USE OF PAWS/AGRIMET WEATHER DATA FOR SCIENTIFIC IRRIGATION SCHEDULING OF POTATOES[1]

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INTRODUCTION

A number of tools are available to assist growers with irrigation management decisions. The routine calculation a root zone soil water balance based on soil water-holding properties, engineering data about the irrigation system, and model estimates of crop water use is termed scientific irrigation scheduling. Scientific irrigation scheduling is an important tool growers can use to improve irrigation water management. It is practically the only approach which provides answers to the questions of when to irrigate, how much water to apply, and how to apply water, in order to satisfy crop water requirements and avoid plant water stress. A true scientific irrigation scheduling program also provides forecasts of future irrigation dates and amounts so that other farm operations can be planned around irrigation events.

When carefully used, irrigation scheduling has been documented around the world to save water, energy, labor, and fertilizer, and in many cases improve crop yields and crop quality. In a situation when water supplies are very tight and deliveries are made at much reduced rates from normal, irrigation scheduling can help to stretch the available water to be of the greatest benefit to the crops being irrigated.

There are many approaches available for trying to answer the questions of when to irrigate and how much water to apply. Some are based on plant observations and measurements and some are based on soil measurements or monitoring. Plant measurements such as plant temperatures, leaf water potentials and so forth provide good information about the plant's water status and thus can give good answers to when irrigation is needed. However, how much water to apply is not readily apparent. On the other hand, soil water measurement can be used to provide good information on when soil water levels are depleted and how much water is needed to irrigate the soil up to field capacity. There are many arguments concerning how well this correlates with plant water status, however.

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In order to adequately answer when, how much and how to apply water, an approach which takes into account the plant, the soil and the irrigation system is necessary. Scientific and engineering data about crops, soils and irrigation systems are available and can be systematically integrated for scheduling irrigations. One of the more difficult pieces of information to obtain is reliable and accurate estimates of crop water use. The objective of this presentation is to discuss approaches which have been used over the years to estimate crop water use. Important tools such as pan evaporation and weather-based methods for calculating evapotranspiration will be discussed. Automated weather station networks have been developed in the Pacific Northwest for the express purpose of providing crop water use data for irrigation scheduling. The WSU Public Agriculture Weather System **(PAWS)** and the US Bureau of Reclamation AgriMet network will be discussed in this context.

ET -- EVAPOTRANSPIRATION: WHAT IS IT, HOW TO USE IT

A large number of factors affect crop water use or evapotranspiration including crop type, crop density, amount of vegetative cover or leaf area, crop health, available soil water, stage of growth, and climatic and environmental factors. Crop water use for all crops typically begins at very low rates in the spring because there is little or no demand, i.e., perennials have not leafed out yet, annuals are very young or just planted, climatic conditions are cool with little atmospheric demand for water. As the crops develop and climatic conditions progress toward those of summer, the demand for water increases rapidly reaching a peak as the summer weather conditions peak. Water use typically falls off as the weather cools down in late summer, or as the crop reaches maturity and is harvested.

<u>ET Defined</u>

Evapotranspiration or ET is traditionally defined as the combined loss of water from the soil surface by evaporation and from plant tissue by transpiration. Evapotranspiration and consumptive use of water are often used interchangeably. However, consumptive use of water by plants includes transpiration, plus water which is used in other plant processes such as tissue-building and growth. The difference is usually less than 1 to 2 percent.

The process of evaporation involves a change of state of water from a liquid to a gas or vapor. The rate of evaporation depends chiefly on the total supply of energy available from radiation (direct solar and radiation which is reflected and/or re-radiated), and advective or horizontal air flow (wind), which carries the water vapor away.

Transpiration is the process of water flow to plant tissue surfaces, primarily those within plant stomata, where it is subsequently converted to a vapor and lost through evaporation. Plant factors such as leaf structure (size, shape, orientation) and degree of stomatal opening control the rate of transpiration. This gives plants a mechanism for reducing water loss to rates less than evaporation rates from free water surfaces.

How is ET Used

ET is of considerable interest (or should be) to anyone involved with irrigation. Some applications are:

1) Peak ET rates during the growing season are used in the design of irrigation systems, i.e., required pump capacity, mainline sizing, etc. to insure that enough water can be applied to meet crop needs. Peak ET rates for periods of a single day to several days must be investigated relative to the expected usable soil water in the crop root zone to ensure adequate irrigation system design capacity.

2) Daily and/or weekly estimates of ET rates during the growing season are used to determine irrigation schedules (when to irrigate and how much to apply).

3) Long-term average ET and rainfall amounts totalled over a growing season are used to determine net crop irrigation requirements. Total irrigation requirements are determined by adding in the leaching requirement for maintaining a favorable salt balance, and the losses of water due to inefficiencies and non-uniformities of the irrigation application system.

4) Aggregate totals of the total irrigation requirement for individual fields or farms over a basin or region are used in irrigation delivery system operation and management, water supply allocations, etc.

Having reliable ET information and using it properly in each of the above situations contributes considerably to the success of individual farming operations, irrigation delivery operations and the long-term sustainability of irrigated agriculture.

Irrigated crops are provided with the correct amount of water at the right time, improving yields. Water, energy and labor are often saved, and water quality maintained as a result.

Approaches to Measuring ET

Evapotranspiration is determined through direct measurement or is calculated using climate and environment data. Direct measurement of actual crop ET is based upon measuring all water entering, leaving and being stored in some defined system. This is called a water balance. The most accurate technique for doing this is with a device called a lysimeter.

