CONSUMPTIVE USE AND SUPPLEMENTAL WATER REQUIREMENTS OF CROPS GROWN IN THE EVERGLADES AGRICULTURAL AREA

#140

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FINDINGS

1. The consumptive water use requirement of rice, sugarcane, pasture, citrus, and truck crops in the Everglades Agricultural Area is estimated to be 67.4, 49.5, 44.6, 44.6, and 45.9 inches, respectively.
2. A portion of the consumptive water use requirement is met by rainfall. Of the 52.36 inches of annual rainfall which the area receives, only a portion of it is effective in crop growing.
3. The net irrigation water required to grow rice in the area (3 crops/year) is calculated to be 30.73 inches. Citrus requires 13.26 inches; sugarcane, pasture, and truck crops need 12.7, 12.8, and 13.47 inches respectively of supplemental water.
4. The system efficiency of flood irrigation and sprinkler irrigation is found to be 50 and 75%, respectively. Therefore, 50% more water than the net requirement will be needed if one uses flood irrigation.
5. It is estimated that at least 2 inches of water is required for flooding a field for pest control. It is estimated that the evaporative loss from the field during flooding conditions will be .3 inch/day. For a 1000 acre farm, this will amount to 25 acre feet of water on a daily basis. However, the usual practice has been to grow one crop per year. The net seasonal irrigation requirement is calculated to be approximately 11.0 inches (June, July, August, and September) for summer crops. For fall crops, the net irrigation requirement will be approximately 12.5 inches (March, April, May, and June.

INTRODUCTION

Increases in yield from the application of supplemental quantities of water during a crop's growing, maturing, and ripening periods has long been demonstrated by soil scientists. However, if the natural rainfall meets all the water requirements of crops, then no supplemental water is needed. The rainfall pattern of south Florida, and especially the Everglades Agricultural Area, is such that almost 70 percent of the yearly rain falls during the period when most of the crops grown in the area do not require any supplemental water. The area is in the drainage mode during this time. The remaining 30 percent of the annual rain falls during the period when most of the crops grown in the area are either growing, maturing, or ripening. This 30 percent of the total yearly amount is not sufficient for optimal plant yield even during normal years. Therefore, depending on the amount of rainfall the area receives, smaller or larger volumes of supplemental water need to be applied for optimal crop yield.

Various Florida scientists have done extensive research in determining the quantity of water needed by different crops during various stages of growth. If the water requirement of a certain crop in a certain area is known, then, using the effective rainfall (that quantity that the soil mantle can hold depending on its water holding capacity and the moisture content at that time) the supplemental water required to grow that crop can be estimated. (Reference 7).

The objectives of this study will be to (1) determine, through literature review, the consumptive water requirements of crops (ET) grown in the Everglades Agricultural Area; (2) to compute the monthly and annual supplemental water requirement of crops grown in the area; (3) to determine the efficiency of the different methods of irrigation used in the area; (4) to compute the gross amount of water needed to be diverted to irrigate a 1000 acre parcel under different crops; and (5) to estimate the quantity of water being lost from a farm when it is being flooded for pest control purposes.

