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Crop Water Requirements
Imperial Valley

by

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This Technical Information Record reviews existing literature with regards to crop water use in the Imperial Valley. Data are by crop categories and a brief explanation is presented as to how these values were computed. Evapotranspiration rates, effective precipitation, and leaching requirements are the major factors in analyzing crop water consumption.

The findings of the TIR are not fully reconciled with all technical aspects of the total investigation, which will be fully reviewed when all phases of the investigation have been completed. Hence, this TIR is only for internal office use and should be considered as preliminary and subject to revision.

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INTRODUCTION

Approximately 85 percent of the water used in California is associated with agriculture. During the 1976-77 drought, people located in the major urban centers complained that, although they were forced to reduce their average annual consumptive water usage, agricultural interests proceeded with their activities with few limitations. This criticism was not completely true. Agricultural interests did make a concerted effort to reduce their demand during this critical period. Even with sufficient water supplies available now, agricultural water conservation is being stressed.

The Imperial Valley has been targeted by the Federal government and the State of California as one of the major areas where agricultural water conservation should be stressed. Of the 202 345 hectares (500,000 acres) currently being subjected to some land use activity, 182 110 hectares (450,000 acres) are under agricultural production. The Imperial Valley ranks second to the San Joaquin Valley in agricultural productivity in the State.

Annual diversions from the Colorado River, along the All-American Canal, for the Imperial Valley totaled 3 458 000 cubic dekametres (2,803,000 acre-feet) for 1979 (DWR, 1981). Assuming a 10 percent reduction of the supply due to system losses and another 4 percent for urban consumption, agricultural activities in the Imperial Valley used an estimated 3 001 000 cubic dekametres (2,433,000 acre-feet) of water (The Bureau of Reclamation, 1980; formerly Water and Power Resources Service, DWR, 1981).

The Bureau of Reclamation estimates that the consumptive use of water in agriculture in the Imperial Valley can be reduced by approximately 8 percent. Most of the savings would occur in the operational aspects of the on-farm deliveries (reducing seepage losses in the canals, drains, and ditches).

All agriculture in the Imperial Valley requires irrigation. Because of its geographic location (situated in a region seldom reached by beneficial winter storms), its general physiographic character (internally draining basin), and the brackish nature of its groundwater, the Imperial Valley must depend on the importation of all its water.

Irrigation requirements for various types of crops must be determined in advance to ensure that adequate supplies of water are delivered. Water requirements entail comprehending such variables as consumption level of each crop (magnitude of evapotranspiration), levels of dissolved solids in the irrigation water, climatic and physiographic parameters, deep percolation losses, irrigation techniques, runoff losses, and leaching requirements.

OBJECTIVE

The objective of this report is to identify reliable consumptive use rates of water that are applicable to crops grown in the Imperial Valley.

SCOPE

Crop consumptive water use rates (evapotranspiration) and leaching requirements are considered only. Evapotranspiration (ET) values computed and derived by several authors will be discussed.

Leaching will also be briefly discussed. Many recent articles have provided new information on the subject.

Finally, Appendix A, "Estimated Crop Evapotranspiration in the Imperial Valley" by Norman A. MacGillivray, Department of Water Resources (DWR), San Joaquin District, listing ET values for the major crops grown in the Valley will also be discussed.

PREVIOUS FINDINGS

Several researchers have published papers that dealt with determining consumptive water use for major crops grown in the Imperial Valley. Unfortunately, each researcher has his or her own interpretation as to what the estimated ET value should be for specific crops. The Bureau of Reclamation, with aid from the Imperial Irrigation District (IID), compiled and published a list of estimated ET values of crops that could be grown in the area. The Department of Water Resources (DWR) updated some of the ET values listed in its Bulletin 113-3 and developed new ones for 19 major Imperial Valley crops.

Table 1 demonstrates the variations in consumptive use values derived for several major crops in the Imperial Valley by various agencies and individuals.

DISCUSSION

Work on deriving ET crop values commenced in the early 1950's with investigations being performed by Blaney and several associates. With the use of a formula he derived, Blaney was able to calculate the estimated ET value for alfalfa grown in the Valley. Applied water use values for barley, flax, milo, carrots, lettuce and cantaloupes were also derived (Donnan, Bradshaw, and Blaney, 1954). The value for alfalfa is listed in Table 1 (column 1). A brief explaination of Blaney's equation (the Blaney-Criddle equation) is provided in Appendix B.

The Soil Conservation Service of the United States Department of Agriculture (1960) published an irrigation guide that listed ET values for the following crops: alfalfa, flax, sugar beets, cotton, grain, citrus (general), carrots, tomatoes, sorghum, and melons (Table 1, colmn 2). The Blaney-Criddle equation was used to compute these ET estimates.

