Role of Technology in Irrigation Advisory Services: The CIMIS Experience[1]

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Abstract

This paper provides the experience of the California Irrigation Management Information System, better known by the acronym CIMIS, as an irrigation advisory service and highlights its success as a tool in irrigation water management. The number of farmers using the system, type of data and irrigation information dissemination, water savings and yield increases achieved as a result of using the system, plans for the future, challenges and constraints, and relevance to other countries are discussed. [3]

Introduction

CIMIS is an integrated network of computerized automated weather stations located throughout the state of California. The system was developed in 1982 through a joint research and development project of the University of California at Davis and the California Department of Water Resources (CDWR). Its goals were to:

- Design a system which would use computerized weather data to estimate reference evapotranspiration.
- Disseminate up-to-date quality information to the public.
- Provide irrigation scheduling programs to CIMIS users.
- Determine crop coefficients.

The University of California completed the research and development phase of CIMIS in 1985 and accomplished the following:

- Established a network of 43 automated computerized weather stations.
- Developed a CIMIS data dissemination system accessible through a phone line and computer.
- Tested and developed crop coefficients.

Upon completion of this phase, the program was implemented by CDWR. Since 1985, the number of stations has tripled, and the number of registered users (persons who have user identification codes and passwords to access the CIMIS computer) has grown by about 20 percent per year on average. As of April 2002, there are 118 active stations in addition to 61 stations that have been discontinued. Historical data for the discontinued stations are available. (*2013, ~145 active stations*)

CIMIS is one of the largest standardized automated weather station network used for irrigation in the United States. CIMIS weather stations are equipped with data loggers that collect hourly weather data throughout the day. At midnight, a microcomputer in the main CDWR building in Sacramento automatically begins the interrogation of stations by telephone. The microcomputer makes a connection with each weather station data logger, downloads data, and transfers the data to the main CIMIS computer. The CIMIS computer then performs three tasks: (1) calculates ETo at each site, (2) checks all weather data for accuracy (quality control), and (3) stores weather and ETo data in a database to provide on-demand localized information. Two equations are currently used to estimate ETo, the modified version of the Penman equation (Pruitt and Doorenbos, 1977) and the standardized Penman-Monteith equation (Walter et al., 2000)

The primary function of CIMIS is to disseminate reference evapotranspiration (ETo) data to water agencies, farmers, farm advisors, and irrigation specialists who use the data for irrigation scheduling and water management. Data is either disseminated directly through the CIMIS website at www.cimis.water.ca.gov or indirectly through secondary channels. A user identification code, obtainable on-line free of charge, is required to access the database. Non-registered users have access to a limited amount of data.

Number of users

As of April 2002, the number of registered users is 4,700. The number of direct users is much likely higher because some people use others' IDs and passwords to access the CIMIS computer. Since the system is unable to detect when several people use one ID, the number of direct users cannot be determined precisely. (*2013, ~45,000 registered users*)

Twenty six percent (1,220 users) of the registered CIMIS users identify themselves as farmers. While this represents the potential number of farmers who access data directly, other farmers receive services from agricultural consultants who make up 10 percent of the registered users. In addition to these consultants, a list of 50 consultants who offer irrigation scheduling services is available on the CIMIS website. In a recent survey of 10 consultants to find out the extent that they used CIMIS in their services, it was found that they used CIMIS data to provide services to 411 customers. By extrapolation, the number of farmers receiving CIMIS related irrigation advisory service is estimated to be over 15,000. Farmers fall into a broad category that includes a range of operations from large agricultural operations and corporate farms to specialty farmers who grow small, intensive truck crops.

Types of data and information provided through CIMIS

Although the primary function of CIMIS is to encourage ET-based irrigation scheduling by disseminating ETo data, CIMIS also provides information related to irrigation in particular and agricultural practices in general. For example, CIMIS air temperature data is used to calculate chill hours by the fruit and nut industry, and degree-days by pest control experts.

The following are some of the weather data provided on the CIMIS database: air temperature, wind speed, wind direction, solar radiation, relative humidity, vapor pressure, and rainfall. Users can obtain hourly, daily, monthly, and historical data over an extended period of time. ETo values, also reported on hourly, daily and monthly time steps, are calculated using a version of the Penman equation modified by Pruitt and Doorenbos (1977) as well as the Penman-Monteith equation (Walter et al., 2000). CIMIS operates 24 hours a day, every day of the year, except during maintenance hours when the data access is not available. Data collection, however, continues even during maintenance.