EVERGLADES AGRICULTURAL AREA

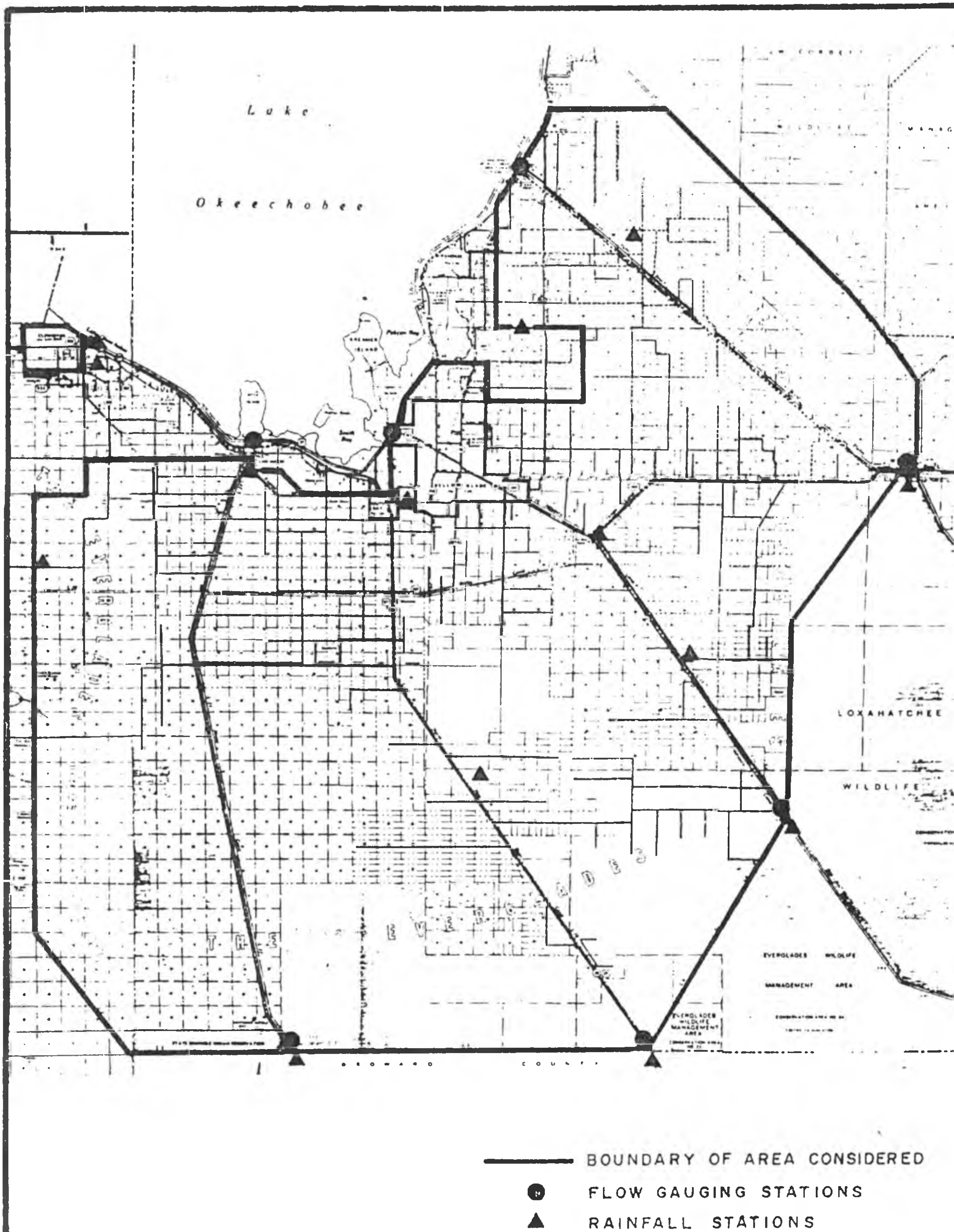
The Everglades Agricultural Area of western Palm Beach County and eastern Hendry County is the largest single body of organic soils under agricultural production (Figure 1). It has been reported by various researchers that these soils are subsiding at a rate of 1.5 to 3.1 cm/year (Shih, et al., 1975). In order to increase the longevity of these soils the agricultural practices have been shifting recently to the production of crops which can tolerate high water tables. In the past, sugarcane, truck crops, and pasture were the predominant crops grown in the area. Recently, however, more and more acreage has been put into rice production. In 1977, about 300 acres of rice was planted by one grower - 9,000 acres were planted in 1980 (Shih, 1981). Therefore, this investigation will be limited to the consumptive water use requirement and the calculation of the supplemental water needed by the above stated crops in the Everglades Agricultural Area.

Consumptive Water Requirement or Evapotranspiration of Crops

The consumptive water requirement of crops can be estimated both directly and indirectly by use of emperical equations - incorporating climatic, soil-crop characteristics. A detailed description of the methods that have been used for estimating crop water requirements has been reported elsewhere (Khanal, 1981). All of the consumptive water use requirement methods try, in some form or other, to incorporate part or all of the following relationships.

Inches of water required/acre = f (soil-water plant relationship, socio-economic - institutional - political environment [human interception]).