Another element presented in the Soil conservation Service's guide was the recommended irrigation method one should use for a specific crop in a certain

TABLE 1
COMPARISONS OF ESTIMATED CROP ET VALUES
IN THE IMPERIAL VALLEY

(in millimetres)*

	Crop	Blaney (1)	SCS Irrig. G. (2)	USDA Bull. 1275 (3)	Erie et al (4)	Kaddah-Rhoades (5)	IID (6)	Robinson (7)	Bureau of Reclm. (8)	DWR (9)	Ehlig (10)
Field and Pasture	Alfalfa	1400.0	1615.4	1295.4	1887.2	1830.0	1828.8	1194.0	1889.8	2047.2	1883.4
	Pasture	---	---	635.0	1102.4	---	1828.8	---	1097.3	2037.1	---
	Wheat	---	---	563.9	581.7	640.0	640.1	502.9	670.6	637.5	639.0
	Barley	---	365.0	---	642.6	640.0	548.6	---	640.1	594.4	472.5
	Sugar beets	---	731.5	660.4	---	1120.0	1127.8	1102.8	1097.3	1191.3	1162.0
	Sorghum	---	792.5	543.6	645.2	760.0	762.0	861.1	670.6	746.8	523.0
	Cotton	---	975.4	886.5	1046.5	1090.0	1097.3	---	1066.8	1088.9	1025.7
	Corn	---	792.4	492.8	497.8	---	762.0	---	670.6	523.4	---
Truck	Broccoli	---	---	---	500.0	---	518.0	485.1	426.7	312.4	---
	Cabbage	---	---	436.9	500.0	---	518.2	381.0	304.8	442.0	---
	Onions	---	---	492.8	600.0	580.0	518.2	426.7	579.1	655.3	---
	Carrots	---	548.6	---	400.0	410.0	396.2	594.4	426.7	477.5	---
	Lettuce	---	182.9	---	200.0	430.0	426.7	355.6	243.8	302.3	---
	Tomatoes	---	518.2	579.1	---	690.0	701.0	---	487.7	736.6	---
	Squash	---	487.7	487.7	500.0	510.0	701.0	---	487.7	299.7	---
	Cantaloupes	---	487.7	485.1	500.0	510.0	701.0	---	487.7	467.4	---
	Asparagus	---	---	---	---	1400.0	518.2	729.0	426.7	1640.8	---
	Citrus	---	1219.2	1097.3	1100.0	1140.0	1158.2	---	1219.2	1170.9	---

* 1 millimetre = 0.03937 inches

type of soil. The pedologic characteristics of the various soil types (texture) degree of permeability, and the depth of the soil profile) and the theorized infiltration rate of applied crop water for a certain method of irrigation were presented in the guide.

Blaney and Criddle (1962) in the United States Department of Agriculture Technical Bulletin 1275 examined variations of ET in selected areas in the United States and in foreign countries. Using the Blaney-Criddle equation, the authors derived ET values for several crops grown in the Salt River Valley, Arizona. These values are listed in Table 1 (column 3). Application of these values to the Imperial Valley might be possible since the meteorological characteristics of the two areas seem to be similar.

Erie, et al, (1965) issued a report that summarized the extensive research and field work conducted in the Salt River Valley from which ET values for high market value crops were derived. As summarized in Table 2, ET estimates were derived for castor beans, cotton, flax, safflower, soybeans, alfalfa, bermuda grass, blue panic grass, barley, grain sorghum, double cropped grain sorghum, double cropped forage sorghum, wheat, grapefruit, grapes, navel oranges, broccoli, cabbage, cantaloupes, carrots, cauliflower, lettuce, dry onions, green onions, potatoes, sweet corn, guar, and sesbania. These values were derived by gravimetrically measuring moisture depletion in the soil around the crop (Table 1, column 4 and Table 2). Samples were taken at various depths and at varying time intervals to measure the volume of water removed from the soil by the crops. Special care was taken to ensure that the soil samples were taken at the time of irrigation.

Kaddah and Rhoades (1976) published a report that gave field tested ET values for several Imperial Valley crops. The authors initially derived these values

TABLE 2
ESTIMATED ET VALUES
FOR MAJOR AND MINOR CROPS IN
IMPERIAL VALLEY
in meters*

CROP	WPRS	Erie et. al.	Kaddah-Rhoades
Alfalfa	1.9	1.9	1.8
Alfalfa hay and seed	1.9	---	---
Alicia	0.7	---	---
Almonds	1.2	---	---
Apricots	1.2	---	---
Asparagus	0.4	---	1.4
Barley	0.6	0.6	0.6
Beans	0.5	---	---
Bermuda Grass	1.0	1.1	0.8
Blue panic grass	---	1.3	---
Broccoli	0.4	0.5	0.5
Cabbage (early)	0.3	0.4	0.5
(late)	0.3	0.6	0.5
Cantaloupes	0.5	0.5	0.5
Carrots	0.4	0.4	0.4
Castor beans	---	1.1	---
Cauliflower	0.3	0.5	0.5
Celery	0.4	---	0.5
Corn (sweet)	0.7	0.5	---
Corn silage	0.7	---	---
Cotton	1.1	1.0	1.1
Cropland not harvested	1.1	---	---
Cucumbers	0.4	---	0.5
Dates	1.2	---	1.2
Ensilage	0.7	---	---
Family Gardens and Orchards	0.6	---	0.5
Flax	---	0.8	---
Garden	0.5	---	0.5
Garlic	0.6	---	0.6
Grapefruit	1.2	1.2	1.2
Grapes (table)	1.3	0.5	1.3
Greens	1.1	---	---
Guar	1.1	0.6	---
Honeydew	0.5	---	---
Lemons and limes	1.3	1.2	1.2
Lettuce	0.2	0.2	0.4
Milo	0.7	---	---
Nursery	0.5	---	---
Oats	0.7	0.6	0.6
Onions	0.6	0.6	0.6
Onions (green)	---	0.5	---
Oranges and tangerines	1.0	1.0	1.2
Orchard	1.2	---	1.2
Pasture	1.1	1.1	1.5
Peaches	1.2	---	---
Peas	0.4	0.5	0.5
Pecans	1.2	---	---
Peppers	0.4	---	---
Popcorn	0.7	---	---
Potatoes	---	2.0	---
Rye	0.7	---	0.8
Rye Pasture	0.7	---	0.8
Safflower	1.0	1.2	---
Sesbania	1.1	0.3	---
Sorghum (grain)	0.5	0.6	0.8
Sorghum (grain, double-cropped)	---	1.3	---
Sorghum (forage, double-cropped)	---	1.4	---
Soybeans	0.5	0.6	---
Sudan Grass	1.1	---	0.8
Squash	0.5	0.5	0.5
Sugar beets	1.1	---	1.1
Tomatoes	0.5	---	0.7
Wheat	0.7	0.6	0.6
Misc. Truck Crops	0.5	---	0.5
Misc. Field Crops	0.7	---	---
Misc. Seed	1.0	---	---