Lysimeters are buried, soil-filled tanks with the crop of interest being grown in and around the tank. Instrumentation is carefully set up in and around the lysimeter to measure all water inputs (irrigation and rainfall), drainage or outflow, and changes in soil water storage.

The water balance results in a measurement of ET. Because of their expense and the careful instrumentation and monitoring required, lysimeters are most often used only in research settings.

Field soil water balances can be carried out to measure ET, but are less accurate than lysimeters. This is due to the difficulty of measuring some of the factors such as deep percolation or subsoil water movement into and out of the study area. These factors are eliminated or are easier to measure in a lysimeter. Soil variation and non-uniform irrigations also cause problems with this approach.

Weather-Based ET Estimates

Several meteorological and climatological methods have been developed for indirect estimation of ET. These range from empirical models based on a single meteorological parameter such as temperature, to more physically-based, theoretical methods requiring considerably more weather data. All of the climatological methods for calculating ET for a given crop involve first determining potential ET or reference crop ET. The actual ET of a given crop is then related to the potential or reference ET using a crop coefficient. Potential ET represents the maximum rate of water use under conditions when water is not a limiting factor, the crop is healthy and actively growing, and usually at full canopy cover development. In this context, estimates of crop water use are going to be conservative in nature, i.e., they represent an upper estimate of what the crop could **potentially** use if all conditions were ideal. For all practical purposes, with very careful water management, high quality crops and yields can be produced with less water.

Reference crop ET is the potential ET for a specific crop under certain growth and environmental conditions. Two reference crops which have received the most study are alfalfa and grass:

> **Alfalfa ET_r** is the daily reference crop evapotranspiration of a well-watered (i.e., soil water does not limit ET), actively growing, erect standing alfalfa crop with at least 8" of top growth and occupying an extensive area.

> **Grass ET_0** is the daily reference crop evapotranspiration from an extensive surface of 3-6" tall, green grass cover of uniform height, which is actively growing, completely shading the ground and not short of water.

Empirical models for estimating evapotranspiration which have been used extensively in Washington include the Blaney-Criddle temperature based model and pan evaporation. These models tend to be less accurate over shorter time intervals than the physically-based methods. There is often a recommended minimum time interval with which these models should be used.

The **Blaney-Criddle model** is one of the more popular methods worldwide because of the minimal data requirements: mean monthly temperatures. Only monthly estimates of potential ET should be derived with this method. A modification called the FAO (Food and Agriculture Organization) Blaney-Criddle model considerably improved the accuracy of the estimates by allowing for some simple local calibration, usually with weather data and/or observations which are not difficult to obtain. This model yields monthly grass reference ET_o.

The FAO Blaney-Criddle model served as the basis for the development of WSU Extension Bulletin EB 1513: Irrigation Requirements for Washington--Estimates and Methodology. This model was chosen after rigorous evaluation of 17 different models showed this one to have the best combination of precision and accuracy for predicting seasonal irrigation requirements for conditions at Prosser, WA. It also was used to develop Appendix B of the State of Washington Irrigation Guide. This appendix gives monthly and season total net irrigation water requirements for up to 40 different crops at 90 locations around Washington. Net irrigation water requirement of a crop is the amount of water needed, over and above effective precipitation, which must be provided either by stored soil water, irrigation, lateral and/or upward movement of shallow groundwater or a combination of all of these to meet potential crop water demand.

Pan evaporation is a method for measuring potential ET which has been and continues to be used extensively in Washington. A number of different types of pans have been researched and utilized, but the most common (and the one used in Washington) is the US Weather Bureau Class A pan. This is a 4-foot diameter pan, 12 inches deep. Daily measurements of the amount of water evaporating from the pan, corrected for rainfall, provide an estimate of potential ET.

It is recommended that pan evaporation readings not be used on time intervals of less than a week to ten days. In other words, a week or ten day's worth of readings should be added up and the average for that interval found. This daily average then becomes an indicator of crop water use. Individual daily pan evaporation readings may be as high as 0.50 to 0.60 inches of water on hot, sunny, windy, dry days. In this case, the pan reading is not a reliable indicator for crop use. Many plants have a mechanism for "shutting off" or reducing water loss under these conditions.

When the evaporation pan is set up and maintained under a set of standard conditions, such as at the WSU Research Units at Prosser and Othello (surrounded by green, well-watered, clipped grass in a large irrigated environment and without influence of buildings, trees or large paved areas nearby), then grass reference crop ET_o is estimated as:

$$\text{grass } ET_o = 0.8 \times E_{pan}$$

WSU Extension Bulletin EB 1304 provides details on how to use pan evaporation readings to schedule irrigations. Evaporation pan crop factors for several crops for conditions when the crops are in full cover are included.

Daily and even hourly estimates of potential ET can be derived from meteorological models which are based on the physics of the evaporation process. Approaches include aerodynamic transport models, energy balance methods, or a combination of the two.

The most popular combination method is called **the Penman method**. Considerable research has been accomplished with this model. Both alfalfa reference ET_r and grass reference ET_o estimates can be obtained. To utilize the Penman model requires measurements of temperature, relative humidity, solar radiation and wind speed. These measurements must usually be taken on an hourly basis to obtain daily maximums, minimums, and/or totals for these parameters. Weather measurements for use with the Penman model are most often being obtained throughout the U.S. with remote automated weather stations equipped with the proper sensors. Weather stations must be carefully sited to represent the irrigated area in which they are located, particularly with respect to irrigated, green fetch in the immediate vicinity of the weather station and for several hundred feet in the prevailing wind direction.

