37	0.44	0.39		0.33
Average K_c	0.50	0.72	0.74	0.76	0.80	0.58	0.42	0.65

Note 1 :Planting and Harvesting dates are as follows :

Lower Egypt		Middle Egypt		Upper Egypt	
Planting	Harvesting	Planting	Harvesting	Planting	Harvesting
Nov. 25	May 12	Nov. 23	May 5	Nov. 20	April 30

Clover (Berseem)

3.38 Berseem is the main forage winter crop in Egypt. It is being grown either as a temporary crop or as a full-season crop that usually yields four cuttings. It follows cotton, maize or rice in the crop rotation. Temporary clover is planted as a catch crop at the same time as the full season crop in most of the land which will be planted with cotton the following spring (El-Tobgy 1976).

3.39 Khafagi *et al*. (1967) computed the consumptive use for full-season clover and the average values were found to be 56.5, 59.4 and 64.0 cms respectively for Lower, Middle, and Upper Egypt. Eid et al (1966) computed consumptive use for Lower, Middle and Upper Egypt and the values obtained were 34.4, 35.5 and 38.4 inches respectively.

3.40 Badawi *et al*. (1969), at Giza, found that the seasonal consumptive use was 53.2 cms. Badawi (1970) indicated that the low levels of soil moisture correlate with low yields of clover either temporary or full-season clover was 53.8 cms.

3.41 El-Gibali and Badawi (1978) using the Blaney - Criddle formula found the evapotranspiration rates for clover to be 45.0, 46.1 and 49.3 cms respectively for Lower, Middle and Upper Egypt regions.

3.42 The data presented in table 9 indicate that the seasonal evapotranspiration rates were 56.15, 67.68 and 74.29 cms respectively for Lower, Middle and Upper Egypt regions. It can be noticed that the average daily water use was 0.27, 0.32 and 0.35 cms for the above mentioned

TABLE 9

Consumptive Use for Clover (cm)

Regions	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Seasonal
LOWER EGYPT								
Monthly rates	4.35	4.96	5.30	6.30	9.39	14.16	11.69	56.15
Daily rates	0.15	0.16	0.17	0.23	0.30	0.47	0.38	0.26
MIDDLE EGYPT								
Monthly rates	5.50	6.17	5.86	8.37	12.87	15.75	13.08	67.68
Daily rates	0.19	0.20	0.19	0.30	0.42	0.53	0.42	0.32
UPPER EGYPT								
Monthly rates	5.76	6.48	6.54	9.97	14.89	16.68	13.98	74.30
Daily rates	0.19	0.21	0.21	0.36	0.48	0.56	0.45	0.35
Average K_c	0.52	0.76	0.74	0.80	0.81	0.80	0.53	0.71

Note 1 : Planting and Harvesting dates are as follows :

Upper Egypt		Middle Egypt		Lower Egypt	
Planting	Harvesting	Planting	Harvesting	Planting	Harvesting
Nov. 1	May 31	Nov. 1	May 31	Nov. 1	May 31

Note 2 : Number of irrigations : 9 to 11 regions respectively.

3.43 The crop coefficient for full-season berseem was 0.52 at the beginning of the season. It ranged from 0.74 to 0.81 through the growing season and decreased to 0.53 at the end of the season (table 9). The seasonal K_c value for clover was found to be 0.71.

3.44 There is a short berseem crop also called Egyptian clover (Trifolium alexandrinum) or temporary berseem. Two local varieties of clover are usually used as a temporary crop. The first is the Fahel variety, which provides only one cutting or clipping. The second is the Miskawi variety which can provide either one or two cuttings. The variety that is planted and the number of cuttings depend upon individual farm operations. The consumptive use values can be taken as the same as permanent clover according to the length of time the short berseem is left standing in the field.

Horse beans

3.45 The bean crop is one of the main protein crops in Egypt. As a winter crop it is usually planted in November and harvested after 5 or 5.5 months. It is grown throughout the country with two-thirds of the planted area in Middle and Upper Egypt and one third in Lower Egypt. Average production per feddan is about one ton (El-Tobgy 1976).

3.46 Eid et al.(1966) using Blaney-Criddle formula reported that the consumptive use by horse beans was 13.61, 13.99 and 15.05 inches for Lower, Middle and Upper Egypt respectively.

Note 2 : Number of irrigations : 9 to 11

Nov. 1 May 31

Nov. 1 May 31

TABLE 10

Consumptive Use for Horse beans (cm)

Regions	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Seasonal
LOWER EGYPT							
Monthly rates	1.27	4.07	4.87	6.92	9.02	4.33	30.48
Daily rates	0.13	0.13	0.16	0.25	0.29	0.22	0.20
MIDDLE EGYPT							
Monthly rates	3.40	5.92	6.48	7.20	11.91	2.43	37.34
Daily rates	0.17	0.19	0.21	0.26	0.38	0.24	0.25
UPPER EGYPT							
Monthly rates	5.76	7.29	7.38	10.70	12.37		43.50
Daily rates	0.19	0.24	0.24	0.38	0.40		0.29
Average K_c	0.48	0.72	0.77	0.80	0.73	0.39	0.65

Note 1 : Planting and Harvesting dates are as follows :

Upper Egypt		Middle Egypt		Lower Egypt	
Planting	Harvesting	Planting	Harvesting	Planting	Harvesting
Nov. 1	Mar 31	Nov. 10	April 10	Nov. 20	April 20

Note 2 : Number of irrigations : 5

El Gibali *et al.* (1968) found that the consumptive use of horse beans at Mallawi (Middle Egypt) was 2013 m^3 per feddan and that seven irrigations were found to be the most suitable number. They also found that the highest yield was obtained at 20 days interval between irrigations at Mallawi, and 15-20 days at Mataana in Upper Egypt.

