State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Southern District
Planning Branch

PRELIMINARY EVALUATION OF EVAPOTRANSPIRATION IN THE IMPERIAL VALLEY

-by-

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This Technical Information Record (TIR) was prepared to document pertinent information regarding evapotranspiration in the Imperial Valley. The findings in this TIR have not been fully reconciled with all the technical aspects of water use in the Imperial Valley. Hence, the contents of this TIR sould be considered to be preliminary and subject to revision

August 1983

Introduction

On February 4, 1981, the Department of Water Resources (DWR) and the U. S. Bureau of Reclamation (USBR) entered into a "Memorandum of Understanding for Water Conservation Opportunities Study, Imperial Irrigation District". The purpose of the Memorandum is to avoid duplication of work and overlap as much as possible. Consequently, DWR and USBR have met informally several times and exchanged information and data. Attachment 1 describes data exchange and coordination that took place through June 1982.

On October 5, 1982, David Overvold, Study Team Leader for the USBR Water Conservation Opportunities Study, met in Los Angeles with staff from the Southern District of DWR and the Colorado River Board of California. (Michael Stover is currently Study Team Leader.) The purpose of the meeting was to review the preliminary results of the USBR study and coordinate the 1982-83 program of DWR with that of USBR. During the meeting, it became clear that data collected by USBR and others should be reviewed to determine if crop evapotranspiration (ET) estimates could be improved. As a result of that meeting, DWR has investigated new data collected by USBR and others relating to crop ET in the Imperial Valley.

Purpose

The purpose of the investigation is to improve the understanding of the water budget for the Imperial Valley. This, in turn, could lead to more effective use of the water supply.

Scope

The scope of this investigation was limited to examining data that have been gathered and made available by USBR and others since 1980. Several recent reports for other areas of the Southwest were also reviewed. Because alfalfa is the single largest crop grown in the Imperial Valley, accounting for 30 percent of the irrigated acreage and about 50 percent of the crop water use, a concentrated effort was made to examine the ET of alfalfa.

Factors Influencing ET in Imperial Valley

ET is the quantity of water transpired by plants, retained in plant tissue, and evaporated from adjacent soil surfaces in a specific time period, usually expressed in depth of water per unit area. As used here, ET is synonymous with consumptive use. Thus, ET is the total amount of water a plant needs for normal growth. This water may be obtained from ground water, precipitation, or irrigation.

Understanding the relationship that crops have with key environmental factors is necessary for determining ET in a specific area. In the Imperial Valley these factors include:

1. Macro- and micro-climates (areal variations in temperature, wind velocity, relative humidity, solar radiation, and precipitation).

2. Availability to the crops of water from a shallow ground water table and seepage from delivery canals and ditches.

3. Characteristics of the soil (infiltration and water-holding capacities as modified through cultivation activities).

4. Salinity conditions of the soils (as determined by leaching practices).

5. Quality of the irrigation water.

6. Frequency of irrigations.

7. Efficiency of the irrigation and tile drainage systems.

In addition, when estimating the total annual ET, it is necessary to consider:

1. Type of crop.

2. Rotation of crops.

3. Double and triple cropping.

4. Land management practices.

5. ET from non-crop areas.

DWR Determination of ET in 1980

In 1980, DWR evaluated empirical ET in the Imperial Valley for use in the Elmore investigation.* This evaluation was done by Norman MacGillivray of the San Joaquin District and is documented in the Southern District Technical Information Record "Crop Water Requirements, Imperial Valley", which is referenced in Attachment 1.

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* "Investigation under California Water Code Section 275 of Use of Water by Imperial Irrigation District", Department of Water Resources, Southern District, December 1981.

MacGillivray derived ET values for 16 of the major vegetable, field, and forage crops. These values were developed using empirical equations (modified Blaney-Criddle, Penman, Jensen-Haise, and evaporation pan), tempered by local climatological and lysimeter tank experiment data. Whenever possible, additional modifications were made to account for the factors mentioned above.

The ET for alfalfa, the major crop in the Imperial Valley was estimated to be 80.6 inches. Calculating total ET for the Imperial Valley by use of empirically derived factors resulted in a demand of 1,815,585 acre-feet. However, when total ET was determined by use of a water budget analysis a total ET of 1,664,000 acre-feet resulted.