One of the purposes of the Washington Public Agriculture Weather System (see following discussion) is to provide the data necessary for calculation of Penman-based daily reference crop ET values. Both alfalfa and grass reference ET estimates are calculated each day for each of the **PAWS** stations. Daily alfalfa ET_r and cumulative ET_r based on weather data collected at the WSU **PAWS** station at Moses Lake for March 1 to October 31 of 1989-93 are graphed in Figure 1.

These figures show that for the five year period (1989-93), 1992 was a relatively high water use/demand year, while 1993 was lowest. The average water use of all five years was not much higher than 1993.

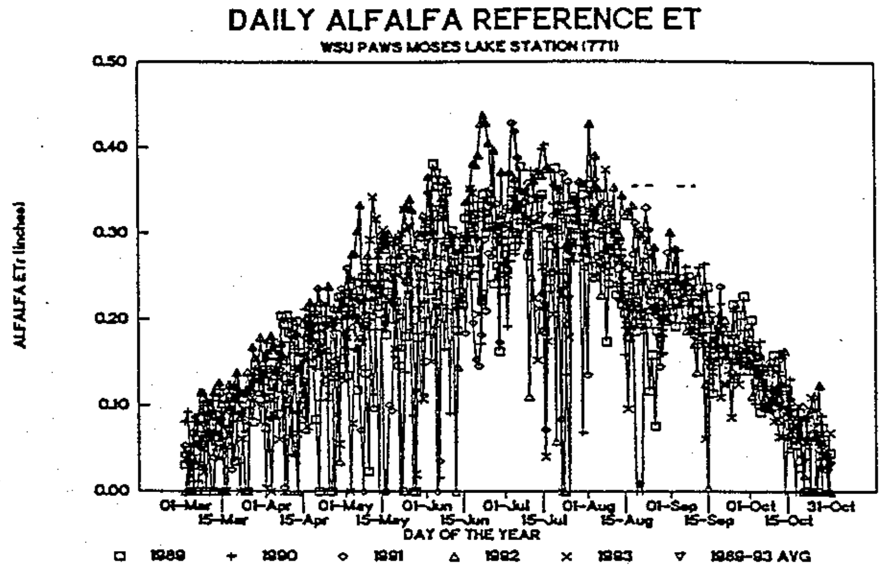
Crop Coefficients

Daily ET_r data and daily crop coefficient data are used to construct crop water use charts which give the crop ET for the last several days and estimates for the coming several days. **Crop coefficients** (K_c) relate the actual rate of crop water use, ET_c to potential ET (ET_r or ET_o above).

$$ET_c = K_c \text{ x potential ET}$$

Values of K_c are determined experimentally and reflect the physiology of the crop, the degree of crop cover, the location where data were collected and the reference crop used to determine potential ET. Thus, different crop coefficients exist for the same crop, but are applicable for use either with alfalfa ET_r or grass ET_o. They are generally not directly interchangeable. The appropriate crop coefficients must be applied to estimate actual crop ET. Research has shown, however, that in general alfalfa reference ET_r is approximately 120% of grass reference ET_o. This would indicate that crop coefficients for use with alfalfa reference ET_r may be estimated as 0.83 times grass reference ET_o crop coefficients.

Monthly average evaporation pan crop coefficients were published in Appendix B of the State of Washington Irrigation Guide. These factors are actually grass-reference crop coefficients multiplied by the pan factor, 0.80, so that they can be used directly with evaporation pan readings. The evaporation pan crop coefficients given in the WA Irrigation Guide divided by 0.80 yield monthly crop coefficients which can be used with grass reference crop ET_o. Further information on these crop coefficients and how they were developed is given in WSU EB 1513 Irrigation Requirements for Washington--Estimates and Methodology.



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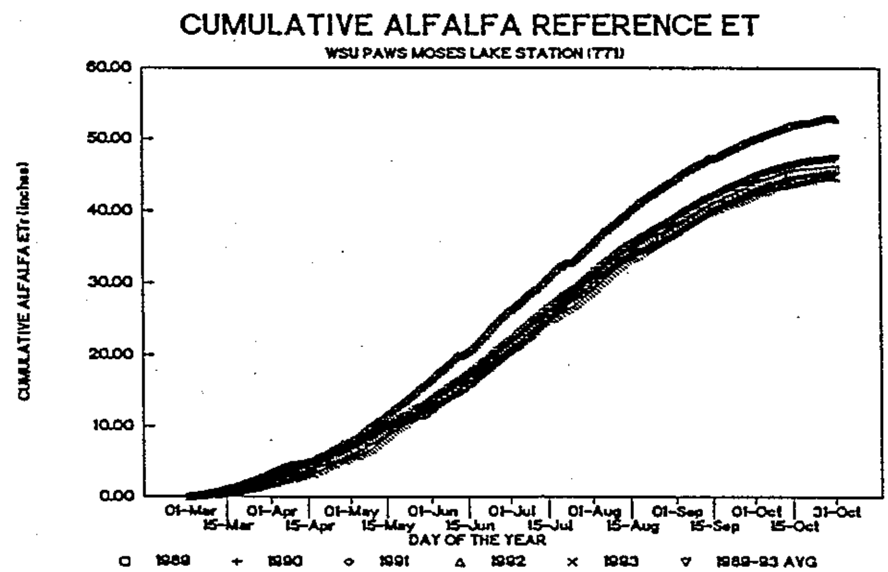

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Figure 1. Daily alfalfa ET_r (a) and cumulative alfalfa ET_r (b) for March 1 to October 31 for 1989-93 and five year average based on weather data collected at WSU PAWS Moses Lake weather station.

A simple model of potato crop coefficient for use with alfalfa ET_r is presented in Figure 2 for planting dates of April 1, April 15 and May 15. In Figures 3, 4 and 5, the three crop coefficient curves in Figure 2 have been applied to the alfalfa ET_r data for the Moses Lake weather station (Figure 1) for the years 1992 (high), 1993 (low) and the five year average.