3.47 It was found by Tawadros *et al.* (1969,71) that the seasonal consumptive use values for horse beans ranged from 35.36 to 38.83 cms at Sids, Middle Egypt. It was reported by the authors that the irrigation water requirements of horse beans were 1898, 1308 and 1200 m^3/feddan for 15, 30, 45 days intervals. Their water use efficiency experiments indicated that one ardab of horse beans was produced by 189,223, and 273 m^3 from short, medium and long application intervals. They reported, also, that for most effective application of water, horse beans should be irrigated at frequent intervals (50%-60% soil moisture depletion) with low application rates (250 m^3/feddan per application). Badawi (1970) indicated that seasonal consumptive use for horse beans, at El-Gimmeza, was 14.9 inches.

3.48 The data presented in table 10 indicate that evapotranspiration rates from horse beans were found to be 30.47, 37.34 and 43.39 cms respectively for Lower, Middle and Upper Egypt. The crop coefficient values were 0.48, 0.72, 0.77, 0.80, 0.73 and 0.39 for the months from November through April, respectively. The seasonal K_c value for horse beans was 0.65.

Note 2 : Number of irrigations : 5

Regional K_c Values

3.49 Average K_c values for Egypt for each crop have been given in the preceding discussion. K_c Values have also been computed on a regional basis, that is, for Upper, Middle, and Lower Egypt. These regional values are presented in table 11.

TABLE 11

Regional K_c Values

(Computed according to Modified Penman

Crop	Zone	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal
	LOWER			0.46	0.35	0.59	0.71	0.84	0.50	0.34				0.54
Cotton	MIDDLE			0.41	0.48	0.65	0.78	0.92	0.48	0.40				0.59
	UPPER			0.52	0.53	0.52	0.67	0.83	0.43					0.58
Summer	LOWER					0.48	0.61	0.96	0.90	0.52				0.75
Corn	MIDDLE					0.41	0.61	0.95	0.76	0.46				0.70
	UPPER					0.42	0.55	0.85	0.64	0.34				0.62
Nili	LOWER							0.58	0.89	1.16	0.89	0.80		0.90
Corn	MIDDLE							0.53	0.74	0.96	0.85	0.72		0.78
	UPPER							0.46	0.62	0.81	0.74	0.50		0.67
Sorghum	UPPER						0.51	0.68	0.84	0.55				0.65
Wheat	LOWER	0.70	0.70	0.80	0.66	0.42						0.48	0.72	0.64
	MIDDLE	0.83	0.85	0.91	0.60	0.43						0.51	0.79	0.70
	UPPER	0.70	0.71	0.70	0.49							0.49	0.65	0.62
Clover	LOWER	0.85	0.80	0.78	0.89	0.56						0.54	0.82	0.74
	MIDDLE	0.77	0.91	0.89	0.82	0.54						0.59	0.85	0.76
	UPPER	0.61	0.70	0.76	0.71	0.49						0.43	0.61	0.61
Horse	LOWER	0.78	0.88	0.75	0.41							0.47	0.67	0.66
beans	MIDDLE	0.85	0.79	0.82	0.38							0.54	0.81	0.69
	UPPER	0.68	0.75	0.63								0.43	0.68	0.63
Sugar	MIDDLE	0.61	0.76	0.70	0.64	0.71	0.73	0.86	1.06	1.14	1.10	1.36	1.02	0.87
cane	UPPER	0.57	0.59	0.51	0.48	0.85	0.88	1.08	1.09	1.05	1.10	1.01	0.87	0.87