Determinations of ET Since 1980

USBR

In 1980, USBR commenced a reconnaisance-level "Water Conservation Opportunities Study, Imperial Valley". USBR utilized 111 water level recorders on irrigation canals and drainage ditches and three neutron probes to measure soil moisture. These instruments were not used to measure ET but to enable USBR to determine the efficiency of selected on-farm irrigation operations. The Imperial Irrigation District (IID) provided personnel and vehicles for most of the field work. The recorders measured applied water (AW), and surface runoff for alfalfa, asparagus, cotton, sugar beets, and wheat from September 1981 through December 1982. In addition two neutron probe access tubes were used per field and moisture content measurements were made at one-foot intervals to a three-foot depth.

According to Overvold, these data were not used to estimate the ET for the USBR report, but the ET was estimated by the Blaney-Criddle equation as modified by coefficients developed in a U. S. Department of Agriculture (USDA) study in Arizona. The total ET for the Imperial Valley was calculated to be 1,797,000 acre-feet.

However, if the neutron probe data are used to estimate ET, the ET for alfalfa could be 46.0 inches and the ET for wheat 14.7 inches, which is much lower than any other determination. The implication is that part of the ET requirements are being satisfied by ground water. However, the following must be considered in an evaluation of the importance of ground water:

a. Quality of the ground water.

b. Field-by-field effectiveness of tile drains for maintaining the ground water level at 6 feet below the ground surface.

c. Significance of water horizontally translocated from recently irrigated fields and seeps from delivery canals and ditches.

d. Actual rooting depth of crops (normal rooting depth for alfalfa and sugar beets is 5 feet but, according to Doug Welch of IID, there is a salt layer at 3 feet, which may prevent roots from penetrating past that point).

e. Pedologic characteristics of each field (dense soils may prevent roots from penetrating to the depth of the ground water table).

The significance of ground water in meeting the ET requirements of crops should not be discounted. Using lysimeter tanks, Tovey* demonstrated that virtually no difference existed in measured ET for alfalfa if grown without irrigation in a tank of fine-grained soil and a water level that was maintained at an 8-foot depth or irrigated when the available moisture was depleted to two-thirds of its original volume.

USBR conducted a neutron probe study (date unknown) in the Wellton-Mohawk region of Arizona to determine ET rates for alfalfa, wheat, and cotton. They estimated ET for the same crops in Imperial Valley by modifying the Wellton-Mohawk data. These were: alfalfa, 67.2 inches; cotton, 40.8 inches; and wheat, 27.6 inches.

USDA-Cooperative Extension Service, University of California-Riverside

From 1976 through 1982, under the direction of Lee Hermsmeier of the USDA field office at Brawley, an extensive data collection program was conducted. DWR assisted in the data collection; IID also was a cooperator. Some of these data were used by DWR in its 1980 determination of ET.

The investigation was designed to measure AW and determine a range of efficiency for irrigation in the Imperial Valley. Measurements were made for 10 different crops on about 400 fields for AW, surface runoff, and tile (subsurface) drainage.

Hermsmeier has left USDA; Jewell Meyer and James Oster, Cooperative Extension Service (CES), are now analyzing the data. Their analysis will be published sometime in the future. In a personal communication to MacGillivray, Meyer states that the average AW for alfalfa, from the USDA brawley data is 72 inches. Surface runoff from 182 fields and subsurface tile drain flows from 141 fields of alfalfa each averaged 15 percent of AW. Reduction of the 72 inches AW by 30 percent (surface runoff plus drain flow) provides an ET for alfalfa of 50.4 inches.

DWR Evaluation of Post-1980 Data

Data from USBR were not received until April and May 1983, so detailed analysis was not possible. In Attachment 2, Norman McGillivray presents his preliminary analysis of some of the recent USBR data. For alfalfa, based on selected USBR data, he finds that if AW=71.4 inches and surface runoff=6.2 inches, then ET plus deep percolation=65.2 inches. If his analysis is carried one step further and it is assumed that deep percolation is accurately represented by the USDA study and it is 15 percent of applied water, then the ET of alfalfa could be 54.5 inches.

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* Tovey, R. "Consumptive Use and Yield of Alfalfa Grown in Presence of Static Water Tables", Nevada Agriculture Experimental Station Technical Bulletin 232, 1963.