Data are provided in the following three formats: (1) standard report, (2) report by sensor, and (3) non-report format. The standard report provides pre-determined data for the stations and date range selected. The report by sensor is similar to the standard report except that one can select any or all 32 weather variables. An example of the report by sensor for CIMS station 6, Davis is shown in Table 1 below. Note that at the end of the data table, quality control flag descriptions are included. The non-report format generates a comma-separated text file (CSV format) based on the stations, sensor/parameters, and date range selected by the users. The non-report format data can be downloaded directly into a spreadsheet such as Excel. Users can also select data output in PDF format for better printing quality and can download data in XML format. XML provides extremely flexible post-download processing, including incorporating data into databases. (*2013, CIMIS data available as Limited, Unlimited, Spatial, and FTP reports, with formats including Web Report, CSV, XML, and PDF*)

Table 1. CIMIS daily standard report

CIMIS (California Irrigation Management Information System)

Daily Report
Rendered in METRIC Units.
June 23, 2002 - June 29, 2002
Printed on June 30, 2002

Davis - Sacramento Valley - Station 6

Date	Sol Rad (W.sq.m)	Max Air Temp (°C)	Min AirTemp (°C)	Avg Air Temp (°C)	Avg Wind Spd (m/s)	Max Rel Hum (%)	Min Rel Hum (%)	PM ETo (mm)
06/23/2002	307	30.1	11.2	20.3	2.2	88	36	5.97
06/24/2002	310	34.2	11.3	22.0	1.9	91	20	6.07
06/25/2002	309	34.6	12.3	23.6	2.1	86	21	6.92
06/26/2002	300	29.8	12.3	20.3	3.1	86	42	6.07
06/27/2002	305	32.5	11.6	21.2	2.6	90	36	6.10
06/28/2002	300	29.9	13.5	21.2	2.9	85	39	6.03
06/29/2002	305	33.4	14.0	23.8	2.1	84	31	6.48
Total/Avg	305	32.1	12.4	21.8	2.4	87	32	43.64

Flag Legend		
A - Historical Average	I – Ignore	R - Far out of normal range
C or N - Not Collected	M – Missing Data	S - Not in service
H - Missing Hourly Data	Q – Related Sensor Missing	Y - Moderately out of range

CIMIS does not have an irrigation scheduling software; however, it provides a list of irrigation scheduling software on its website. The list includes software sold by various vendors and those that are provided free of charge by University of California Cooperative Extension. Also, CIMIS works closely with other agencies to provide irrigation schedule services.

Public agencies and consultants now provide irrigation scheduling programs on the World Wide Web. The California Avocado Commission has designed a CIMIS Water Requirement Calculator (www.avoinfo.com/growers/cimiscalculator.shtml) on its website, which allows avocado growers to calculate the amount of water needed by an avocado tree each day, and irrigation duration. To use the calculator, one must know a few facts about their crops, including the distribution uniformity (DU) of the irrigation system, trees per acre, tree spacing, sprinkler output, and the leaching requirement. If the distribution uniformity is not known, a default value of 85 percent is used. Monthly crop coefficients are provided on the site. The second website is called Wateright (www.wateright.org). It was developed by the Center for Irrigation Technology at California State University, Fresno. The site allows one to develop an irrigation-scheduling guide by answering a few field-specific questions about the irrigation system, soil type, crop, and nearby CIMIS station. Five-year historical CIMIS ETo data is used to develop an irrigation guide. Wateright compares the historically based irrigation guideline with current weather data and notes any run times that are significantly different than current weather conditions predict. A drop-down menu allows a site-specific adjustment of the initial run-time estimates for each field entered.

CIMIS also works with California State Universities, University of California, state agencies, federal agencies, local agencies, and other programs within the California Department of Water Resources to conduct irrigation scheduling workshops. Topics covered in recent workshops include a basic understanding of soil moisture relationships; determination of soil moisture depletion; irrigation scheduling; crop coefficients; determination of irrigation efficiency and irrigation system distribution uniformity; and regulated deficit irrigation.