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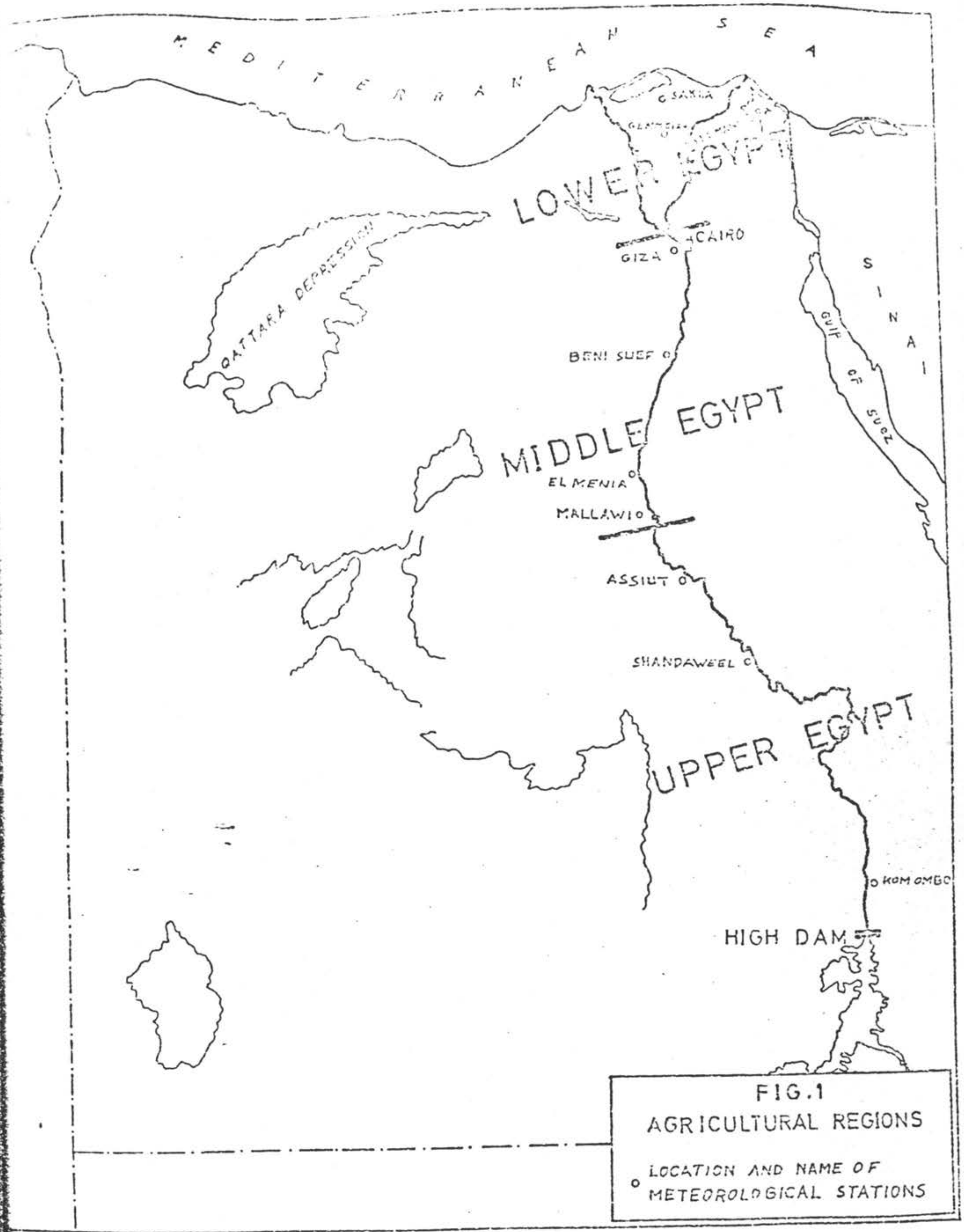

FIG.1
AGRICULTURAL REGIONS

Number	Title
12.	Sediment Processes in the Nile River.
13.	Fisheries, Ecology, Health and Fish Farming.
14.	Hydrological Simulation of Lake Nasser.
15.	Mathematical Model for the Upper Nile.
16.	Agro Economic Model.
17.	Consumptive Use of Water by Major Field Crops in Egypt.
18.	Hydrogeological Evaluation of Environs of Lake Nasser.
19.	Economic Evaluation of Land Reclamation.
20.	The Irrigation System.

The first phase of the project was executed by the International Bank for Reconstruction and Development, financed by the United Nations Development Program, and the Ministry of Irrigation was the Co-operating Agency. Work began in October 1977 and the first phase concluded in March 1981. A bridging project document was signed in March 1980 to extend the work to December 1981 and to prepare for a second phase commencing January 1982.

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Dr. Samir Nabawy of the Master Water Plan project staff was responsible for liaison between the project and the Agricultural Research Centre. He was also responsible for report editing.

Report typing and production were in the capable hands of Mrs. V. Rizkallah.

SUMMARY

This report was prepared to consolidate experimental information on the rate of water use for some of the major field crops being raised in the Nile Delta, Middle Egypt and Upper Egypt. Experimental Data on evapotranspiration rates has been collected, revised, and summarised for each region.

Using Et_o values calculated according to the modified Penman formula, and actual consumptive use values, crop coefficients have been computed for cotton, corn, sorghum, sugar cane, wheat, clover and horse beans.

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CHAPTER 1

Introduction

1.01 The most important factor in computing irrigation water requirements is the amount of water consumed by plants, and usually referred to as crop consumptive use or evapotranspiration. Crop consumptive use is a function of climatic factors, soil characteristics, water supply and kind of vegetation.

1.02 The data presented in this report summarize most of the experimental work that had been carried out in Egypt to compute consumptive use values for major field crops at different stages of plant growth. For this report, the country was divided into three main regions namely, Lower, Middle and Upper Egypt. Crop coefficients at different stages and for different regions were computed using actual consumptive use and Et_o according to the modified Penman formula, recommended by FAO experts in 1970 (Irrigation paper N° 24).

1.03 It is hoped that this report will make it possible to estimate actual evapotranspiration for various crops. However, those who use the report for that purpose should be cautious of the limitations of the experimental methods used and the different conditions facing the many investigators such as, climatic conditions, soil characteristics, date of planting, crop varieties, previous crops, soil fertility and types of fertilizers used, plant density and population, weed and pest control.