Concerning the evapotranspiration of crops grown in the Everglades Agricultural Area, IFAS (University of Florida Institute of Food and Agricultural Sciences) has done extensive studies (1, 5, and 6). Presented in Table 1



EVERGLADES AGRICULTURAL AREA

FIGURE 1

is the evapotranspiration of crops grown in the Everglades Agricultural Area as reported by IFAS (1). It can be seen from Table 1 that rice has the highest consumptive water use requirement. This is due to the fact that the area where rice is grown must be flooded most of the time. The rest of the crops grown in the area need anywhere from 44 to 49 inches of water (excluding rainfall).

Table 1. Evapotranspiration of Crops Grown in the Everglades Ag. Area

Months	Rice	Sugarcane	Citrus	Pasture	Truck Crops
January	-	1.40	2.10	2.10	2.70
February	-	1.10	2.60	2.60	2.70
March	4.40	2.50	3.60	3.60	3.40
April	6.10	3.40	4.50	4.50	3.70
May	8.40	4.80	5.30	5.30	4.80
June	8.20	6.00	4.40	4.40	4.80
July	9.20	6.50	4.90	4.90	5.20
August	10.20	6.70	4.80	4.80	5.10
September	7.40	5.10	4.00	4.00	4.00
October	8.60	5.20	3.60	3.60	3.50
November	4.90	3.20	2.70	2.70	2.90
December	-	2.60	2.10	2.10	2.60
Total	67.40	49.50	44.60	44.60	45.90

Rainfall and Effective Rainfall for Crop Growth in the Everglades Ag. Area

Presented in Table 2 are the average monthly rainfall values from S-2. This station has monthly values dating back to 1924. For calculation of effective rainfall, however, only values from 1960 are used.

SCS Tech. Pub. No. 21 (7) shows a method of calculating effective rainfall based on the monthly consumptive water use requirement and the mean monthly rainfall (Table 3). The table is based on 3 inch net depth of application.

Table 2. Monthly Rainfall Values (Inches) at S-2

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
1960	.24	3.15	2.25	5.30	4.18	6.87	10.04	9.22	18.10	4.05	1.67	.30	65.37
1961	3.12	.71	1.48	1.40	8.57	6.60	5.52	8.26	1.41	3.53	1.07	.23	41.90
1962	1.31	.72	3.32	4.22	2.47	11.01	8.62	8.56	10.67	2.72	1.02	.33	54.97
1963	1.09	3.01	.80	.28	7.13	6.43	3.38	6.58	7.54	1.83	2.45	5.06	45.58
1964	2.38	2.32	2.74	2.67	2.34	8.29	8.22	8.55	4.43	9.69	.84	2.96	55.43
1965	.23	2.99	2.25	1.00	.85	9.24	9.06	6.84	5.72	8.57	.54	1.30	48.59
1966	4.61	2.78	1.16	2.77	4.52	16.87	7.69	7.72	7.48	4.06	.34	.79	60.79
1967	.91	3.52	.84	.02	1.00	9.93	7.54	5.31	5.96	4.58	.14	1.95	41.70
1968	.59	3.19	1.42	1.45	8.63	15.49	8.05	5.15	8.05	7.54	1.88	.07	61.51
1969	1.70	1.69	5.56	4.30	6.68	9.43	5.94	7.59	8.32	6.98	3.03	1.35	62.57
1970	2.89	2.29	12.68	.38	7.10	7.34	8.46	6.31	4.69	2.96	.20	.30	55.60
1971	.75	1.90	.64	.26	4.98	9.01	8.64	6.85	6.80	6.47	3.32	1.40	61.02
1972	1.53	1.80	2.37	6.92	7.61	9.01	5.61	5.67	3.17	1.63	2.90	2.05	50.27
1973	2.62	1.52	3.60	.85	4.53	7.29	10.20	8.09	4.37	3.20	.33	1.95	48.55
1974	2.09	.20	.92	1.34	3.93	12.11	9.08	7.13	7.85	1.83	2.25	1.30	50.03
1975	.16	.93	1.02	.88	5.58	9.77	10.16	5.30	9.14	5.26	1.27	.26	49.73
1976	.62	3.30	1.50	1.13	9.95	5.98	5.52	7.51	6.94	.38	1.72	2.29	46.84
1977	4.25	.63	.32	.59	8.90	4.58	4.13	7.14	10.44	.63	4.43	4.78	50.82
1978	2.47	1.60	2.04	1.21	6.67	8.80	9.58	6.23	5.39	3.49	3.00	3.94	54.42
Average	1.75	2.00	2.47	1.94	5.56	9.16	7.65	7.05	7.18	4.17	1.70	1.71	