CIMIS provides information on training classes, seminars, or workshops on different aspects of irrigation and water budget irrigation scheduling offered by many public and private agencies. The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo, and the Center for Irrigation Technology at California State University at Fresno are the two main institutions that offer this training on a regular basis.

A description of crop coefficients and how they work is provided on the CIMIS website, and there is a link to crop coefficient values recently developed by University of California Cooperative Extension. In addition, information on where to obtain hard copies of publications by University of California on crop coefficients is provided.

During the past 15 years, CIMIS, in cooperation with other agencies, has developed publications on CIMIS and irrigation such as the CIMIS Agricultural Resource Book. This book provides comprehensive information for the CIMIS program and includes information on how public and private agencies are using CIMIS. This information will reduce the research time for other agencies that might want to prepare water management plans or irrigation scheduling programs. CIMIS has developed, in collaboration with the Department of Land Air and Water Resources, University of California, Davis, a color ETo zone map for California with average monthly ETo values for each of the 18 zones. The purpose of the ETo map is to provide a means for an irrigation manager or farmer to plan an irrigation schedule based on historical weather data. This schedule can be developed before the irrigation season and can be used to estimate when irrigations will most likely be needed during the season. Educational workshops have been conducted on how the historical schedule can be updated during the irrigation season using current ETo information to reflect current conditions. The ETo zone map can be used by water agencies to plan water deliveries.

Mobile Irrigation Laboratories

ETo data disseminated by CIMIS helps irrigators develop water budgets to determine when to irrigate and how much water to apply. However, ETo data by itself is not sufficient for successful water budget irrigation scheduling. The success of ETo based water budget irrigation scheduling also hinges on the performance of an irrigation system. In particular, it depends on the uniformity with which water is applied across the field, the distribution uniformity, and by extension the efficiency of the irrigation system. The farmer or manager must therefore know the performance of the irrigation system. Mobile Irrigation Laboratories are services that evaluate the performance of irrigation systems. The laboratories measure water application rates and system distribution uniformity and give recommendations for irrigation system improvement if necessary. Farmers can still benefit from mobile irrigation laboratories even if they do not practice a water budget irrigation scheduling.

Mobile Laboratory services are provided by a variety of public and private agencies. Each Mobile Laboratory is managed by a team leader. One or more trained technicians assist the team leader. Several laboratories were established in the 1980's with support from CDWR. CDWR provided seed money to several local agencies that enabled them to establish the laboratories. Eight of the laboratories are still in operation and operate independent of CDWR, they are supported through a combination of contributions from local water agencies and grants. Financial support enables these public agency laboratories to provide services free of charge. Over the last few summers, additional laboratories operated by the ITRC conducted field evaluations in various areas of California. Also, there are a handful of laboratories operated by consultants.

For the most part, all Mobile Irrigation Laboratories use the evaluation methodology developed by the ITRC. Evaluation of pressurized systems involves checking the operation of pumps, filters, and emitters or sprinklers. On surface systems, furrow advance times are measured at several locations throughout the field. Before the actual field measurement, the mobile laboratory technician will generally ask the farmer some basic questions about the system. Usually it takes a few minutes to conduct the interview. Field evaluation itself takes anywhere from three to eight hours depending on the type and components of the irrigation system. Once the evaluation is completed, the technician enters the collected data into the ITRC software. The software generates a report that includes the distribution uniformity of the system and recommendations for improvement.

Many farmers who receive irrigation system evaluations are satisfied with the service. Here are a few quotes from Farmers whose systems were evaluated by the Pond-Shafter-Wasco Resource Conservation District Mobile Irrigation Laboratory:

1. "We have improved our linear system distribution from 67 percent to 85 percent. This is a direct result of recommendations form the Mobile Lab."
2. "After I made the recommended changes to my drip system, the Lab returned to do a follow-up evaluation. The results of the follow-up showed an 11 percent increase in uniformity."
3. "The Mobile Lab came out and tested one of our flood-irrigated vineyards. It was an eye opening experience to see how inefficient my irrigation practices were."