CHAPTER 2

Methodology

Crop Consumptive Use Values

2.01 Crop consumptive use was computed as the difference in soil moisture content in the soil samples taken before and after irrigation. Moisture content in the soil samples was determined gravimetrically and calculated on an oven-dry basis. Transformation to water depths was done with the aid of bulk density and thickness of soil layer. Average daily consumptive use was obtained by dividing the amount of moisture consumed between two successive irrigations by the number of days elapsed in that interval. The above mentioned technique was used for the determination of actual evapotranspiration rates for all major crops except rice.

2.02 For rice, a simple drum culture technique was used for the assessment of consumptive use and percolation losses. (Dastane et al., 1966). Each container (drum), with 40 gallons capacity and 100 cm. height, was installed with 20-25 cm. protruding above the soil level in a rice field. Water levels were recorded daily. Difference between two consecutive readings gives the values of actual consumptive use by rice.

Crop Coefficients

2.03 Crop coefficient values were calculated for each crop in the different regions, as follows :

$$K_c = ET_c/ET_o$$

where:- K_c : is the crop coefficient

ET_c : actual consumptive use values

ET_o : potential evapotranspiration

The regional K_c values for selected crops for Lower, Middle and Upper Egypt are reported in table 11. In tables 3 to 10 inclusive, average K_c values for the whole country have been given.

The values of ET_o were calculated according to the modified Penman formula (FAO Irrigation paper N° 24), using climatic data given in table 1. Figures were obtained from Meteorological Normals of Egypt, published in 1960, and Rijtema _et al_. (1975). Three stations, namely El-Mansoura, Sakha and El-Gimmeza, were used to represent Lower Egypt. Middle Egypt was represented by Giza, Beni-Suef, El-Menya and Mallawi stations. Assuit, Shandweel and Kom-Ombo were considered representative of Upper Egypt. Table 2 shows values of ET_o calculated by modified Penman formula for the previously mentioned stations. It should be noted that the climatological stations used are in the irrigated areas. Non-representative stations at airports or in desert areas were not used.

CHAPTER 3

Discussion and Conclusion

3.01 In this chapter, each of the seven major crops has been discussed separately. For each crop there is brief discussion of the data available, and a general review of experimental results. The consumptive use and crop coefficients for each crop have been calculated and presented in tabular form.

3.02 The sequence of presentation was determined by the growing season, that is :

(A) Summer Crops :

1. Cotton 2. Rice 3. Corn
4. Sorghum 5. Sugar cane.

(B) Winter Crops :

1. Wheat 2. Clover 3. Horse beans

3.03 The consumptive use values reported are concerned with the highest yields under experimental conditions.

<u>Cotton</u>

3.04 Cotton is the main cash crop in Egypt. It is grown for its fiber and oil. It is also the leading export crop of the country.

3.05 The average consumptive use for cotton was 2680, 3411 and 4390 m^3 per feddan for Lower, Middle and Upper Egypt respectively, in addition to the water added for seed germination (Khalil <u>et al</u>. 1962). Mahmoud (1966) in Upper Egypt, reported that the average daily rates of

TABLE 1

Climatological Data for Upper, Middle and Lower Egypt

	Month / Element	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
LOWER EGYPT	Mean temperature °C	12.37	12.97	15.33	18.50	22.4	25.43	26.43	26.27	24.63	22.23	18.93	14.60
	Relative humidity %	75.33	71.67	69.00	62.00	57.33	60.33	67.67	69.66	69.67	69.67	73.33	74.67
	Cloudness (oktas)	2.80	2.77	2.37	1.77	1.60	0.73	0.67	1.00	1.07	1.67	2.40	2.87
	Wind velocity (m/sec)	1.54	1.78	1.79	1.69	1.59	1.50	1.26	1.10	1.08	1.11	1.26	1.46
MIDDLE EGYPT	Mean temperatuer °C	12.30	13.78	16.73	20.93	24.85	27.05	27.75	27.60	25.50	23.15	18.63	14.23
	Relative humidity %	64.75	59.50	52.75	45.50	41.25	45.50	51.75	56.25	59.50	60.25	65.00	67.50
	Cloudness (oktas)	2.10	2.10	1.83	1.63	1.58	0.40	0.40	0.48	0.55	1.00	1.73	2.53
	Wind velocity (m/sec)	1.36	1.44	1.65	1.85	2.12	2.09	1.58	1.44	1.77	1.65	1.32	1.31
UPPER EGYPT	Mean temperature °C	14.33	16.40	19.40	24.30	28.23	30.23	30.27	30.67	28.30	25.53	20.67	16.17
	Relative humidity %	51.33	44.33	35.33	27.33	24.33	27.67	34.33	35.67	39.67	45.67	49.67	53.67
	Cloudness (oktas)	1.07	1.17	1.00	0.90	1.10	0.13	0.13	0.13	0.13	0.37	0.77	1.40
	Wind velotity (m/sec)	1.68	2.19	2.05	2.04	2.20	2.29	1.92	1.92	2.20	1.70	1.66	1.52

TABLE 2

Reference Crop Evapotnanspiration (Et_o) for Different Regions of Egypt as Calculated by Modified Penman (mm/day)