Table 3--Average monthly effective rainfall[1/] as related to mean monthly rainfall and average monthly consumptive use

Monthly Mean Rainfall r_t Inches	Average Monthly Consumptive Use, u, in Inches										
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.00
	Average Monthly Effective Rainfall, r_e, in Inches										
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.45	0.47	0.50
1.0	0.59	0.63	0.66	0.70	0.74	0.78	0.83	0.88	0.93	0.98	1.00
1.5	0.87	0.93	0.98	1.03	1.09	1.16	1.22	1.29	1.37	1.45	1.50
2.0	1.14	1.21	1.27	1.35	1.43	1.51	1.59	1.69	1.78	1.88	1.99
2.5	1.39	1.47	1.56	1.65	1.74	1.84	1.95	2.06	2.18	2.30	2.44
3.0		1.73	1.83	1.94	2.05	2.17	2.29	2.42	2.56	2.71	2.86
3.5		1.98	2.10	2.22	2.35	2.48	2.62	2.77	2.93	3.10	3.28
4.0		2.23	2.36	2.49	2.63	2.79	2.95	3.12	3.29	3.48	3.68
4.5			2.61	2.76	2.92	3.09	3.26	3.45	3.65	3.86	4.08
5.0			2.86	3.02	3.20	3.38	3.57	3.78	4.00	4.23	4.47
5.5			3.10	3.28	3.47	3.67	3.88	4.10	4.34	4.59	4.85
6.0				3.53	3.74	3.95	4.18	4.42	4.67	4.94	5.23
6.5				3.79	4.00	4.23	4.48	4.73	5.00	5.29	5.60
7.0				4.03	4.26	4.51	4.77	5.04	5.33	5.64	5.96
7.5					4.52	4.78	5.06	5.35	5.65	5.98	6.32
8.0					4.78	5.05	5.34	5.65	5.97	6.32	6.68

Note:
Values below line exceed monthly consumptive use and are to be used for interpolation only.

1/ Based on 3-inch net depth of application. For other net depths of application, multiply by the factors shown below.

Net Depth of Application	(D)	.75	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0
Factor	(f)	.72	.77	.86	.93	.97	1.00	1.02	1.04	1.06	1.07

Note: Average monthly effective rainfall cannot exceed average monthly rainfall or average monthly consumptive use. When the application of the above factors results in a value of effective rainfall exceeding either, this value must be reduced to a value equal the lesser of the two.

$$r_e = (0.70917\ r_t^{0.82416} - 0.11556)(10)^{0.02426u}\ (f)$$

$$\text{where } f = (0.531747 + 0.295164D - 0.057697D^2 + 0.003804D^3)$$

However, the effective rainfall can be calculated for any net depth of application. Presented in Tables 4 through 8 is the effective rainfall calculated for various crops grown in the Everglades Ag. Area for a net 3 inch depth of application.

The net annual supplemental water required to grow rice in the Everglades Ag. Area (EAA) is calculated to be 30.73 inches (Table 4). This figure is slightly higher than the 26.0 inches reported by IFAS. However, the net irrigation requirement for summer crops is estimated to be 11.0 inches and 12.5 inches for fall crops.

The volume of supplemental water needed to be applied to a 1000 acre parcel of land under rice irrigation is calculated as follows:

Month	Supplemental Water Required, Inches	Acres	Volume of Water Needed Acre Feet
Jan.	-	1,000	-
Feb.	-	1,000	-
Mar.	2.61	1,000	217.5
Apr.	4.51	1,000	375.8
May	4.01	1,000	334.1
June	1.20	1,000	100.0
July	3.20	1,000	266.6
Aug.	4.24	1,000	353.3
Sept.	2.23	1,000	158.8
Oct.	5.31	1,000	442.5
Nov.	3.42	1,000	285.0
Dec.	-	1,000	-
Total	30.73		2,533.6

The above calculation shows that the nine month water requirement of rice is 30.73 inches or 2,533.6 acre feet for a 1,000 acre parcel. However, if rice is planted only once during a year, the supplemental water can be computed from the above table, depending on when the crop is planted.

