

AGRIMET: MODELING EVAPOTRANSPIRATION FOR IRRIGATION WATER MANAGEMENT

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ABSTRACT

In 1983, the U.S. Bureau of Reclamation and Bonneville Power Administration entered into a formal agreement to promote irrigation water use efficiency. This agreement resulted in the installation of a network of automated agricultural weather stations called “AgriMet” (for Agricultural Meteorology) in the Pacific Northwest. These stations collect and telemeter the meteorological parameters required to model crop evapotranspiration (ET). The information is used by irrigation districts, farmers, resource conservation agencies, and agricultural consultants for irrigation scheduling and related purposes. Since the initial installation of 3 stations in 1983, the network has grown to over 60 stations in Reclamation’s Pacific Northwest region, 21 stations in the Great Plains Region in Montana, and seven stations in the Mid Pacific region. These automated weather stations transmit their data by the GOES satellite, and the information is used in the Kimberly-Penman 1982 evapotranspiration model to compute reference ET at each station. Crop coefficients are then applied to estimate water use for specific crops grown at each station for every day of the growing season. This information is available on the Internet, and is integrated into various on-farm technical assistance programs by local agricultural consultants, the Cooperative Extension Service, and the USDA Natural Resources Conservation Service. Use of AgriMet information in irrigation scheduling results in water and energy savings, reduced soil erosion, and protection of surface and ground water supplies. Various agricultural consultants have reported water and power savings ranging from 15 to 50 percent (Dockter, 1996). Some irrigators have reported real savings of as much as \$25 per acre in pumping costs when using AgriMet ET data to schedule their irrigations (Palmer, 2004).

INTRODUCTION

Modeling evapotranspiration (ET) with weather data has evolved over the years with refinements in modeling procedures and data collection methods. Current technologies typically involve automated agricultural weather stations and data transfer by satellite, phone, radio, or wireless networking. Powerful computers now make fast work of the typically complex mathematical ET models, and the Internet makes the information almost instantly available to the users.

The U.S. Bureau of Reclamation entered the automated ET world in 1983, when it partnered with Bonneville Power Administration to promote irrigation water use efficiency. This partnership resulted in the installation of a network of automated agricultural weather stations called “AgriMet” (for Agricultural Meteorology) in the Pacific Northwest. These stations collect and telemeter the meteorological parameters required to model crop evapotranspiration (ET). Since the initial installation of three stations in 1983, the network has grown to over 60 stations in Reclamation’s Pacific Northwest region, 21 stations in the Great Plains Region in Montana, and seven stations in the Mid Pacific region (see map, Figure 1). Reclamation has established partnerships with more than 25 entities, including other federal and state agencies, soil and water conservation districts, universities, public utilities, and private enterprise to help fund the operation of the AgriMet network. The Northwest Energy Efficiency Alliance, a consortium of electric utilities in the Northwest, provides significant financial support for the AgriMet network.