* 1 meter = 3.28 feet

using the Blaney-Criddle equation and then field checked them by using the weighing lysimeter tank at the Agricultural Research Station in Brawley. Based on the results of their field tests and those performed by others, the authors report that reliable ET values have been assigned for the following crops: alfalfa, barley, cotton, sugar beets, sorghum, and wheat. A partial listing of Kaddah and Rhoades values can be found in Table 1 (column 5) and a complete listing in Table 2.

The IID (1977) adopted Kaddah and Rhoades' ET values for a ten-year summary report on agricultural water use activity within their service area. IID's report examined annual and average agricultural water use characteristics for the years 1967 through 1977. These values are listed in Table 1 (column 6).

Robinson and Luthin (1976) prepared a report in cooperation with the University of California Agricultural Extension Service that also provided ET values for several crops (Table 1, column 7). Although the research project dealt with testing the reaction of certain crops to various levels of TDS (total dissolved solids) in the irrigation water, Robinson had to derive these values so as to ensure that the test specimens were being sufficiently irrigated. Using evaporation data obtained from a standard "Class A" evaporation pan, Robinson was able to compute an estimated ET value for each of his test crops.

The Bureau of Reclamation (1980) supplied a list of ET values for both major and minor crops grown in the Valley. The exact methodology of computing these values remains unknown although the IID was apparently consulted for help. A partial listing of these values may be found in Table 1 (column 8) and a complete listing in Table 2.

The Department of Water Resources (DWR) has two publications that supply water use values for Imperial Valley crops. The DWR Bulletin 113-3 has in

Table 35 an applied water use listing for several crops. MacGillivray, DWR, derived ET values for 19 major truck, field, pasture, and citrus crops in the Valley (this work has ET computed by the growing season so that crops grown several times during the year will have different values assigned to them). Effective precipitation values were assigned to each crop and, though, the overall annual rainfall total is small, the authore felt that some benefit would be received by each crop (Table 1, column 9 and Appendix A).

Researchers stationed at the U. S. Department of Agriculture, Imperial Valley Conservation Research Center in Brawley have conducted experiments trying to determine reliable ET values. Ehlig (1978) field tested the following crops with a weighing lysimeter tank: alfalfa, barley, cotton, sugar beets, sorghum, and wheat (Table 1, column 10). Hermsmeier (1979) has been conducting an off-farm water balance study since 1976. Field experiments with alfalfa, cotton, sugar beets, and wheat have led to ET values being partially derived. Evaporation data gathered from standard Class A pans were used to derive these values.

The control of soil salinity in the Imperial Valley has been the most serious problem confronting the farmers and IID. Studies initiated by Blaney, et al, in the 1950's, began to examine the problem and offered possible solutions. The U. S. Department of Agriculture developed a salinity equation (1954) that Imperial Valley farmers and IID technicians have used to determine the leaching requirement of a crop. The equation computes the leaching requirement by examining the ratio of irrigation water electroconductivity over the drain water electroconductivity. Recently though, doubts have been expressed by Rhoades (1980), U. S. Salinity Laboratory, as to the reliability of this method for computing crop leaching requirements.

Molof (1960) contends that drainage is the key towards controlling the soil salinity problem in the Valley. Use of tile drains and the application of additional water to "flush" the soil of unwanted salts are recommended by Molof. He presents data on levels of salts in the soil that could be withstood by the various crops grown (Table 3).

Jack Smith (1966) contends, along with Molof, that soil salinity in the Valley will become a major problem if steps are not taken to improve the drainage of irrigation water. Smith makes recommendations on leaching requirements for sensitive and tolerant crops. He feels that sensitive crops need an additional 25 percent of water for leaching of harmful salts while the more tolerant crops need only 10 percent. He also states that salinity levels can be reduced in one foot of soil by 80 percent with one foot of water.