Table 4. Effective Rainfall and Supplemental Water Requirements for Rice Growing in the EAA

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
Average Rainfall	1.76	2.01	2.47	1.94	5.56	9.16	7.65	7.05	7.18	4.17	1.70	1.71	52.36
Consumptive Use/ET	-	-	4.40	6.10	8.40	8.20	9.20	10.20	7.40	8.60	4.90	-	67.40
Eff. Rainfall for 3" of application	-	-	1.79	1.59	4.41	7.00	6.00	5.96	5.17	3.29	1.48	-	36.69
Average yrly. Supplemental Water Reqmt.	-	-	2.61	4.51	4.01	1.20	3.20	4.24	2.23	5.31	3.42	-	30.73

Table 5. Effective Rainfall and Supplemental Water Requirements for Citrus Growing in the EAA

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
Average Rainfall	1.76	2.01	2.47	1.94	5.56	9.16	7.65	7.05	7.18	4.17	1.70	1.71	52.36
Consumptive USe/ET	2.10	2.60	3.60	4.50	5.30	4.40	4.90	4.80	4.00	3.60	2.70	2.10	44.60
Eff. Rainfall for 3" of Application	.98	1.30	1.68	1.46	3.70	4.88	4.78	4.51	4.26	2.53	1.00	1.00	32.08
Average yrly. Supplemental Water Reqmt.	1.12	1.30	1.92	3.04	1.60	-	.12	.29	-	1.07	1.70	1.10	13.26
Volume needed to irrigate 1000 AC. (A/F)	93.3	180.3	160.0	253.3	133.0	-	10.0	24.1	-	89.0	141.6	91.6	1104.20

Table 6. Effective Rainfall and Supplemental Water Requirements for Sugarcane Growing in the EAA

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
Average Rainfall (Inches)	1.76	2.01	2.47	1.94	5.56	9.16	7.65	7.05	7.18	4.17	1.70	1.71	52.36
Consumptive Use/ET	1.40	1.10	2.50	3.40	4.80	6.00	6.50	6.70	5.10	5.20	3.20	2.60	48.50
Eff. Rainfall for 3" of Application	.99	-	1.60	1.40	3.67	-	6.20	4.85	4.51	2.79	1.35	1.30	28.66
Average yrly Supplemental Water Reqmt.	.41	-	.90	2.00	1.13	-	.30	1.85	.59	2.41	1.85	1.30	12.74
Volume needed to irrigate 1000 AC. (A/F)	34.1	-	75.0	166,7	94.1	-	25.0	154.1	49.1	200.8	154.1	108.3	1061.20

Table 7. Effective Rainfall and Supplemental Water Requirements for Pastures in the EAA

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
Average Rainfall (Inches)	1.76	2.01	2.47	1.94	5.56	9.16	7.65	7.05	7.18	4.17	1.70	1.71	52.36
Consumptive Use/ET	2.10	2.60	3.60	4.50	5.30	4.40	4.90	4.80	4.00	3.60	2.70	2.10	44.60
Eff. Rainfall for 3" of Application	1.12	1.30	1.70	1.45	3.70	-	4.78	4.51	-	2.53	1.15	1.20	23.44
Average yrly Supplemental Water Reqmt.	.98	1.30	1.90	3.05	1.60	--	.12	.29	-	1.07	1.55	1.00	12.86
Volume needed to irrigate 1000 AC. (A/F)	81.6	108.3	158.3	254.1	133.3	-	10.0	24.1	-	89.1	129.1	83.3	1071.20

Table 8. Effective Rainfall and Supplemental Water Requirements for Vegetable Growing in the EAA

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
Average Rainfall (Inches)	1.76	2.01	2.47	1.94	5.56	9.16	7.65	7.05	7.18	4.17	1.70	1.71	52.36
Consumptive Use/ET	2.70	2.70	3.40	3.70	4.80	4.80	5.20	5.10	4.50	3.50	2.90	2.60	45.90
Eff. Rainfall for 3" of Application	1.00	1.30	1.70	1.40	3.67	-	4.78	4.51	-	2.54	1.05	1.00	22.95
Average yrly Supplemental Water Reqmt.	1.70	1.40	1.70	2.30	1.13	-	.42	.41	-	.96	1.85	1.60	13.47
Eff. Rainfall for 1.5" of Application	.86	1.11	1.46	1.20	3.15	4.12	4.11	3.87	3.87	2.18	.90	.86	23.79
Average yrly Supplemental Water Reqmt.	1.84	1.59	1.94	2.50	1.65	.68	1.09	1.23	.63	1.32	2.00	1.74	18.21
Volume needed to irrigate 1000 AC. (A/F)	153.3	132.5	161.6	208.3	137.5	56.6	90.8	102.5	52.5	110.0	166.7	145.	1517.30