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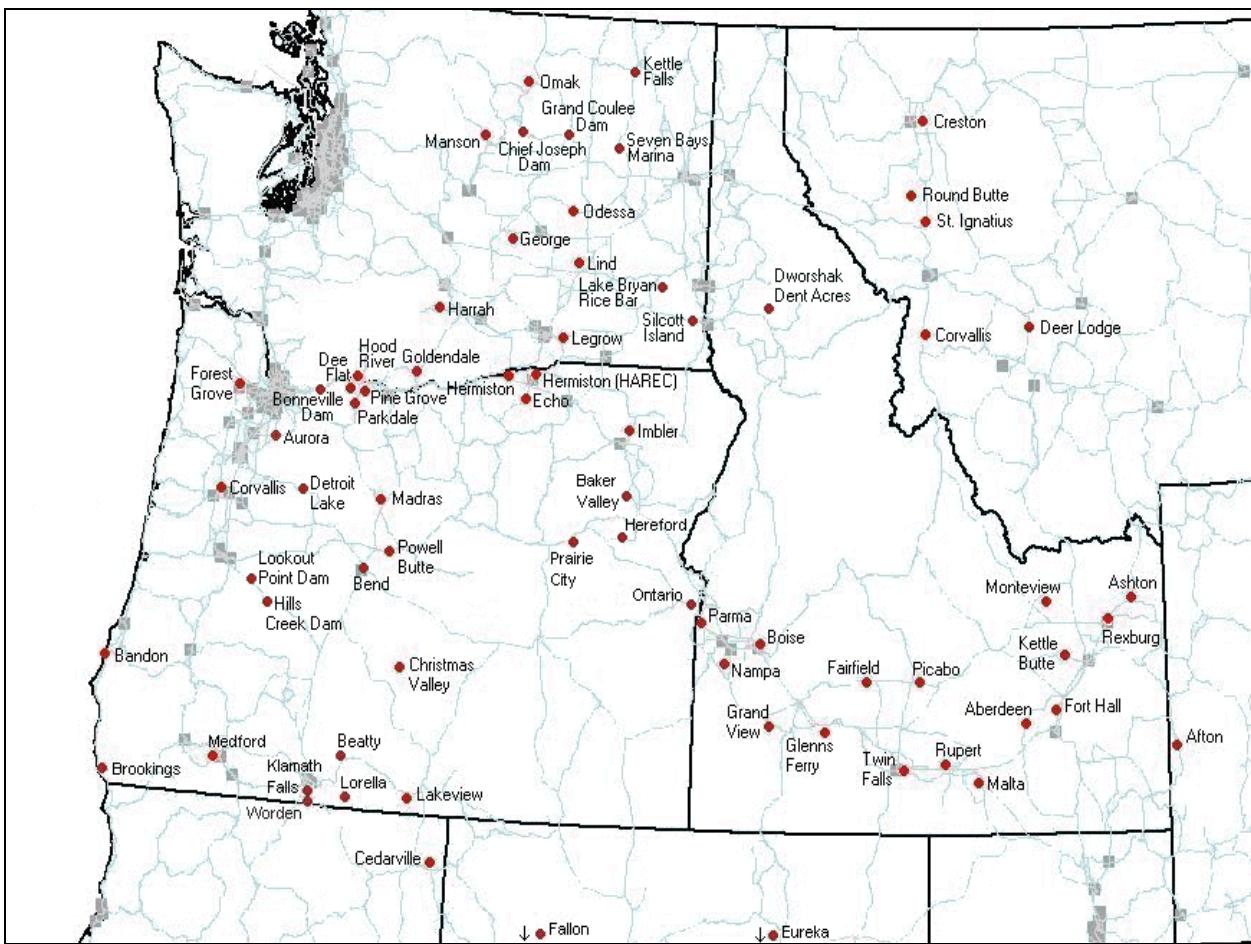


Figure 1: AgriMet Weather Station Locations: Pacific Northwest and Mid Pacific Regions

AGRIMET DATA COLLECTION AND TRANSMISSION

AgriMet stations are located in agricultural areas throughout Idaho, Montana, Oregon, and Washington, with additional stations located in northern California, western Wyoming, and Nevada. The stations are typically located on the edge of irrigated fields so that the data collected approximates the meteorological conditions affecting the cultivated crops in the area (Figure 2). Each AgriMet station is configured with a standard set of sensors, including air temperature, precipitation, solar radiation, wind speed and direction, and relative humidity. These standard sensors collect the meteorological parameters required for modeling crop ET. Some sites have special sensors, including soil temperature, diffuse pyranometers for special solar radiation studies, crop canopy temperature, leaf wetness, and evaporation pan sensors.

All components, including sensors, solar panel, antenna, data logger and transmitter are mounted on a sturdy aluminum tripod. Sensors are mounted at standard heights for agricultural weather data collection requirements. Power for the site is provided by a heavy duty lead acid storage battery that is recharged daily by a solar panel.

The data logger at the site monitors each of the sensors once every second. These readings are used to derive the final data parameters for subsequent transmission, such as 15 minute air temperature observations, total hourly precipitation, etc. These parameters are transmitted from the weather stations via the GOES satellite (Geostationary Operational Environmental Satellite) in a one-minute window every four hours according to a strict transmission



Figure 2: Typical AgriMet Weather Station

schedule. The telemetered information is down-linked at the Bureau of Reclamation's Pacific Northwest Regional Office in Boise, Idaho. The receive site also down links data for other Reclamation programs, as well as for other cooperating federal agencies. An effort is currently underway to upgrade all AgriMet stations from four hour transmissions to hourly transmissions, improving the timeliness and hence the usefulness of the weather data.