THE WASHINGTON PUBLIC AGRICULTURE WEATHER SYSTEM (PAWS) AND THE US BUREAU OF RECLAMATION AGRIMET SYSTEM

During 1988 Washington State University (WSU), in cooperation with the National Weather Service (NWS), the Washington State Energy Office, the U.S. Bureau of Reclamation (USBR), and several private organizations, installed a remote, automated, real-time weather data acquisition and reporting network to serve Washington agriculture. This network has become known as the Washington Public Agriculture Weather System (**PAWS**).

Washington State University's intent in developing the **PAWS** system is to provide growers with a tool, and the educational support for the effective use of that tool, to help improve efficiency in crop production. The real-time weather data collected and reported by the **PAWS** network are being used in a variety of crop production and management practices including scientific irrigation scheduling, frost warning and protection, and integrated pest management.

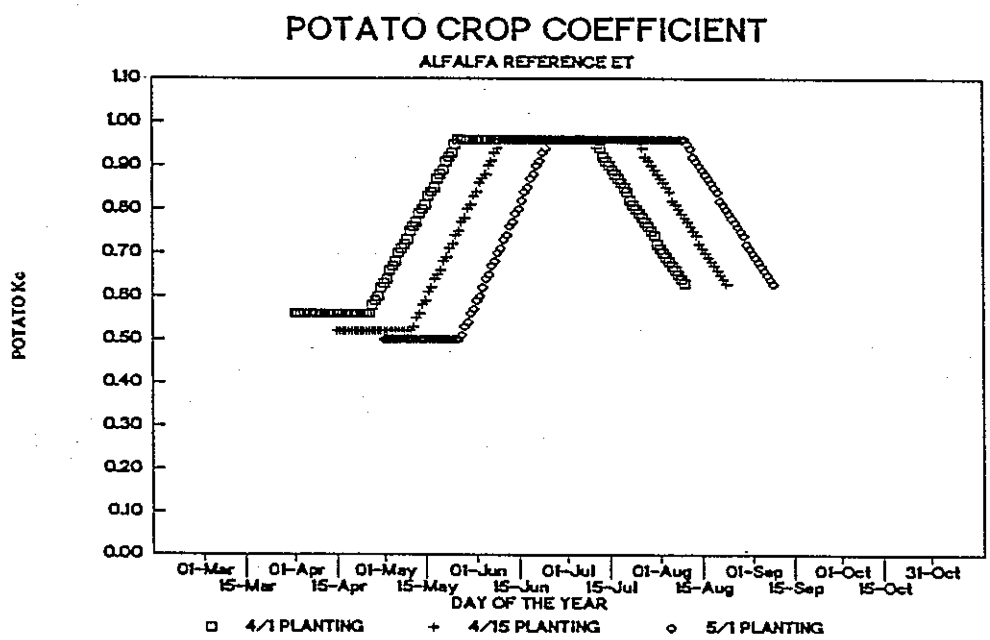
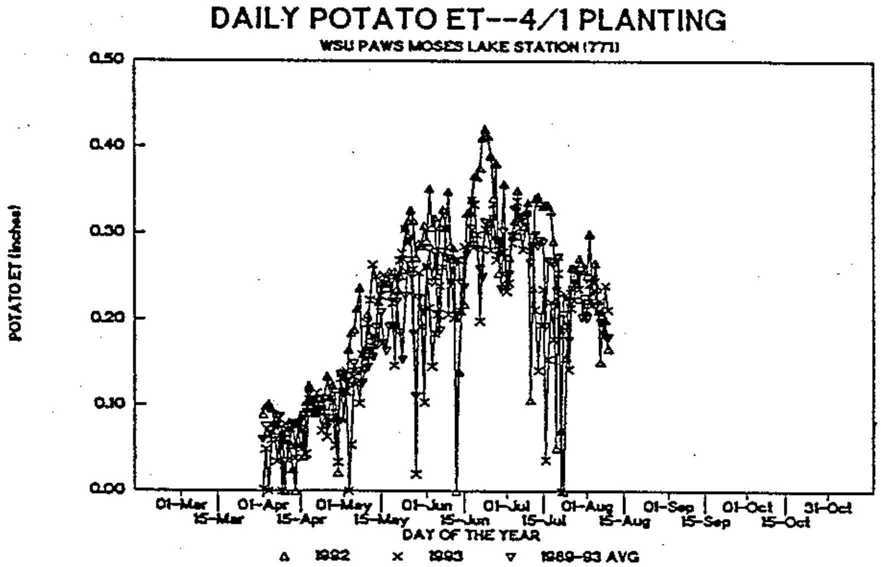


Figure 2. Simple potato crop coefficient model for use with alfalfa ET_r data for three planting dates.