Leaching studies conducted in the 1970's demonstrated the need for additional water for flushing salts from the soils. Bernstein and Francois (1973) concluded that alfalfa yield variations were closely related to the salt levels of the incoming irrigation water and soil. The TDS level of the incoming irrigation water was pinpointed by the authors as being the major contributor of additional salts in the fields.

The studies done in the 1970's, including the one by Lonkerd, Ehlig, and Donovan (1979), indicate that the amounts of additional water needed for leaching can be reduced. Bernstein and Francois suggest a reduction in application quantities of 25 percent for low salt tolerant crops and 40 percent for high salt tolerant crops. Lonkerd, et al, studied leaching requirements of crops on specific soil types. Table 4 summarizes their findings. The authors contend that leaching for a specific crop, depending on the soil, can be either insufficient or over excessive. Holtville and Indio soils were generally overleached while the opposite held true for the Imperial and Meloland soils. The authors also recommend a leaching percentage of 10 to 15 percent for lettuce and 5 to 10 percent for all other crops.

TABLE 3
CLASSIFICATION OF CROPS BASED ON
SALT TOLERANCE LEVELS
IMPERIAL VALLEY *

Good Salt Tolerance 8-16 mmhos/cm** Yield 50% Below Optimum	Medium Salt Tolerance 4-8 mmhos/cm** Yield 50% Below Optimum	Low Salt Tolerance 0-4 mmhos/cm** Yield 50% Below Optimum
Date Palm	Tomatoes	Grapefruit
Garden Beets	Cabbage	Oranges
Asparagus	Lettuce	Lemons
Kale	Carrots	Radishes
Spinach	Onions	Celery
Sugar beets	Cucumbers	Green Beans
Cotton	Sudan Grass	Alsike Clover
Bermuda Grass	Alfalfa	
Barley	Sorghum	
	Flax	
	Castorbeans	
	Cantaloupes	

*From Molof (1960).

**millimhos per centimetre

TABLE 4

COMPARISON OF LEACHING REQUIREMENTS FOR CROPS VERSUS SOIL TYPE IN THE IMPERIAL VALLEY *

Soil Series	Crop	Leaching Requirement Range	Leaching Requirement Median
		%	%
Holtville	Alfalfa	3-23	9
	Cotton	1-42	6
	Lettuce	2-76	27
	Sugar beet	1-49	28
	Wheat	3-50	12
Imperial	Alfalfa	2-11	5
	Cotton	2-5	3
	Lettuce	1-44	7
	Sugar beet	1-24	4
	Wheat	1-42	5
Indio	Alfalfa	2-22	6
	Cotton	1-26	4
	Lettuce	1-100	28
	Sugar beet	9-38	15
	Wheat	3-48	23
Meloland	Alfalfa	2-5	3
	Cotton	2-86	5
	Lettuce	2-18	4
	Sugar beet	1-17	5
	Wheat	3-16	4

*From Lonkerd, Ehlig, and Donovan (1979)

The IID (1977) issues a list of recommended crop leaching requirement percentages which was included in their 10-year report. Those values may be found in Table 5, which gives estimated crop consumptive use values. IID's values were derived by using the USDA salinity equation based on the electroconductivity ration of the incoming irrigation water versus the drain water.

Robinson and Luthin (1976) conducted experiments with crops using the salinity content of the irrigation water as control. Yield levels for several crops decreased as irrigation water with a higher TDS content was used. Robinson's study concentrated mainly on the effects of irrigation water on various crops (changing the TDS level of the irrigation water); soils were not examined in the study.

Rhoades (1980) does not believe that the current method of computing leaching requirements for crops in the Valley is successful. He contends that without taking into consideration numerous pedological factors (porosity, pH, density, particle texture, grain size, and mineralogy), an accurate leaching requirement cannot be made. This point was emphasized by Lonkerd, et al, in their study.

TABLE 5

ESTIMATED TOTAL CROP WATER USE REQUIREMENT FOR MAJOR CROPS IN THE IMPERIAL VALLEY *

CROP	Est. ET (mm)	Effec. Precip. (mm)	ETAW (mm)	ETAW (m)	LR %	LR (m)	Total C.U.
Alfalfa (hay)	2047.2	25.4	2021.8	2.0	16	0.3	2.3
Pasture	2037.1	25.4	2011.7	2.0	16	0.3	2.3
Wheat	637.5	20.3	617.2	0.6	09	0.1	0.7
Barley	594.4	20.3	574.1	0.6	09	0.1	0.7
Sugar beets Fall	1165.9	50.8	1115.1	1.1	08	0.1	1.2
Summer	1219.2	38.1	1181.1	1.2	08	0.1	1.3
Grain Sorghum Spring	713.7	10.2	703.5	0.7	11	0.1	0.8
Summer	774.7	15.2	759.5	0.8	11	0.1	0.9
Forage Sorghum Single	810.6	7.6	803.0	0.8	11	0.1	0.9
Double	1371.6	20.3	1351.3	1.4	11	0.2	1.6
Cotton	1038.9	20.3	1018.6	1.0	08	0.1	1.1
Corn	523.4	7.6	515.8	0.5	16	0.1	0.6
Broccoli	312.4	27.9	284.8	0.3	21	0.1	0.4
Cabbage	442.0	30.5	411.5	0.4	21	0.1	0.5
Onions	655.3	27.9	627.4	0.6	21	0.1	0.7
Carrots	477.5	33.0	444.5	0.4	31	0.2	0.6
Lettuce Spring	381.9	15.2	266.7	0.3	25	0.1	0.4
Fall	320.0	27.9	292.1	0.3	25	0.1	0.4
Tomatoes (canning)	894.1	7.6	886.5	0.9	16	0.2	1.1
Tomatoes (market)	579.1	15.2	563.9	0.6	16	0.1	0.7
Squash Fall	279.4	20.3	259.1	0.3	36	0.1	0.4
Winter	317.5	12.7	304.8	0.3	36	0.1	0.4
Cantaloupes Spring	543.6	10.2	533.4	0.5	36	0.2	0.7
Fall	388.6	7.6	381.0	0.4	36	0.2	0.6
Asparagus	1640.6	40.6	1600.0	1.6	21	0.3	1.9
Citrus	1170.9	48.3	1122.6	1.1	43	0.5	1.6