	Region	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
LOWER EGYPT	El-Mansora	2.25	3.37	4.45	5.85	7.06	7.69	7.00	6.13	5.33	4.28	2.99	2.55
	Sakha	2.04	2.57	3.78	5.00	6.31	6.90	6.50	5.97	5.09	3.81	2.63	1.86
	Gimmeza	1.75	2.48	3.46	5.04	6.77	7.05	6.83	5.76	4.81	3.95	2.51	1.48
	Average	2.01	2.81	3.90	5.30	6.71	7.21	6.78	5.95	5.08	4.01	2.71	1.96
MIDDLE EGYPT	Giza	2.33	3.16	4.63	6.08	7.49	8.48	7.87	6.89	5.92	4.68	2.88	2.32
	Beni-Suef	2.55	3.42	4.76	6.69	7.49	8.16	7.84	7.21	6.89	5.36	3.48	2.52
	El-Menya	2.42	3.20	4.58	6.19	7.19	7.90	7.68	7.09	5.97	4.79	3.22	2.32
	Mellawi	2.50	3.31	4.81	6.78	9.03	8.74	7.19	6.47	6.24	4.41	3.03	2.24
	Average	2.45	3.27	4.69	6.43	7.80	8.32	7.64	6.91	6.25	4.81	3.15	2.35
UPPER EGYPT	Assuit	3.51	4.75	6.49	8.40	10.12	11.00	9.90	9.54	8.67	6.39	4.74	3.37
	Shandaweel	3.24	5.65	5.89	7.63	9.14	9.62	8.56	8.23	7.45	5.04	3.89	3.16
	Kom-Ombo	3.72	4.93	6.56	7.65	8.31	9.14	8.72	8.63	7.70	6.33	4.77	5.77
	Average	3.49	5.11	6.31	7.89	9.19	9.92	9.06	8.80	7.94	5.92	4.47	3.43

consumptive use were 0.35, 0.33, 0.48, 0.64, 0.78, 0.63 and 0.37 cm. for the months from March to September respectively. Talha (1966) at Giza, mentioned that the consumptive use of cotton ranged from 102.38 to 134.24 cms. He added that the daily rates ranged from 0.49 to 0.64 cms.

3.06 It had been found by Khafagi et al.(1968) that the water consumptive use values were 71.61, 73.50 and 80.54 cms for Lower , Middle and Upper Egypt respectively. Chaudhry (1969) at Giza reported that the mean consumptive use values were 5580, 4080, 3591 and 2950 m^3/feddan respectively for the 8, 15, 22 and 29 day intervals. The average daily rates were found to be 0.76, 0.56, 0.47 and 0.41 cms for the four irrigation intervals in the same order. Badawi (1970) found in Gemmeiza that the average seasonal consumptive use was 59.35 cms for Giza 67 cotton variety. For the same variety, Mahrous (1971) at Northern Delta, obtained highest yields when 3000 m^3/feddan were used. El-Serougy et al.(1973) found in Bahteem (Southern Delta) that seasonal consumptive use by cotton reached 72.88 and 71.51 cms for 1969 and 1970 seasons respectively.

3.07 Kenawi (1976) pointed out that the consumptive use for cotton reached 3400, 3900 and 4700 m^3/feddan for Lower, Middle and Upper Egypt, respectively. Mahrous (1977) found that the consumptive use was 61.22 cms, at Northern Delta. Omar et al.(1978), mentioned that potential evapotranspiration reached its maximum in June and July (6.67 and 6.61 mm/day). El-Gibali and Badawi (1978) calculating the consumptive use in Egypt using the Blaney-Criddle formula found that the values for cotton were 69.7, 71.6 and 73.1 cms respectively for Lower, Middle and Upper Egypt.

TABLE 3

Consumptive Use for Cotton (cm)

Regions	Mar.	Apr.	May	June	July	Aug.	Sept.	Seasonal
LOWER EGYPT								
Monthly rates	2.69	5.52	12.31	15.36	17.73	9.21	4.28	67.10
Daily rates	0.18	0.18	0.40	0.51	0.57	0.30	0.17	0.35
MIDDLE EGYPT								
Monthly rates	3.04	9.30	15.81	19.50	21.79	10.23	4.95	84.62
Daily rates	0.19	0.31	0.51	0.65	0.70	0.33	0.25	0.45
UPPER EGYPT								
Monthly rates	10.26	12.45	14.78	19.92	23.25	11.78	–	92.44
Daily rates	0.33	0.42	0.48	0.66	0.75	0.38	–	0.50
Average K_c	0.46	0.45	0.59	0.72	0.86	0.47	0.37	0.56

Note 1 Planting and Harvesting dates are as follows :

Lower Egypt		Middle Egypt		Upper Egypt	
Planting	Harvesting	Planting	Harvesting	Planting	Harvesting
March 16	Sept. 25	March 15	Sept. 20	March 1	Aug. 3

Note 2 Number of irrigations : 9 to 11.

3.08 The consumptive use values found for producing highest cotton yields in Lower, Middle and Upper Egypt are summarized in table 3. It can be noticed that the seasonal consumptive use values for Lower, Middle and Upper Egypt respectively, are 67.09, 84.64 and 92.44 cms. The average daily rates for the whole season were found to be 0.35, 0.45 and 0.50 cms for the same regions. The peak water use occurs during June and July. The crop coefficients (K_c) for cotton was found to be 0.46, 0.45, 0.59, 0.72, 0.86, 0.47 and 0.37 for the months from March to September, with an average seasonal value of 0.56.