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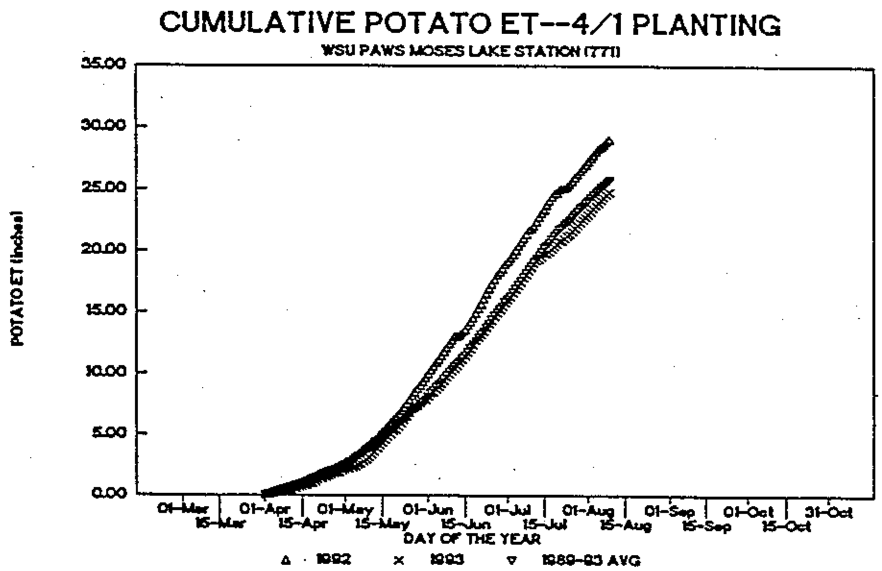

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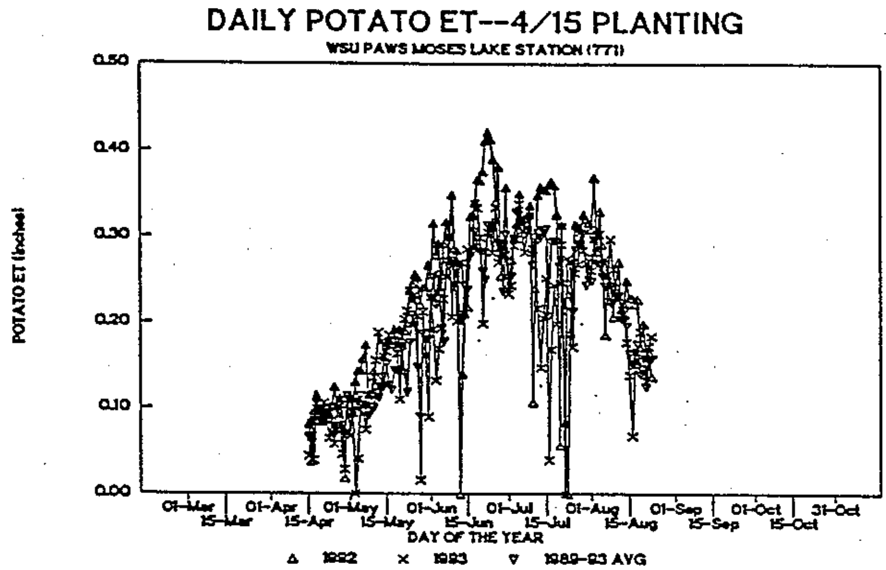
Figure 3. Daily potato ET (a) and cumulative potato ET (b) for April 1 planting date for 1992, 1993 and five year (1989-93) average based on weather data collected at WSU **PAWS** Moses Lake weather station.



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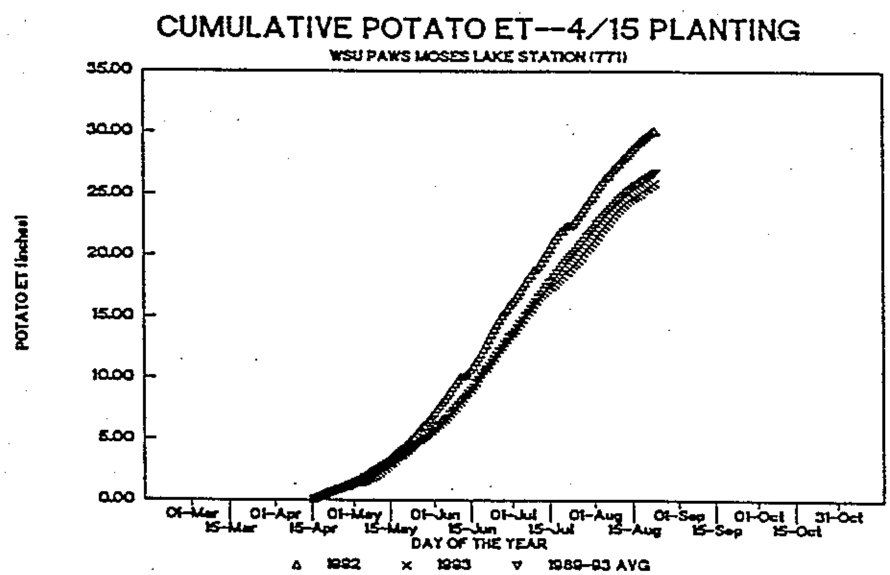

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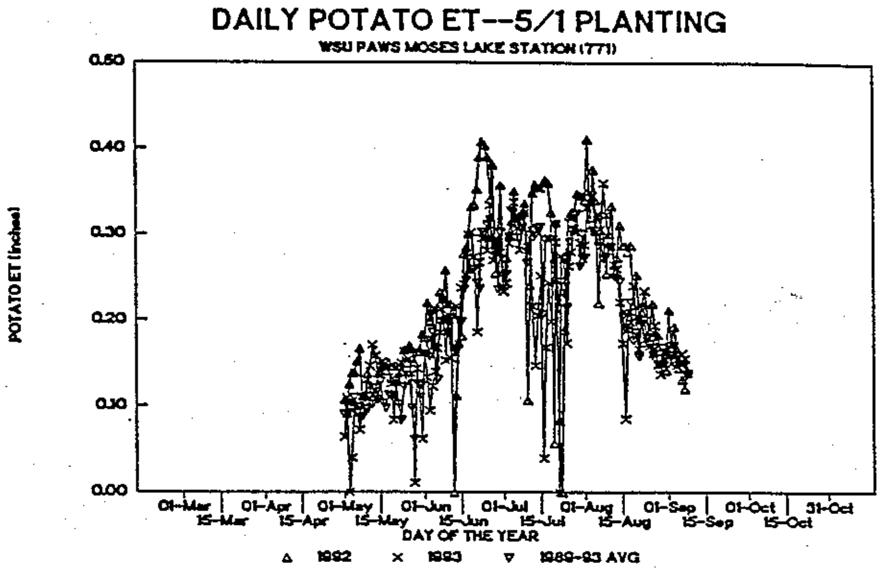
Figure 4. Daily potato ET (a) and cumulative potato ET (b) for April 15 planting date for 1992, 1993 and five year (1989-93) average based on weather data collected at WSU PAWS Moses Lake weather station.