*MacGillivray (1980).

1 millimetre = 0.03937 inches.
1 metre = 3.28 feet.

Est. ET = Estimated Evapotranspiration
Effec. Precip. = Effective Precipitation
ETAW = Evapotranspiration of Applied Water
LR = Leaching Requirement
C.U. = Consumptive Use

CONCLUSION

Satisfactory work has been undertaken in the derivation of crop water use (ET) data for Imperial Valley. Several researchers have been able to derive estimated ET values for a wide variety of crops grown in the Valley. But one striking characteristic of these values is the lack of uniformity among them. The variation among these estimates may be attributed to the following causes: (1) different interpretations of the Blaney-Criddle equation and the other empirical methods used to compute ET estimates, (2) possible inconsistencies in the climatic data used in the computations (due to a lack of standards in meteorological data collection), and (3) the apparent lack of sound historic, field tested ET data.

Kaddah and Rhoades, in agreement with Ehlig and MacGillivray, feel that reliable ET values have been derived and field tested for the following crops: alfalfa, barley, cotton, grain sorghum, sugar beets, and wheat.

Table 5 was compiled to provide an estimate on what the growing season water requirement should be for the major crops grown in Imperial Valley. ET and ETAW values were derived by MacGillivray (1980) and the leaching requirement percentages were obtained from the ten-year IID report. Table 6 shows what the theoritical crop water demand (for major crops only) should have been in 1979. One should realize that these values are only estimates and that actual crop water demands may differ.

Special attention should be paid to the Imperial Irrigation District-U. S. Department of Agriculture study being conducted in Imperial Valley. Crop applied water use data and on-farm efficiencies for several truck and field crops are being gathered in the study. These data will be beneficial in computing total agricultural water demands for the area.

TABLE 6
ESTIMATED CROP WATER REQUIREMENTS
FOR IMPERIAL VALLEY, 1979

	Crop	Acreage Hectares	Acreage (Acres)	ETAW Metres	ETAW (feet)	Annual Water Requirement in Cubic Dekametres	Annual Water Requirement in (acre-feet)
Pasture and Field	Alfalfa	77 316	(190,971)	2.02	(6.63)	1 561 781	(1,266,138)
	Pasture	3 236	(7,993)	2.01	(6.59)	52 674	(64,973)
	Wheat	40 466	(99,952)	0.62	(2.03)	250 280	(202,902)
	Barley	1 659	(4,098)	0.57	(1.87)	7 663	(9,452)
	Sugar Beets	19 346	(47,784)	1.15	(3.77)	222 210	(180,146)
	Grain Sorghum	3,440	(8,497)	0.73	(2.39)	25 050	(20,308)
	Forage Sorghum	206	(510)	1.08	(3.54)	2 226	(1,805)
	Cotton	33 505	(82,757)	1.02	(3.35)	341 971	(277,236)
	Corn	251	(620)	0.52	(1.71)	1 308	(1,060)
Truck	Broccoli	1 134	(2,800)	0.28	(0.92)	3 178	(2,576)
	Cabbage	321	(792)	0.41	(1.35)	1 319	(1,069)
	Onions	3 819	(9,419)	0.63	(2.07)	24 050	(19,497)
	Carrots	3 747	(9,256)	0.44	(1.44)	16 440	(13,328)
	Lettuce	17 704	(43,729)	0.28	(0.92)	49 625	(40,231)
	Tomatoes	1 302	(3,215)	0.73	(2.39)	9 478	(7,684)
	Squash	463	(1,143)	0.28	(0.92)	1 298	(1,052)
	Cantaloupes	4 221	(10,427)	0.46	(1.51)	19 421	(15,745)
	Asparagus	1 406	(3,473)	1.60	(5.25)	22 490	(18,233)
	Citrus	690	(1,705)	1.12	(3.67)	2 356	(1,910)
	Total	214 226	(529,141)			2 628 906	(2,131,257)

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ESTIMATED CROP EVAPOTRANSPIRATION IN THE IMPERIAL VALLEY, CALIFORNIA

By

Introduction

This report presents estimated monthly and growing season total evapotranspiration (ET) rates for 19 crops grown in the Imperial Valley. For each of three recent years, the aggregated acreage for those 19 crops represented over 90 percent of the total crop acreage within the Valley.[1/]

A method for estimating effective precipitation is suggested and effective precipitation for the "average" rainfall year was calculated. Methods used for estimating crop ET and effective precipitation are described below.