MacGillivray also reports on a recent study by Donovan and Meek that relates production per acre to ET. If production information from the Imperial Valley Agricultural Commissioner is used, ET of alfalfa is 65.0 inches. This corresponds to ET for alfalfa in the San Joaquin Valley and to information published in United Nations, F.A.O. Irrigation and Drainage Paper No. 33. With an ET of alfalfa of 65.0 inches, the total ET for the Imperial Valley is about 1,622,000 acre-feet.

Findings and Conclusions

1. Since 1980 there have been extensive data collection and analysis relative to determining ET values in the Imperial Valley (Tables 1 and 2).

2. The empirical ET estimated by DWR in 1980 is considerably higher than recent work indicates. Therefore, the 1980 DWR estimated empirical ET may be too high.

TABLE 1

Comparison of Estimated ET for Alfalfa for the Imperial Valley

Technique	ET (inches)
Empirical, 1980 DWR	80.6
Neutron Probe, Wellton-Mohawk	67.2
Production data, Donovan and Meek	65.0
AW and Runoff Measurements (USBR data)	54.5
AW, Runoff, Drainage Flow (USDA data)	50.4
Neutron Probe, (USBR data)	46.0

TABLE 2

Comparison of Total ET for the Imperial Valley

Investigator	Total ET (acre-feet)	Period of Analysis
DWR - 1980		
Empirical Analysis	1,815,585	1977-79
Water Budget	1,664,000	1975-79
USBR (from Overvold meeting 10/5/82)	1,797,000	1977-80
DWR - 1983		
(Preliminary estimate based on Donovan-Meek method)	1,622,000	1977-79

Recommendations

On the Basis of these findings and conclusions, it is recommended that:

1. DWR continue to coordinate and work with USBR, USDA, CES, and others in determining crop ET in the Imperial Valley.

2. Crop ET values be reevaluated and revised as necessary and incorporated in the Bulletin 113 series, "Vegetative Water Use in California".

ATTACHMENT 2

Memorandum

To : John Tenero, Chief
Land and Water Conservation Unit
Southern District

Date : July 7, 1983

File No.:

Subject: Crop Evapotranspiration
Imperial Valley

From : Norman A. MacGillivray
Water Utilization Section
San Joaquin District
Department of Water Resources

This is in response to your request for an evaluation of recent agricultural water use data for the Imperial Valley.

This evaluation is an attempt to resolve differences between my recent (1980) estimate of total crop evapotranspiration (ET) for the Valley of 1,814,000 acre-feet per year and the total of 1,664,000 acre-feet per year ET determined by a hydrologic balance (inflow-outflow for cropped land). Both of these estimates were prepared for the Southern District's "Elmore Investigation". My estimate was for crop ET only and should be increased to include ET from miscellaneous sources (fallow fields, weeds, water surfaces, etc.) for a more valid comparison to the results attained by the inflow-outflow method. Increasing the ET estimate by, say, 5 percent makes the discrepancy even wider.

The evaluation indicates that a downward adjustment of as much as 1 acre-foot per acre for unit ET of alfalfa would be reasonable. Alfalfa is the largest single crop in the Valley with about 145,000 acres now planted. Even with such a large change in the unit ET of alfalfa, the estimated total ET still would not agree with the inflow-outflow estimate.

My evaluations of two recent field studies are discussed below.

These are (1) an ongoing cooperative study by the Imperial Irrigation District (IID) and the U. S. Bureau of Reclamation (USBR) and (2) a field study conducted by the U. S. Department of Agriculture's Agricultural Research Service (ARS). Data for the latter study are currently being analyzed by University of California Cooperative Extension (UCCE). These data were obtained from the study leaders and furnished to me by David Inouye of your staff. Both studies are similar in that amounts of irrigation water applied to selected fields were measured as were amounts of surface runoff, and for UCCE-ARS drain tile effluent was measured. In addition to evaluating data from the two studies, I reviewed a technical paper dealing with the response of alfalfa to various irrigation amounts in the Imperial Valley. This paper, authored by Donovan and Meek, is published in the current issue of "Agronomy Journal" (Vol. 75, No. 3, May-June 83).

IID-USBR Study

The USBR is presently analyzing field data collected by IID. A report is scheduled for release this fall. Irrigation water applied to a large number of fields as well as tail water runoff from these fields was measured. Soil moisture content was measured frequently. Deep percolation losses were calculated.