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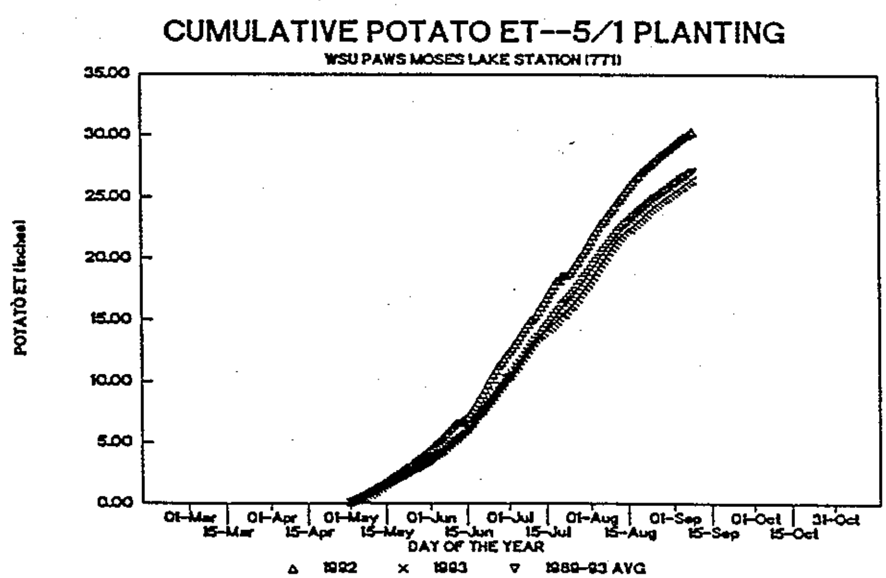

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Figure 5. Daily potato ET (a) and cumulative potato ET (b) for May 1 planting date for 1992, 1993 and five year (1989-93) average based on weather data collected at WSU **PAWS** Moses Lake weather station.

The **PAWS** automated weather station network consists of 61 automated agro-meteorological stations located primarily in irrigated lands of central Washington and northern Oregon (see Figure 6). These include 50 stations operated and maintained by WSU and 11 stations operated and maintained by the US Bureau of Reclamation (which are part of the USBR AgriMet network). Data are accessible from 5 computer base stations and 2 NWS offices in Washington and from USBR PNW headquarters in Boise ID. Weather data are available by personal computer and telephone modem access to **PAWS** base stations at WSU Prosser, WSU Mt Vernon, WSU Wenatchee, Oroville-Tonasket Irrigation District and Lake Chelan Reclamation District.

Only daily data for the USBR AgriMet stations are available from **PAWS**. Access to hourly AgriMet data is available by computer and modem access to the USBR computer in Boise ID. Contact Monte McVay, USBR, 1150 N. Curtis Rd., Boise, ID 83706-1234, (208) 378-5282 for information and an ID number and password.

Touchtone telephone access to **PAWS** weather data is possible at WSU Prosser and planned for the Okanogan base station. Contact the author or Tony Muzzy, **PAWS** Engineering Technologist, at (509) 786-2226 for further information on computer or touchtone telephone access.

PAWS has been fully operational in south central Washington since the spring of 1989. Weather data have been used operationally by individual growers, crop consultants, and in demonstration projects which illustrate data applications. These include:

1) Reporting of hourly temperatures, dewpoints and wind during the spring frost season by the National Weather Service over the NOAA Weather Radio as part of the fruit frost warning program.

2) Reporting of daily maximum and minimum air temperatures, precipitation, soil temperature, blossom degree days and evapotranspiration by the NWS over the NOAA Weather Radio.

3) Pest management updates and warnings for fruit growers compiled by WSU Cooperative Extension in Yakima County and reported over the NOAA Weather Radio. Information on such pest problems as apple scab, codling moth and fire blight was provided.

4) Scientific irrigation scheduling using **PAWS** weather data or evapotranspiration estimates and the **Washington Irrigation Forecaster** computer model.

Weather-driven computer models currently available on-line include pest management models for tracking and predicting pest problems. These are codling moth, fire blight, cherry fruit fly and apple scab, and a base 5 degree Celsius soil temperature degree day model. Crop growth models include growing degree day models with base temperatures of 40, 43, 45, 50, 55 and 60 degrees Fahrenheit. Reference crop evapotranspiration for alfalfa and grass reference crops is calculated daily and made available by another model. Crop water use charts are developed daily for each weather station location using the reference ET values and crop coefficient data. These charts show the water use by crop for the past several days, expected water use for the coming few days and total water use for the season to date. Estimated air stability and inversion conditions for weather stations having air temperature measurements at both 5 ft (1.5 m) and 33 ft (10 m) above the ground surface is also available. Additional models will be added as they become available.