Locally Measured Crop ET

Over the last ten years, Carl F. Ehlig, Robert D. LeMert, Burl D. Meeks, and their colleagues at the U. S. Department of Agriculture (USDA), Imperial Valley Conservation Research Center (CRC), have determined ET rates for several important crops grown in the Valley. Reliable ET measurements have been made for alfalfa hay, barley, cotton, sugar beets, and wheat.

The measured monthly ET rates were used for these crops. Slight adjustments were made to account for differences between actual growing season of the measured crop and the growing season assumed to characterize current prevalent cultural practices.

Leonard Erie and his associates in the USDA Agricultural Research Service have published semimonthly ET values for a number of crops measured in southwestern Arizona (11).[2/] Observed ET rates for crops measured in both the Imperial Valley and southwestern Arizona are in reasonable agreement. Thus ET rates for other crops measured in Arizona should also be reasonable values for the Imperial Valley.

Estimated Crop ET

There were no ET measurements made in the southeastern California desert area for many crops grown in the Imperial Valley. Estimates of ET for these crops were made. Generally, regional estimates of crop water use made by the Department of Water Resources (DWR) are based upon measured evaporation from Class 'A' pans within the specific area and the relationship between measured crop ET and measured evaporation determined at ET field plot sites. As evaporation from pans is markedly influenced by the immediate pan environment, the validity of this method is dependent upon the evaporation pans within the region having the same surroundings as the pans at the ET field plot locations. The prescribed environment for the Class 'A' pan at a Department agroclimate station is a large well-managed irrigated pasture (6).

1/ Imperial Irrigation District, Annual Inventory of Areas Receiving Water. Years 1978, 1977, and 1976. I. Crop Survey.

2/ Numbers in parenthesis refer to publications listed in "References".

In the Imperial Valley, the paucity of evaporation data measured under the prescribed environmental conditions excluded the ET/evaporation method for estimating crop ET (7 and 15).

In 1975, the United Nations Food and Agriculture Organization published a paper that describes a method of estimating crop ET from measured (or estimated) ET of a grass reference crop (9). The grass crop must have a smooth surface, be sufficiently large in size to minimize local advective effects, provide 100 percent ground cover, and be adequately supplied with soil moisture to prevent plant moisture stress. ET of grass meeting those criteria is defined as potential evapotranspiration (PET).

Potential ET was estimated for the Imperial Valley using six different methods. Four estimates were calculated using methods described in the United Nations publication and local climate records. One estimate was based upon ET of alfalfa measured in the Imperial Valley and one estimate was made using the Blaney-Criddle formula with crop coefficients determined from alfalfa ET measured in southwestern Arizona and adjusted for cutting and regrowth cycles.

Monthly estimates of PET calculated by each of the six methods were in reasonable agreement. Those estimates are listed in Table 1. Table 2 lists souces of climate data used in making PET estimates by the four methods described in the United Nations publication.

Crop ET was estimated from average monthly PET and coefficients (Kc) relating crop ET to PET. The crop Kc's were obtained from the United Nations publication.

Local growing seasons for field and truck crops were obtained from a bulletin published by the Imperial Irrigation District in cooperation with the University of California Cooperative Extension and from a University of California publication (13 and 14).

Crop growing seasons used are shown in Table 3. Table 3 also shows the estimated total growing season ET for the 19 selected crops. Estimated monthly ET for nine field crops is presented in Table 4. Table 5 lists estimated monthly ET for nine truck crops. Table 6 presents estimated monthly ET for citrus -- the major tree crop in the Imperial Valley.

Effective Precipitation

A casual examination of precipitation records for five locations in the Imperial Valley (see Table 2) indicates that rainfall there is both sparse in amount and unpredictable as to time of occurrence. The long-term average annual precipitation is only 2.27 inches.

Except for delays in irrigations following the infrequent occurrence of heavy rains (1 inch or more), growers most probably disregard rainfall when scheduling irrigations. However, 2.3 inches of precipitation over the approximately 480,000 cropped acres in the Valley amount to about 90,000 acre-feet of water -- an amount too large to ignore.

Estimates of effective precipitation for an "average" rainfall year are shown for each crop in Table 3. The rationale used for estimating effecting precipitation is described in the following paragraph.

TABLE 1

NORMAL POTENTIAL EVAPOTRANSPIRATION[1/]
IN THE IMPERIAL VALLEY
AS ESTIMATED BY VARIOUS METHODS
(inches per month)

Month	Calculation Method							
	Modified Blaney-Criddle[2/]	Radiation[2/]	Modified Penman[2/]	Adjusted Evaporation[2/]	Bulletin 113-3[3/]	Blaney-Criddle[4/]	Average[5/]	Average[6/]
January	2.4	2.3	2.4	2.5	2.7	2.9	2.6	2.6
February	3.0	3.0	3.2	3.5	3.6	3.8	3.4	3.4
March	5.4	6.2	5.4	5.8	5.9	5.9	5.9	5.8
April	8.0	8.9	6.9	6.6	7.6	7.4	7.7	7.6
May	10.5	10.8	9.0	8.5	10.1	9.9	9.9	9.8
June	12.3	11.7	9.8	10.6	11.4	11.5	11.4	11.3
July	11.0	9.8	9.6	9.8	11.6	12.0	10.8	10.9
August	9.9	9.0	8.9	9.2	9.6	10.6	9.7	9.7
September	8.1	7.2	7.0	7.9	8.5	8.1	7.9	7.9
October	4.7	4.8	4.8	6.0	6.3	5.9	5.5	5.6
November	3.0	3.1	3.0	3.7	3.5	3.5	3.4	3.4
December	2.1	2.1	2.1	2.6	2.0	2.5	2.3	2.2
Total	80.4	78.9	78.2	76.7	82.8	84.0	80.5	80.2