Rice

3.09 Rice is unique among the cereal crops in being able to thrive in water.

3.10 It has been reported by El-Tobgy (1976) that after cotton, rice is second in importance as an export crop and it also follows winter crops in the rotation. He pointed out too that to conserve land and water, transplanting is the most common method of planting rice fields. Nurseries are planted in late May and the young plants are transplanted a month later in June. One feddan of nursery usually is sufficient to supply the plants needed for 6 to 8 feddans of rice. Because it requires a special irrigation regime, the main rice area is restricted to the northern part of the Delta where a special irrigation rotation of 4 days on, and 4 days off in the irrigation canals is provided by the Ministry of Irrigation.

Note 2 Number of irrigations : 9 to 11.

3.11 Willcocks (1913) and Olivier (1964) estimated the water requirements of rice as 163 cms. Khafagi et al. (1968) calculating the seasonal water use by rice, it was found that it ranged from 103 to 110 cms. El-Gibali and Mahrous (1970) found that seasonal consumptive use by rice was 107 cms in the transplanting method while it reached 149 cms in the broadcast method of planting. El-Refai (1974) found that the yield of rice increased with increasing water applications up to 8000 m^3/feddan, while increasing the volume applied beyond that has insignificantly lowered the yields. El-Gibali and Badawi (1978) using the Olivier formula for computing water consumptive use values for rice, found that it was 104 cms for Lower Egypt and 109 cms for Middle Egypt.

3.12 Actual evapotranspiration for Giza 170 rice was studied by El-Refai (1974) at Gemmeiza, for three successive years (1968, 69,70) using a tank experiment. The tank was placed adjacent to the rice field in order to be surrounded by a buffer area of paddy. Water level in the tank was maintained at 10 cm depth above the soil surface. Depth of water in the tank was measured daily to determine water loss and it was added when needed to maintain the desired level. Seedlings were transplanted from the nursery beds into the tank after 35 days from seeding.

3.13 It was found that the average daily water use by rice was low after transplanting, then, it reached a maximum through August and September. The lowest consumption occured during October owing to maturation (table 4). Daily rates were 0.99, 1.12, 1.13 and 0.68 cms for July, August, September and October respectively with a daily average value of 1.03 cm. The use of modified Penman in estimating crop water use by rice gives very high crop coefficients due to the aquatic environment of rice culture. Thus, it is advisable to take the actual figures presented in table 4 for the Delta region in calculating rice water requirements.

TABLE 4

Consumptive Use for Rice (cm.)

Lower Egypt Region	June	July	Aug.	Sept.	Oct.	Seasonal
Monthly rates	_ 1/	30.69	34.72	33.90	8.84	108.15
Daily rates	_ 1/	0.99	1.12	1.13	0.68	1.03

Note 1/ Irrigation water exceeds for rice nurseries could be based on values found by El-Madany (1970). He reported that the water requirement at the nursery is about 30 m^3 per feddan per day which corresponds to 900 to 1200 m^3/fed. for a 30 to 40 day period, plus 420 m^3 per feddan for initial flooding. The total will be 1320 to 1620 m^3/feddan according to the soil conditions. It should be noted that one feddan of nursery is sufficient to provide transplanting for 6 to 8 feddans.

Note 2/ Number of irrigations : flooding every four days.

Corn

3.14 Corn (or maize) is an important cereal for human and animal consumption in rural areas. It outranks both wheat and rice in area and cash value, (El-Tobgy 1976).

Of the total area planted with maize, 75%, 20%, and only 5% are in Lower Egypt, Middle Egypt, and Upper Egypt respectively. He also pointed out that for the five years 1970-74, summer maize covered 78% of the total maize area the balance being nili maize.

3.15 Using the Blaney-Criddle formula, Eid et al. (1966) calculated the consumptive use values for the summer and nili maize. These values were found to be 22.94, 23.85, and 25.61 inches respectively for the Delta, Middle Egypt, and Upper Egypt. Values for the nili crop were found to be 21.95, 22.57 and 24.19 inches for the same regions.

3.16 It was pointed out by Khalil et al. (1966) that for proper water management, the most suitable intervals are 15 and 12 days for Lower and Middle Egypt respectively. At Giza, these intervals were found by El-Serougy et al. (1966) to be 12 and 15 days for the summer and nili crops respectively. For the same locality, maximum evapotranspiration values were found to be 8.0 and 7.6 mm/day during tasseling and silking stages for early and late planting respectively (Rijtema & Abou Khaled (1975). For Sids Middle Egypt total water use of 738 mm and a peak rate of 9 mm/day at the flowering stage was reported by Tawadros et al. (1969).

3.17 El-Gibali and Badawi (1978) computed the evapotranspiration rates for the early corn crop at 45.8, 47.9 and 50.0 cms for Lower, Middle and Upper Egypt respectively. The corresponding values for the late crop were 41.1, 41.4 and 44.3 cms for the same regions.