Data/information retrieval

Data access from the CIMIS computer has averaged about 50,000 annually in the last three years. With the launching of a new CIMIS website in late 2001, which has made data access more user-friendly than in the past, access to CIMIS data is expected to rise to 70,000 annually. This number represents only direct access by registered users. It does not include potential dissemination of CIMIS information by these users to others. It is difficult to determine the number of people who use CIMIS information received through other computer databases, newspapers, public and private agency newsletters, and radio stations.

Some users prefer to download data automatically every morning through special computer scripts. To meet their needs, CIMIS has an FTP site where hourly and daily data for all stations for the past seven days are automatically deposited each night.

A survey of 17 agencies indicated that the monthly number of calls to telephone recording systems varied widely. Five of the agencies had records of the number of calls to their systems while others only had estimates. The average number of calls to the five telephone recording systems was 680 calls per month or 8,160 a year. The potential number of calls to all 19 telephone-recording systems is 31,000 per year. (*2013, Note - telephone data retrieval has been superceded by computer access*)

Other dissemination points

In addition to data and information provided directly through CIMIS, various groups and organizations disseminate the information they obtain from the CIMIS computer. They include consultants, newspapers, telephone recording, radio stations, and other World Wide Web pages. Telephone recording is a service provided by many water and irrigation districts. They access the CIMIS computer, retrieve ETo data, record it, and provide a daily telephone recording of the data for access by their water users. Some of these agencies also calculate specific crop water use, then record and provide it for public access. The exact number of people who receive information from some of these sources is impossible to calculate due to modes of dissemination. Table 2 lists five of these categories.

Table 2. Dissemination points

Media	Number

Consultants	470
Newspapers	15
Telephone Recordings	18
Radio Stations	13
Computer Databases	3

Benefits of CIMIS

To evaluate the impact of CIMIS on efficient water use and to determine the main reason why farmers were interested in the service, CIMIS contracted with the Department of Resource Economics at the University of California, Berkeley in 1996 to conduct a survey on the benefits from using CIMIS. The main reason for interest in CIMIS was benefits from applied water reduction and yield increases. For the 54,000 hectares of irrigated land that the survey represented, there was an average annual yield increase of 8 percent and an average applied water reduction of 13 percent. For the 55 farmers interviewed, reduction in applied water and the increase in yield amounted to an estimated annual benefit of $14.7 million. Table 3 shows the amount of money some of the 55 farmers saved as a result of using CIMIS. Only a few crops were selected from each of the fruit and nut, vegetable, and field crop categories.

Table 3. Water, Yield and Total Benefits to Farmers from CIMIS

Crop	Water+ $US	Yield++ $US	Total $US	Benefit/Hectare $US
Trees and Vines Sample				
Almonds	246,000	2,426,500	2,672,500	408
Apples	900	13,900	14,800	366
Avocados	-141,350*	738,000	596,500	760
Grapes	100,850	1,336,500	1,437,3500	730
Pistachios	370,150	6,755,000	7,125,000	630
Plums	556	12,445	13,000	402
Vegetable Sample				
Artichoke	2,500	326,200	328,700	160
Broccoli	2,750	106,100	108,850	730
Cauliflower	5,750	334,100	339,850	870
Celery	3,350	345,750	349,100	1700
Lettuce	26,000	1,361,000	1,387,000	920
Field Crop Sample				
Alfalfa	47,790	325,700	373,500	100
Cotton	345,300	810,500	1,155,800	110

+Money saved due to reduced water bill resulting from using CIMIS.
++Increased income from increased yield resulting from using CIMIS.
*Negative number indicates increased water use with CIMIS.

Another reason for adopting CIMIS is that it allows for automation, that is, computerized irrigation scheduling. Automation in irrigation scheduling, however, is most applicable to pressured irrigation systems where water flow can be measured precisely.

Challenges and constraints

CIMIS faces some challenges and constraints. These include finding ideal weather station sites to meet the increasing demand for ETo data, securing adequate financial and human resources, and overcoming some farmers' distrust or reluctance to adapt high technology.