1/ Potential evapotranspiration (PET) = ET of large expanse of low-growing clipped grass at 100-percent cover with no moisture stress.
2/ From method described in U.N. - F.A.O. No. 24 (9).
3/ From Table 6, DWR Bulletin 113-3. Estimate of ET grass based upon measured ET alfalfa (6).
4/ Based upon monthly Blaney-Criddle "K's" for alfalfa determined in Arizona and average monthly Blaney-Criddle "f" values calculated for Imperial Valley (1).
5/ Average of PET calculated by the six methods shown.
6/ Estimated PET from smoothed curve of calculated monthly PET.

TABLE 2

CLIMATOLOGICAL DATA USED FOR ESTIMATING
POTENTIAL EVAPOTRANSPIRATION IN THE IMPERIAL VALLEY

Station	Air Temperatures	Wind Movement	Humidity	Solar Radiation	Evapo-ration	Precipi-tation
Brawley 2SW	1/	2/	2/	5/	2/	8/
Calexico	-	-	-	-	-	8/
El Centro 2SSW	1/	-	-	-	-	8/
El Centro 7NW	-	-	-	6/	-	-
Imperial	1/	3/	4/	-	7/	8/
Niland	-	-	-	-	-	8/

1/ Average monthly maximum/minimum air temperatures; January 1970 - December 1978. From U. S. National Weather Service, "Climatological Data - California" (16).
2/ Unpublished field records from USDA Imperial Valley Conservation Research Center, January 1977 - April 1980.
3/ Unpublished field records from Imperial Irrigation District, March 1975 - April 1980.
4/ Unpublished field records from Imperial Irrigation District, January 1970 - May 1980.
5/ From Table 3, DWR Bulletin 187, "California Sunshine, Solar Radiation Data", for period January 1962 - December 1971 (8).
6/ From Table 3, DWR Bulletin 187, "California Sunshine, Solar Radiation Data", for period January 1963 to December 1977 (8).
7/ Unpublished field records from Imperial Irrigation District, August 1974 - April 1980.
8/ Monthly average for period 1941 - 1970. From U. S. National Weather Service, "Climatological Data, California" (16).

TABLE 3

SUMMARY OF GROWING SEASON EVAPOTRANSPIRATION
AND EFFECTIVE PRECIPITATION FOR MAJOR CROPS
IN THE IMPERIAL VALLEY

Crop	Assumed Growing Season	Growing Season ET (inches)	Estimated Effective Precipitation (inches)1/
Field Crops			
Alfalfa hay	1/1 - 12/31	80.6	1.0
Barley	12/15 - 5/31	23.4	0.8
Cotton	4/1 - 11/30	40.9	0.8
Forage sorghum	4/1 - 8/31	31.9	0.3
Forage sorghum	4/1 - 11/30	54.0	0.8
Grain sorghum	3/1 - 8/15	28.1	0.4
Grain sorghum	6/1 - 10/15	30.5	0.6
Onions	11/1 - 5/15	25.8	1.1
Sugar beets	7/1 - 4/30	48.0	2.0
Sugar beets	10/1 - 7/15	45.9	1.5
Tomatoes (canning)	2/1 - 6/30	35.2	0.3
Wheat	12/15 - 5/31	25.1	0.8
Truck Crops			
Asparagus	1/1 - 12/31	64.6	1.6
Broccoli	9/15 - 1/31	12.3	1.1
Cabbage	9/15 - 2/15	17.4	1.2
Cantaloupes	2/1 - 5/31	21.4	0.4
Cantaloupes	8/15 - 11/15	15.3	0.3
Carrots	10/1 - 3/31	18.8	1.3
Corn (sweet)	2/1 - 5/15	20.6	0.3
Lettuce	9/15 - 12/15	11.1	0.6
Lettuce	11/1 - 3/15	12.6	1.1
Squash	9/15 - 12/31	11.0	0.8
Squash	12/15 - 3/31	12.5	0.5
Tomatoes (market)	1/1 - 5/15	22.8	0.6
Tree Crops			
Citrus	1/1 - 12/31	46.1	1.9

1/ Based upon long-term average precipitation.