TABLE 5

Consumptive Use for Corn (cm)

Zone & Rates	Summer Crop May	June	July	Aug.	Sept.	Seasonal total(cm)	Nili Crop July	Aug.	Sept.	Oct.	Nov.	Seasonal total(cm)
LOWER EGYPT												
Monthly rates	4.79	13.30	20.08	16.51	3.18	57.86	5.90	16.37	17.64	11.05	2.59	53.55
Daily rates	0.32	0.44	0.65	0.53	0.27	0.49	0.39	0.53	0.59	0.36	0.22	0.45
MIDDLE EGYPT												
Monthly rates	4.85	15.24	22.41	16.21	3.48	62.19	6.02	15.84	17.91	12.62	2.72	55.11
Daily rates	0.32	0.51	0.72	0.52	0.29	0.52	0.40	0.51	0.60	0.41	0.23	0.46
UPPER EGYPT												
Monthly rates	5.75	16.44	23.77	17.47	3.28	66.71	6.29	16.88	19.40	13.63	2.67	58.87
Daily rates	0.38	0.55	0.77	0.56	0.27	0.56	0.42	0.54	0.65	0.44	0.22	0.49
Average K_c	0.41	0.59	0.92	0.76	0.44	0.68	0.49	0.75	0.98	0.83	0.67	0.77

Note 1 : Planting and Harvesting dates are as follows :

	Planting (all regions)	Harvesting (all regions)
Summer crop	May 15	Sept. 12
Nili crop	July 15	Nov. 12

Note 2 : Number of irrigations : 7 to 9.

3.18 Evapotranspiration rates for summer and nili crops are presented in table 5. The seasonal values for the summer crop were found to be 57.86, 62.19 and 66.71 cms for Lower, Middle and Upper Egypt respectively. The corresponding values for the nili crop were 53.55, 55.11 and 58.87 cms for the same regions. Seasonal K_c values were 0.68 and 0.77 for summer and nili crops respectively.

Sorghum

3.19 It has been reported by El-Tobgy (1976) that sorghum is the fourth important cereal crop in Egypt in both area and value after maize, wheat, and rice. This crop is usually grown as a summer crop. It is planted in mid-March to mid-May and harvested after four months from planting. Only about 6% of its area is grown as a nili crop in Middle Egypt. Upper Egypt accounts for 80% and Middle Egypt for 20% of the sorghum area. In the southern-most region of the country, sorghum replaces maize as the main cereal for human and animal consumption in rural areas.

3.20 Little work has been carried out in Egypt concerning the response of sorghum to soil moisture conditions. Erie et al. (1965) found that grain sorghum consumed 24.5 inches of water at Mesa, Arizona. Jensen and Sletten (1965) indicated that evapotranspiration rates ranges from 0.1 inch/day at the beginning of the season, to 0.3 inch/day through August.

3.21 Eid et al. (1966) found that the consumptive use for the summer crop was 24.78 and 26.64 inches for Middle and Upper Egypt respectively. The corresponding values for the nili crop were 21.16 and 22.79 inches. Robins et al. (1967) stated that the depression of sorghum grain yield will be negligible if no more than 55-65% of the available[1] water is depleted. They added that at maturity up to 70% or 80% can be safely used. It has been reported by Dastane (1970) that during summer, irrigation of sorghum at 50% depletion of available soil moisture in the top 30 cm layer gave the highest yield, and the corresponding consumptive use was 550-575 mm water in 9-10 irrigations.

3.22 El-Gibali and Badawi (1978) found that the consumptive use for sorghum crop in Upper Egypt was estimated at 44.0 cm and 37.1 cm for early and late summer crops, respectively. The corresponding values were 42.2 and 34.3 cm for Middle Egypt.

3.23 Table 6 illustrates evapotranspiration rates for sorghum in Upper Egypt. As shown in the table, the seasonal consumption is 65.56 cm. The daily rates are 0.51, 0.62, 0.74 and 0.44 cm for the months starting from June to September with an average value of 0.58 cm. Crop coefficients (K_c-values) were found to be 0.51, 0.68, 0.84 and 0.55 for June, July, August and September respectively and the seasonal value was 0.65. The peak monthly consumtive use occured in August.

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[1] Volume of water required to raise soil moisture content from wilting point to field capacity.

TABLE 6

Consumptive Use for Grain Sorghum (cm.)

Zone	Rates	June	July	Aug.	Sept.	Seasonal
Upper Egypt	Monthly	10.20	19.22	22.94	13.20	65.56
	Daily	0.51	0.62	0.74	0.44	0.59
	K_c	0.51	0.68	0.84	0.55	0.65

Note 1 : Planting and harvesting dates are as follows :

Planting	Harvesting
June 10	Sept 30

Note 2 : Number of irrigations 7 to 8.

Sugar Cane

3.24 Sugar cane is the main source of sugar in Egypt. It occupies about 20% of the total cropped area in Upper Egypt, Sugar cane is a soil exhausting crop and, therefore, irrigation and fertilization are important requisites for high production. The effectiveness of fertilizer application in sugar cane fields depends upon soil moisture availability.

3.25 It was reported by El-Tobgy (1976) that sugar cane is a well established and major industrial crop in Egypt and it is the main field crop in Qena and Aswan Governorates. It is also grown in Middle Egypt and is expanding in Sohag and Assuit in Upper Egypt. Sugar cane is usually planted in January and February and it is recommended that the first year crop be followed by only two successive ratoons. Also, he pointed out that autumn-planted cane could be interplanted during the first year with broad beans or clover.