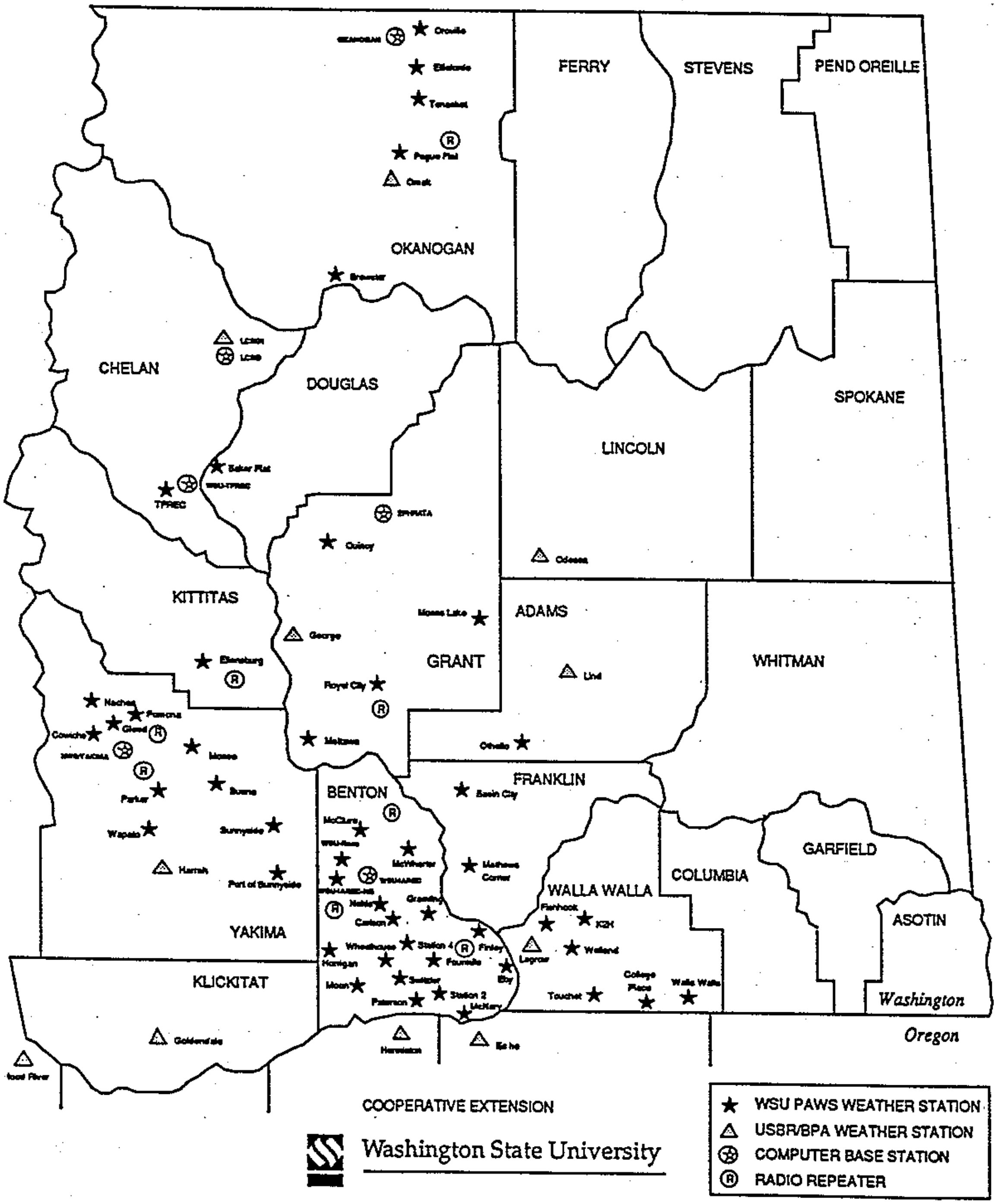

Figure 6. Map of Eastern Washington showing the WSU **PAWS** automated weather station network.

SOIL WATER BALANCE

The soil water balance or checkbook approach to irrigation scheduling is not difficult to implement once the appropriate data have been assembled. The checkbook method requires that you know the net amount of water applied at each irrigation, the total available and usable soil water in the crop root zone, and the rate at which the crop extracts water from the soil. These three factors are balanced against each other to ensure the plant available soil water is maintained at readily available levels. These data are also used in projecting when plant available soil water content in the root zone should be replenished.

The total available soil water in the crop root zone represents the bank account. The amount of usable soil water in the crop root zone is the checkbook balance. We want to keep this balance between certain limits to avoid "service charges". If it gets too low or dry, then the crop may experience moisture stress and yields or crop quality can be reduced. There is also a maximum soil water level, which is equivalent to the field capacity of the soil. If you irrigate so that the soil water goes above field capacity, then deep percolation occurs. This results in leaching of nutrients from the root zone, and a loss of a water and nutrients to the crop. Crop water use represents writing a check or making a withdrawal from the bank account. When you irrigate, or it rains, a deposit is made. So, the key is to use available information to determine the size of the bank account for your fields and then keep track of withdrawals and deposits so that the checkbook balance is maintained within desirable limits with the least amount of service charges.

Soils Information

The minimum amount of soils data needed for this process are the soil depth and the **soil water-holding capacity** (which is defined as the difference between the soil field capacity and the soil permanent wilting point). **Soil depth** is important because it may represent a barrier to root growth. If soil depth does not limit the root growth, then the depth of plant rooting defines the size of the soil water bank account.