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I worked with preliminary irrigation application and tail water data. Soil moisture data are not yet available.

I selected 20 alfalfa fields and calculated average application amount, tail water runoff, and crop ET plus deep percolation losses. Results are listed below.

	Inches Depth	Standard Error
Water applied	71.4	3.1
Surface runoff	6.2	0.8
ET and deep percolation	65.2	3.1

By comparison, I had used 79.6 inches for evapotranspiration of applied water (ETAW) for alfalfa based upon lysimeter measurements made at the ARS Brawley field station. Thus my estimated ET exceeded the field measurements of ET plus deep percolation by 14 inches.

ARS-UCCE Study

Lee Hermsmeier and Malak Kaddah, both formerly with the ARS, collected several years' data on amounts of water applied, tail water runoff, and drain tile effluent for a large number of fields. These are very competent researchers so the data should be highly reliable. Lee retired and Malak resigned from the ARS before they had a chance to summarize and analyze the data collected. Fortunately, recognizing the value of this study, Jewel Meyer and Jim Oster, both with UCCE, have undertaken that analysis. Two papers entitled "Field Studies of Surface Irrigation Efficiency in Imperial Valley" authored by Jim, Jewel, Lee, and Malak are in preparation and will be submitted for publication in "Hilgardia" (detailed report) and in "Agricultural Water Management" (summary of findings) in late summer of this year. This work will significantly increase understanding of Imperial Valley hydrology. Data were collected for ten different crops and a total of over 400 fields.

Jewel provided us with preliminary results. For alfalfa, the average amount of surface runoff from 182 fields was 15 percent of the water applied. Drain flow from 141 fields also amounted to 15 percent of the irrigation water applied. Total amount of water applied is not yet available, but 6 feet (from IID-USBR) is a reasonable estimate. Thus ETAW-alfalfa would be on the order of 50 inches per year. This is much less than my estimate of alfalfa ET.

Generally, in the Imperial Valley, perched water lies within 5 or 6 feet of the land surface. Alfalfa can extract water from perched waters to meet the climatically-controlled ET demand. For example, Tovey, working in Nevada, showed alfalfa ET from a nonirrigated lysimeter with fine-textured soil and with a water table maintained at depth of 8 feet was the same as that from a drained lysimeter irrigated when two-thirds of the available soil moisture was depleted.

There is still a question that the quality of the perched water in the Imperial Valley might limit its use by alfalfa. Also, the very fine-textured soils in the Valley may restrict crop rooting depth, thus not allowing the roots to extract the perched water.

Donovan-Meek Paper

Terry Donovan and Burl Meek, both with the ARS, have published a paper "Alfalfa Responses to Irrigation Treatment and Environment" in "Agronomy Journal", Vol. 75, No. 3, May-June 1983. Results of their good work, which was done at the ARS Brawley field station, are very significant to understanding the present problem.

They irrigated alfalfa with varying amounts of water and determined the resultant yields. The water application which gave maximum yield (10.6 tons per acre) was 83 inches. That amounted to 75 percent of pan evaporation. (This is in excellent agreement with our own work in the San Joaquin Valley. We found annual alfalfa ET to equal 75 percent of pan evaporation -- Table 5, Bulletin 113-3.)

They determined that yield (at 0.0 percent moisture) is linearly related to ET.

Yield = -3.73 tonnes per hectare + 0.120 centimetres x ET

Using this relationship and the average alfalfa yield for the Valley as reported by the Imperial County Agricultural Commissioner for the years 1981 and 1982 (8.6 tons per acre adjusted for an assumed hay moisture content of 10 percent), the corresponding ET would be about 65 inches. This is in good agreement with the IID-USBR results. Of course, management practices other than irrigation will also affect yield.

The alfalfa yield-ET relationship determined by Donovan and Meek in the Imperial Valley is in excellent agreement with that reported in United Nations, F.A.O., Irrigation and Drainage Paper No. 33, "Yield Response to Water".

The Donovan-Meek results suggest a downward revision of alfalfa ET is in order. However, we should await the soon-to-be-published ARS-UCCE data before making that change.

cc: Fred Stumpf
Dave Inouye
Ed Craddock
Glenn Sawyer