TABLE 4

SUMMARY OF ESTIMATED MONTHLY ET FOR
MAJOR FIELD CROPS IN THE IMPERIAL VALLEY

Month	PET	Alfalfa hay	Cotton	Grain Sorghum		Forage Sorghum		Sugar Beets		Tomatoes, Canning	Barley	Wheat	Onions
				Spring	Summer	Single	Double	Fall Plant	Summer Plant				
	← - - - - Estimated ET - Inches[1/] - - - - →												
Jan	2.6	2.6						3.0	2.8		1.8	1.4	2.5
Feb	3.4	3.0						3.9	3.3	1.5	3.2	3.1	3.4
Mar	5.8	6.2		1.9				5.3	5.0	4.2	6.8	5.9	5.8
Apr	7.6	7.0	3.0	9.1		1.1	1.1	8.0	5.7	8.5	9.0	8.5	7.0
May	9.8	9.3	4.9	9.8		7.8	7.8	9.8		12.0	2.1	5.5	4.0
Jun	11.3	10.9	6.0	4.9	3.7	11.6	11.6	8.8		9.0			
Jul	10.9	12.2	7.8	2.4	13.1	7.7	7.7		3.7				
Aug	9.7	8.8	8.1		9.7	3.7	7.4		6.8				
Sep	7.9	9.2	6.9		3.4		11.1		7.9				
Oct	5.6	5.8	2.9		0.6		5.1	1.9	6.4				
Nov	3.4	3.7	1.3				2.2	2.4	3.9				1.4
Dec	2.2	1.9						2.8	2.5		0.5	0.7	1.7
Growing Season Total	80.2	80.6	40.9	28.1	30.5	31.9	54.0	45.9	48.0	35.2	23.4	25.1	25.8

1/ ET for maximum crop yield

TABLE 5

SUMMARY OF ESTIMATED MONTHLY ET FOR
MAJOR TRUCK CROPS IN THE IMPERIAL VALLEY

Month	PET	Asparagus	Broccoli	Cabbage	Cantaloupes		Carrots	Corn, Sweet	Lettuce		Squash		Tomatoes, Market
					Spring	Summer			Fall	Winter	Fall	Winter	
		← - - - - - -	- - - - - -	- - - - - -	Estimated ET - Inches[1/]			- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - →
Jan	2.6	.8	2.5	2.6			2.8			2.5		2.0	1.7
Feb	3.4	1.0		3.2	1.5		3.6	1.7		3.5		3.0	2.9
Mar	5.8	2.0			3.5		5.6	5.3		2.8		5.3	6.4
Apr	7.6	5.0			7.1			8.4				1.4	8.1
May	9.8	9.0			9.3			5.2					3.7
Jun	11.3	10.7											
Jul	10.9	10.3											
Aug	9.7	9.2				2.7							
Sep	7.9	7.5	1.6	2.3		5.7			2.3		2.3		
Oct	5.6	5.3	2.9	3.9		5.4	2.5		4.3		3.8		
Nov	3.4	3.0	3.1	3.2		1.5	2.1		3.4	2.0	3.0		
Dec	2.2	0.8	2.5	2.2	___	___	2.2	___	1.1	1.8	1.9	0.8	___
Growing Season Total	80.2	64.6	12.3	17.4	21.4	15.3	18.8	20.6	11.1	12.6	11.0	12.5	22.8

1/ ET for maximum crop yield

TABLE 6

ESTIMATED MONTHLY EVAPOTRANSPIRATION OF
IN THE IMPERIAL VALLEY

Month	PET	Estimated ET, Citrus Inches 1/
January	2.6	1.3
February	3.4	1.7
March	5.8	3.2
April	7.6	4.2
May	9.8	5.4
June	11.3	6.8
July	10.9	6.5
August	9.7	5.8
September	7.9	4.7
October	5.6	3.4
November	3.4	1.9
December	2.2	1.2
Totals	80.2	46.1

1/ ET for maximum crop yield

Rains occur throughout the year, falling upon both fallow and cropped lands. Rain falling on fallow land is evaporated from the soil surface and does not contribute to meeting crop ET demands, thus none of that precipitation is effective. Rain falling on vigorously growing crops at full ground cover is assumed to be 100 percent effective; that is, all of the rainfall contributes to meeting crop ET demand. Some portion of precipitation occurring after crops have been planted, but before they reach maximum vegetative cover, is effective. For this study, 50 percent of the total precipitation falling on crops at less than full cover was considered to be effective. While crop ET in the Imperial Valley probably does not vary greatly between years, precipitation can vary by fairly large amounts from year to year. Effective precipitation should be calculated for each specific year studied.

Both crop ET and effective precipitation are needed to calculate crop irrigation requirements. Estimates of leaching requirements and irrigation application efficiencies are also required. These last two items have not been included in this report.

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Blaney-Criddle Equation

Blaney and Criddle developed an equation in 1950 that would enable one to empirically derive the estimated water consumption of a crop over a certain period of time. The equation consists of the following components:

$$ET = k(p \quad T/100), \text{ where}$$

ET - evapotranspiration in inches,
k - crop coefficient,
T - temperature in ^{o}F, and
p - percentage of total annual daylight hours.

Modifications have been made on the equation since 1950. One of the main criticisms of the equation was that it did not allow for variations in climatic conditions in an area where a particular crop was grown. Doorenbos and Pruitt (1977) presented a modified version of this equation which have the following components:

$$ET = c(p(o.46T + 8)), \text{ where}$$

ET - evapotranspiration in mm/day,
c - adjustment factor which depends on minimum relative humidity, sunshine hours, and daytime wind estimates,
T - mean daily temperature in ^{o}C, and
p - mean daily percentage of total annual daytime hours.