All AgriMet sites receive an annual inspection visit in the spring that includes calibration and maintenance of all sensors. Data logger and transmitter parameters are checked for conformance to specifications. System battery voltage, solar panel output, and voltage regulator output are checked; these items are replaced or adjusted as needed. All sensors are compared against laboratory calibrated standards and are adjusted or replaced as needed. This special attention given to the sites during these annual calibration and maintenance visits provides high quality meteorological data not only for crop water use modeling, but also for a variety of research and other weather related applications.

EVAPOTRANSPIRATION MODELING

AgriMet uses the 1982 Kimberly-Penman equation for computing reference ET, adapted by Dr. James L. Wright of the USDA Agricultural Research Service through his research performed in Kimberly, Idaho (Jensen et al., 1990). This procedure requires several meteorological inputs for modeling ET, including maximum and minimum daily air temperatures, relative humidity, solar radiation, and wind speed. All of these parameters are collected by the AgriMet system.

Because of the variability of ET rates from crop to crop and the complexity of modeling ET, the accepted standard for deriving crop specific ET (ET_c) is to model ET for a reference crop, such as alfalfa (ET_r), and then apply this reference ET_r value to specific crops by multiplying by a crop coefficient (K_c). These crop coefficients are unique to the reference crop and the individual specific crop, and they vary through time with the growth stage of the plant. These crop coefficients typically are expressed as percent of water use compared to the reference crop.

AgriMet publishes the results of this computation in a crop water use chart for each weather station, updated daily and available on the Internet (see Table 1).

Table 1. Daily AgriMet Crop Water Use Chart

ESTIMATED CROP WATER USE - JUL 6, 1998 Ashton, Idaho											
CROP	START DATE	DAILY CROP WATER USE- (IN)				DAILY FORECAST	COVER DATE	TERM DATE	SUM ET	7 DAY USE	14 DAY USE
		2	3	4	5						
ALFP	501	0.35	0.32	0.29	0.23	0.28	625	925	9.3	2.0	3.3
ALFM	501	0.30	0.27	0.25	0.20	0.24	625	925	8.4	1.8	2.9
PAST	420	0.24	0.22	0.20	0.16	0.19	610	925	8.1	1.4	2.3
LAWN	420	0.28	0.26	0.23	0.18	0.22	601	925	9.9	1.6	2.7
WGRN	415	0.35	0.32	0.29	0.23	0.28	625	815	12.1	2.0	3.3
SGRN	520	0.34	0.31	0.29	0.23	0.28	801	901	5.6	2.0	3.2
POTA	620	0.12	0.12	0.11	0.09	0.11	815	1015	1.2	0.7	1.1

DISSEMINATION OF AGRIMET INFORMATION

There are four major products provided by the AgriMet program:

- A table of daily ET values for the last five days for a reference crop (Alfalfa) and specific crops grown in the area. This table includes a 7-day, 14-day, and growing season ET total. In addition, a forecast of ET for the current day is displayed (based on the average of the last three days ET value) (see Table 1).
- A table of weather parameters for the last 5 days or 10 days for each station.
- A summary of ET for each day of the growing season for each crop grown in the vicinity of each station.
- Historical weather and crop water use data for all stations for the entire period of record.

All of these products are available from Reclamation's AgriMet website at <http://www.usbr.gov/pn/agrimet>. Information for the Great Plains AgriMet program (east of the continental divide in Montana) is available at <http://www.usbr.gov/gp/agrimet/index.cfm>. Several local newspapers in the region publish AgriMet crop water use during the growing season, providing an additional means of local dissemination. AgriMet information is further distributed to the user by county extension agents, producer cooperatives, and crop consultants.

USES OF AGRIMET PRODUCTS AND INFORMATION

AgriMet crop water use information is integrated into various on-farm technical assistance programs by local agricultural consultants, the Cooperative Extension Service, and the USDA Natural Resources Conservation Service. As competition for limited water supplies increases - as well as the cost of pumping for irrigation - farmers are turning more and more to scientific irrigation scheduling.