3.26 Earlier studies in Upper Egypt showed that water requirements of sugar cane were 91.6 inches for a growing season from March till November (Willcocks, 1913). Oliver (1961) showed that cane plant requires about 87 inches. At Kom Ombo (Upper Egypt), El-Gibali (1969) found that the best water requirement is equal to 500-600 m^3/feddan per irrigation, and added that the total requirements reached 12258-14828 m^3/feddan.

3.27 Seasonal consumptuve use values for first-year cane in Upper Egypt were found to be 75.8, 64.9, 56.9 and 57.8 inches respectively for 10-15, 15-20, 20-25 and 25-30 days irrigation intervals. The values for the first ratoon were found to be 83.3,66.9, 57.8 and 51.7 inches in the same order (El-Gibali <u>et al</u>, 1970). At Mallawi (Middle Egypt), El-Gibali <u>et al</u>.(1970) indicated that the actual consumptive use by sugar cane was about 117 cm. The authors also found that the estimated value according to the Blaney - Criddle formula with a variable (K_c) coefficient for each stage of growth, was the nearest value to actual evapotranspiration. At Assuit, the seasonal consumptive use by sugar cane averaged 179.9 cms and 181.4 cms for the first and second ratoons respectively (Mahmoud 1966).

3.28 Recent studies by Abdel-Rasool <u>et al</u>.(1975) showed that evapotranspiration rates by first-year cane were 244.5, 207.3 and 176.4 cms for wet, medium and dry soil moisture levels, respectively. The corresponding values for the first ratoon were 263.4, 226.7 and 185.8 cms;

and for the second ratoon they were 248.8, 183.1 and 139.6 cms in the same order. El-Gibali *et al.*(1978) concluded that irrigating sugar cane at different intervals resulted in a high yield of either the spring or autumn crop. They added that water requirements were found to be 11157, 12551 and 12107 m^3/feddan respectively for planted cane, first and second ratoons respectively.

3.29 It was pointed out by Doorenbos *et al.*(1979) that adequate available moisture throughout the growing period is important for obtaining maximum yields since vegetative growth, including cane growth, is directly proportional to the water transpired. They reported also that depending on climate, water requirements (ET_m) of sugar cane averaged from 1500 to 2550 mm and should be evenly distributed over the growing season. They found also that the crop coefficients (K_c) values relating ET_m to reference evapotranspiration (Et_o) for the different stages of growth range between0.40 and 1.30 depending on the stage of development.

3.30 Tawadros *et al.*(1979) found at Mallawi that consumptive use of cane was 178.2 cms, when irrigation was practiced after the depletion of 40% of available soil moisture. They added that the peak monthly use occurred during September for planted cane and August for the ratoons. The authors also reported that for maximizing crop yields per unit volume of water, irrigation should be applied when 40% to 60% of the available water is still remaining in the soil profile for first-year and ratoon cane.

TABLE 7

Consumptive Use for Sugar Cane(cm)

Regions	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Seasonal
MIDDLE EGYPT													
Monthly rates	7.00	10.20	12.30	17.05	18.30	20.46	22.63	21.30	16.43	12.90	7.44	4.65	170.66
Daily rates	0.25	0.33	0.41	0.55	0.61	0.66	0.73	0.71	0.53	0.43	0.24	0.15	0.47
UPPER EGYPT													
Monthly rates	8.40	9.92	13.65	24.18	26.22	30.41	29.64	24.99	20.12	13.86	9.30	6.20	216.89
Daily rates	0.30	0.32	0.46	0.78	0.87	0.98	0.96	0.83	0.65	0.46	0.30	0.20	0.59
K_c aver.	0.68	0.61	0.61	0.78	0.81	0.97	1.07	1.09	1.10	1.20	0.95	0.59	0.87

Note 1 : Planting and Harvesting dates are as follows :

Middle Egypt		Upper Egypt	
Planting	Harvesting	Planting	Harvesting
Feb. 1	Jan. 31	Feb. 1	Jan. 31

Note 2 : Number of irrigations 24 to 28

3.31 The data presented in table 7 indicate that the seasonal consumptive use for sugar cane was 170.69 and 216.89 cms respectively for Middle and Upper Egypt. The peak values occur during June through September in both regions. The average daily rates were found to be 0.47 and 0.59 cms. for the two regions respectively. The average seasonal crop coefficient for sugar cane was found to be 0.87.

Wheat

3.32 Wheat is the main cereal crop being raised during winter in Egypt. Proper irrigation of wheat is important to achieve high yields, and especially in view of the heavy fertilization programme being implemented to maximize crop production.

3.33 It was reported by El-Tobgy (1976) that wheat is one of the five most important field crops with respect to value and to area and one of the three important cereals : maize, wheat, and rice. It is the main winter cereal crop and is widely distributed all over the country. It is usually planted in November and harvested in May. He also reported that 60% of the wheat area is in Lower Egypt and 40% in Middle and Upper Egypt.

3.34 Eid et al. (1966) calculated the consumptive use for Lower, Middle and Upper Egypt regions and the values were found to be 21.2, 22.0 and 23.7 inches respectively. Badawi (1970) at Middle Delta (El-Gimmeza) found that the seasonal consumptive use was 39.52 cms.