General information on soil water-holding capacity can be obtained from a number of sources. The best place to start is with soil survey information prepared by the Natural Resource Conservation Service (formerly SCS). You need to determine the soil series or type for each irrigated field and the variability of the soils within the field. For many irrigated locations this information is mapped out in published Soil Surveys. The water-holding capacity in the soil profile has been measured or estimated for the soils which are included in the surveys. This information is also given in the State of Washington Irrigation Guide available as a reference book at each NRCS or WSU Cooperative Extension Office.

The water holding capacity for a given soil will most often be given as so many inches of water per foot of soil, i.e., for a Warden silt loam the number might be 2.3 inches per foot, while for a Quincy sand it may only be 1 inch per foot

The soil depth or the crop rooting depth, whichever is less, is multiplied by the water-holding capacity per foot to find the **total available water in the crop root zone.** For instance, for the Quincy sand above, if a potato crop root zone is taken as 2 feet, then the total available in the root zone is (2 x 1) = 2 inches.

Not all of this should be allowed to be used between irrigations, otherwise the soil approaches permanent wilting point and the crop may be seriously moisture-stressed. A **maximum allowable depletion (MAD)** of the total available soil water should be used to avoid this stress situation. For most crops a safe level of allowable depletion is about 50%. Some crops are more drought tolerant and may have MAD values near 65%. Moisture sensitive crops such as potatoes should be managed with a MAD of 20% to 35% depending on soil type. MAD values near 20% should be used for both coarse textured soils and very fine textured soils. Coarse textured soils have such low water holding capacity that the difference between a 20% MAD value and a 35% MAD value may often be the equivalent of less than one day of crop water use during high water use periods. Potatoes grown on coarse soils may undergo serious enough stress by going across this range of soil water that significant crop quality problems result.

The total available water in the root zone is multiplied by the MAD value to determine the **usable water** in the root zone. For the above example, if MAD is 20% then the usable water is (0.20 x 2) = 0.4 inches. This is the amount of water which should be allowed to be used from the root zone in between each irrigation. Consult your local WSU Extension office for more information.

Irrigation System Information

The key piece of information is the net amount of water applied by the system. Determining this requires measurements of the system gross application rate and the irrigation application efficiency. The net amount of water applied equals the gross application rate of your irrigation system multiplied by the irrigation set time and the irrigation application efficiency. This net amount of water represents the amount which actually enters the root zone and is available for the plant to use.

The application efficiency of an irrigation system varies significantly through the irrigation system due to prevailing environmental conditions (wind, humidity, temperature, etc.) at each irrigation. Typical **seasonal average** application efficiencies have been listed in many publications.

Application efficiencies of 75-85% for center pivot systems (depending on the sprinkler package and mounting configuration) and 70-75% for wheel-line and hand-line sprinklers are commonly listed. A strong precaution against using these values lock, stock and barrel during the entire irrigation season is given. The author has personally measured application efficiencies on large numbers of pivots, wheel-lines and other sprinkler systems which deviate considerably from the season average values.

Early season irrigation application efficiencies near 90% for nighttime irrigations have been measured. Conversely, daytime catch can tests under center pivots with sprinklers mounted on top of the lateral have revealed efficiencies as low as 50%.

In an operational irrigation scheduling context it is important that as accurate a measure as possible of the amount of water actually entering the root zone be used. This often will dictate the use of a number of irrigation catch containers located at the top of the crop canopy.

Rainfall also represents an addition to the bank account. Rainfall amounts of 0.2 inches and less falling on bare soil are generally considered ineffective, because most of it evaporates rapidly. When the crop has developed a vegetative canopy which shades at least 70% of the ground surface, then most of the rainfall can be considered effective since it temporarily reduces crop transpiration.

Crop Information

In addition to crop water use estimates, information about crop rooting characteristics is needed. This includes the depth of rooting and the distribution of roots with depth. Many annual and perennial crops can develop deep rooting, given deep soils. However, it is important to realize that 75% of the water uptake is probably coming from the top 50% to 75% of the root zone. Irrigation management must be tailored to reflect this. Crop susceptibility to stress at various growth stages should also be factored into irrigation management decisions. This is usually accomplished by using a variable MAD value rather than a constant for the entire growing season.

It is recommended that soil water content should be routinely measured through the season to keep the estimating procedures used in the soil water balance on track. Several crop consultants provide this service. Pacific Northwest Extension Publication 475: Soil Water Monitoring and Measurement provides a detailed overview of the measurement/monitoring process and different tools available for this purpose. Flow measurement (i.e. flow meters, etc.) or several in-field catch containers should be employed to check that the desired depths of irrigation are actually be applied.

SUMMARY

The process of performing a soil water balance, or scientific irrigation scheduling, will result in the maintenance of appropriate soil water content in the crop's root zone. The term appropriate in this context means not being too dry as well as avoiding being too wet. This process will help to save and stretch water, especially in situations where there previously has been no attempt to use the scientific information available in a systematic record-keeping procedure.

The number of approaches and methods for estimating crop water use in addition to trying to interpret crop coefficients can be very confusing. This presentation has provided information on how reference or potential evapotranspiration is calculated. Crop coefficients for translating reference ET into crop ET for the crop of interest were presented and discussed.

Washington State University and the US Bureau of Reclamation operate the **PAWS** and AgriMet weather station networks, respectively, for the purpose of collecting the necessary detailed weather data to compute reference evapotranspiration for a large number of agricultural locations. Both systems make crop water use estimates available for each location for a variety of crops using published crop coefficient data. These crop water use estimates reduce the number of steps an irrigation manager must go through to perform a daily soil water balance.

WSU has developed **The Washington Irrigation Forecaster (WIF)**, a computer software package with much of the required basic soils, crop and irrigation system information pre-programmed into the package, to assist growers with irrigation scheduling. For further information on WIF contact the author.