The most common method for irrigation scheduling is known as the "checkbook method," accounting for deposits and withdrawals to the soil moisture balance. For this procedure, the farmer must first know the plant root depth and water holding capacity of his soil. This information is typically available from detailed soil surveys of the area, or from site specific soil tests. After each irrigation during the growing season, the farmer tracks the daily crop specific ET, available from AgriMet. When the cumulative water use equals the Management Allowable Depletion (MAD) for that crop, it is time to irrigate again. Specific knowledge of the irrigation system, combined with ET information from AgriMet, allows a farmer to apply the right amount of water at the right time for optimum crop production. Not only does the farmer realize savings in water and pumping costs, but reduced leaching results in lower costs for fertilizer, herbicides, and pesticides. Various agricultural consultants have reported water and power savings ranging from 15 to 50 percent through the use of AgriMet supplied ET data (Dockter, 1996). Some irrigators have reported real savings of as much as \$25 per acre in pumping costs after using AgriMet ET data to schedule their irrigations (Palmer, 2004). Indirect benefits of scientific irrigation scheduling include reduction in non-point source surface water pollution (through reductions in nutrient and chemical laden irrigation tail water) as well as protecting ground water supplies through reduced leaching of agricultural chemicals.

AgriMet ET information is being extensively used by irrigators for on-farm irrigation water management. In a study conducted for the Bonneville Power Administration, "on-line services, primarily AgriMet, are the most commonly used source for obtaining this (ET) information and account for 45 percent of cases. These figures, however, under-represent the actual use of ET information, particularly from AgriMet, since they do not take into account cases where commercial irrigation service providers provide this data" (Kema-Xenergy, Inc., 2003).

AgriMet weather data are used for a variety of applications in addition to ET computation, and requests for current and historical weather information from the AgriMet network are common. Agricultural producers depend on wind speed and direction for scheduling such practices as field burning and pesticide applications. Weather data is used by state DEQ's for investigating pesticide application and ground water contamination issues. The National Weather Service uses AgriMet weather data for short term forecasting and forecast verification. Several electric utilities use the weather information to forecast daily energy requirements, including peaking power. University researchers frequently use AgriMet data for a variety of applications, ranging from regional consumptive water use modeling to locating new orchards. ET information is being used by other agencies, such as the National Resources Conservation Service, to document compliance with irrigation water management practices on individual farm tracts. Increasingly, ET information from weather station networks is being used in water rights management by state water resource agencies.

SUMMARY

In the early 1980's, the U.S. Bureau of Reclamation, in partnership with Bonneville Power Administration, developed a network of automated agricultural weather stations in the Pacific Northwest. From the original three sites installed in 1983, the AgriMet system has now grown to over 90 sites in Idaho, Oregon, Washington, Montana, Wyoming, and California. Reclamation has cultivated partnerships with over 25 federal, state, and private interests to help fund the operation of the network.

AgriMet stations collect the weather data required for modeling crop evapotranspiration and transmit this information via satellite to Reclamation's Regional Office in Boise, Idaho. Every day during the growing season, crop water use charts are developed for crops grown in the vicinity of each AgriMet station. This information is available daily through the Internet and is also published in many local newspapers throughout the region. The information is used by federal and state agencies, conservation districts, irrigation districts, extension agents, agricultural consultants, corporate farms, and individual irrigators for water management purposes. The weather data collected is also used for a wide variety of other applications. A rigorous field calibration and maintenance program, and data quality assurance program ensures a high level of data quality and integrity.

Competition for limited water resources is increasing, cost of irrigation water and pumping is rising, and concerns for surface and ground water quality are growing. In response to these factors, scientific irrigation scheduling is becoming more commonplace. AgriMet is providing the information required to meet these challenges in the Pacific Northwest.

LITERATURE CITED

- Cross, Paul. 1997. Lake Chelan Reclamation District, Personal communication. October, 1997.
- Dockter, Douglas T. 1996. "AgriMet - Applied Technology for Agricultural Conservation.". Proceedings of Conserv96, January 4-8, 1996, Orlando, Florida. Published by American Water Works Association, Denver, Colorado. pp. 41-45.
- English, Marshall. 2002. PowerPoint Presentation on Irrigation Scheduling. Oregon State University.
- Jensen, M.E., R.D. Burman, and R.G. Allen (Editors). 1990. "Evapotranspiration and Irrigation Water Requirements." Committee on Irrigation Water Requirements of the Irrigation and Drainage Division of the American Society of Civil Engineers. New York, N.Y.
- Kema-Xenergy, Inc. 2003. "A Study of Irrigation Scheduling Practices in the Northwest." Prepared for Bonneville Power Administration, Portland, Oregon, September 5, 2003. Principal Investigators: Hossein Haeri, Kema-Xenergy and Marshall English, Oregon State University
- Palmer, Peter L. 2004. Personal communication with Jeff Harper, an irrigator in Mountain Home, Idaho, who farms 1400 irrigated acres. April 19, 2004.