A CIMIS weather station's location should represent the largest possible surrounding area. Buildings or trees close to a weather station can affect wind speed data, which in turn affects the estimated ETo. The absence of healthy green grass around a weather station affects humidity, which will adversely affect ETo. Bare soil instead of cropped grass around the station can increase advective energy, resulting in increased temperatures and decreased humidity, which in turn increase the ETo value. It is often difficult to find a suitable site or ideal site. CIMIS is planning to conduct a California-wide study to investigate the possibility of installing stations in “non-ideal” sites and correlating data from such sites with data from ideal sites to come up with ETo data, at the non-ideal, that are representative of the region.

As the number of CIMIS stations increase, the demand on existing staff time will increase as well. It will become increasingly challenging to keep a regular station maintenance schedule. Since most new stations will be purchased by local agencies, the agencies will be responsible for maintaining the stations. To maintain a high quality of data, however, close oversight will still be needed. Unfortunately, it is unlikely that the number of staff working on the program will be increased. As new stations are added to the network, the cost of data collection, analysis, storage and dissemination will increase as well.

The number of farmers using CIMIS information directly still represents a relatively small percentage of farmers in California. However the number of farmers receiving CIMIS information is high. Many water agencies provide CIMIS information to farmers in their service area. Much more effort, though, is needed to increase the number of farmers using the information and to alleviate the distrust that some of them may have toward weather-based irrigation scheduling. Ideally, setting-up demonstration farms where farmers can observe the application of the technology would be one way of convincing them, but that requires financial resources.

Due to financial constraints, television, radio, and print advertisement have not been used by CIMIS. Also, television has not been used extensively for outreach activities largely because it is cost prohibitive. This is unlikely to change in the near future.

Future plans

To continue providing farmers with accurate and timely information, CIMIS will need to keep up with the pace of new hardware and software, and emerging technology. Future plans include development of a methodology for short-term ETo forecasting; integration of wireless technology into CIMIS; real or near real time data dissemination; integration of remote sensing, such as Geosynchronous Operational Environmental Satellite (GOES) data with CIMIS to improve spatial coverage; and development of a web-GIS data retrieval user interface. The number of stations will continue to grow in areas that do not currently have stations. (*2013, most of these plans have been realized.*)

Several emerging technologies are being evaluated by CIMIS for implementation in the future. One such technology is an ET irrigation control valve that is capable of sending a signal via satellite to query the previous day’s ETo value from the CIMIS database. This value is uploaded to the controller, which then calculates how much water should be applied to the crop based on the irrigation history of the particular field. The controller turns on an irrigation pump and turns it off when the water requirement of the field is met. Another technology is wireless telecommunication technology via a hand held PDA. A farmer using a hand held PDA with GPS transmits his location to a central computer which then relays back information specific to that location. This information, along with other necessary crop coefficients and irrigation system efficiency stored in the hand held device, provides the farmer information that can be used to accurately calculate and determine specific crop water requirement.

Relevance of the CIMIS experience to other countries

Weather-based irrigation scheduling is moving from the realm of irrigation research into operational and applied research in various aspects of agriculture. Improvements in weather sensor electronics have made stations very robust. Hence, stations can now be installed even in remote locations. CIMIS was one of the first networks designed exclusively for irrigation scheduling. Since CIMIS went into operation, several networks have been installed, some of which are modeled after CIMIS. CIMIS has provided technical assistance to many States in the United States and to many countries to help them set up evapotranspiration weather networks.

The CIMIS model, which is based on collaborative support by a central government and local agencies (60 percent of the weather stations on the network are owned by local agencies), would certainly be relevant to other countries provided the benefits derived from the system outweigh the cost. In 1996, the University of California, Berkley estimated the statewide benefit/cost ratio for CIMIS to be 28 to 1. Such a high benefit/cost ratio may not be realized in some countries because of low cost of water and price of agricultural produce. Another issue, especially in developing countries, is technology transfer. Small farmers would most likely need considerable hand-holding by agricultural extension agents or irrigation service providers. The technology can more easily benefit large farms that have had exposure to some level of technology. CIMIS can act as a good model for such farms. As any irrigation scheduling technique, weather-based irrigation scheduling should not be used exclusively by itself, rather it should be an integral part of a comprehensive irrigation management program.

Footnotes

[1]The views expressed in this paper are those of the authors and do not in any way reflect the official position of the California Department of Water Resources.

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[3]Minor updates in parenthesis and italics included in 2013 CIMIS website copy by Jared Birdsall (birdsall@water.ca.gov)

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