Presented in Table 9 is the length of crop growing seasons as reported by Criddle (1). The length of crop growing seasons can be estimated by use of this table.

Table 9. Normal Seasonal Consumptive Use Coefficients for the More Important Irrigated Crops of the West (after Criddle)

Item	Length of Growing Season or Period
Beans	3 months
Corn	4 months
Citrus orchard	7 months
Deciduous orchard	frost-free
Pasture, grass, hay annuals	frost-free
Rice	3 to 4 months
Small grains	3 months
Sorghum	5 months
Sugar beets	5½ months

Irrigation Efficiency

The supplemental quantity of water calculated by use of the modified Blaney-Criddle method is the net quantity of water required at the root zone itself. In order to apply that quantity, some method of irrigation system has to be used. In the past, crown flood, furrow, and seepage methods were the predominant types of irrigation systems used in south Florida farming. Now, however, more and more sprinkler and drip irrigation systems are being used.

IFAS has done extensive research on the efficiency of different methods of irrigation. They estimate that crown flood and furrow irrigation systems are only 50% efficient, and that seepage irrigation systems are from 30 to 50 percent efficient. The efficiency of sprinkler irrigation systems is estimated to be 75 percent and the drip irrigation system is estimated to be 90 percent efficient.

Therefore, depending on what method of irrigation is being used, some provision has to be made for irrigation system efficiency. Table 10 shows the gross quantity of water that needs to be diverted for citrus growing in the Everglades Ag. Area. Gross quantity of water needed is estimated for citrus using (a) flood irrigation, and (b) sprinkler irrigation. It is estimated that flood irrigation is 50 percent efficient and sprinkler irrigation is 70 percent efficient.

The calculations in Table 10 show that if flood irrigation (which is cheaper) is shifted to sprinkler irrigation, the gross water requirement reduces significantly.

Field Flooding for Pest Control

Mierau (1974) based on the soil moisture desorption and adsorption curves, has determined the storage coefficient of the soil to be .31. In other words, it will require 3.75 inches of water to raise the groundwater table from 2.0 ft. below ground surface to 1 foot below land surface. Raising the water table from eighteen inches to six inches below land surface is equivalent to adding 1.2 inches of water. He recommends 2 inches of free water for pest and disease control. However, he further states that this 2 inches can be met from rainfall excess alone. It should also be pointed out that as the land is being flooded for pest control, evapotranspiration will take place at the maximum rate. It is estimated that water loss from evaporation during flooding will be approximately .3 in. per day. This statement is based on the consumptive water use requirement of rice growing during the month of August. Therefore, evaporation loss from a 1000 acre parcel of land during flooding periods would amount to 25 acre feet/day.

Table 10. Gross Quantity of Water Needed for Citrus Using FLood Irrigation and Sprinkler Irrigation

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
Net Supplemental Water Required (Inches)	1.12	1.30	1.92	3.04	1.60	-	.12	.29	-	1.07	1.70	1.10	13.26
Gross Supplemental Water Required for Flood Irrigation (Inches)	2.24	2.60	3.84	6.08	3.20	-	.24	.58	-	2.14	3.40	2.20	26.52
Volume of Water Needed to Irrigate 1000 AC. (A/F)	186.6	216.6	320.0	506.6	266.6	-	20.0	48.3	-	178.3	283.3	183.3	2183.3
Gross Supplemental Water Required for Sprinkler Irrigation (Inches)	1.49	1.73	2.56	4.05	2.13	-	.16	.38	-	1.42	2.26	1.46	17.68
Volume of Water Needed to Irrigate 1000 AC. (A/F)	124.1	144.1	213.3	337.5	177.5	-	13.3	31.6	-	118.3	188.3	121.6	1473.3

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