Estimating Growing Season Hydraulic Loading Rate Using U.S. Bureau of Reclamation Agricultural Meteorological System (AgriMet) Data

Bradley King
USDA ARS
Northwest Irrigation and Soils Research Laboratory
Kimberly, Idaho

Introduction

In Idaho, wastewater approved for land application must be done in a manner that does not degrade ground water or result in fugitive wastewater such as runoff or wind drift beyond site boundaries.

Specific Reqt's

Hydraulic and constituent loading must be such that they do not exceed the removal rate of the crop. One of these will be the land limiting constituent which determines the land area required for efficient treatment of the wastewater.

Optimum Hydraulic Loading

The optimum hydraulic loading rate is that which maintains efficient operation of the agronomic production system i.e. hydraulic loading is substantially equal to crop water use.

Optimum Hydraulic Loading

Hydraulic Loading <> Crop Water Use

- reduces crop growth and subsequently reduces constituent use. With an annual crop, growth is not recoverable.

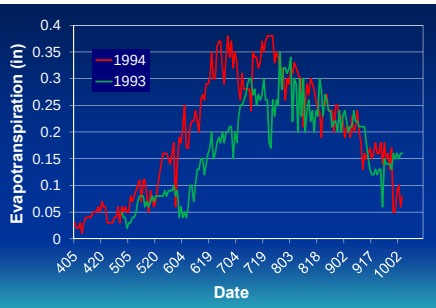
Crop Water Use

Crop water use is the sum of water loss to the atmosphere by evaporation from soil and plant surfaces and transpiration from the crop leaf internal structure during photosynthesis, commonly called evapotranspiration or ET.

Evapotranspiration

Evapotranspiration is dynamic as it depends upon crop type, crop growth stage, nutrient availability, and environmental conditions (solar radiation, temperature, humidity, wind speed).

Sugar Beet ET – Kimberly



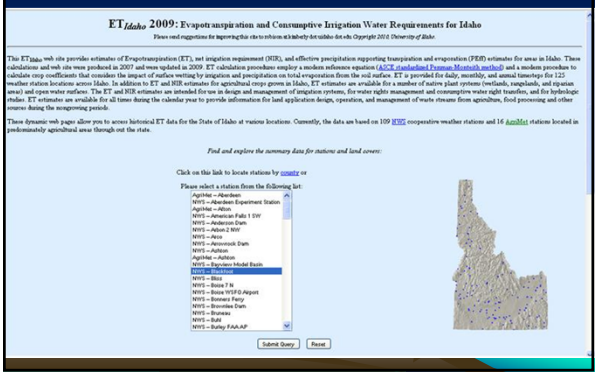
Estimating ET

Wastewater land application permits may specify a source for estimating ET. For example:

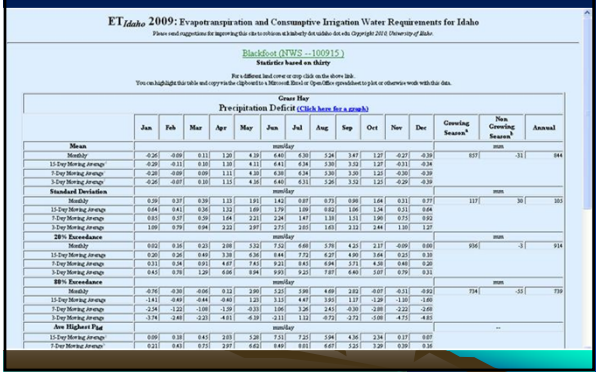
- www.kimberly.uidaho.edu/ETIdaho/

- www.usbr.gov/pn/agrimet/

www.kimberly.uidaho.edu/ETIdaho/



www.kimberly.uidaho.edu/ETIdaho/

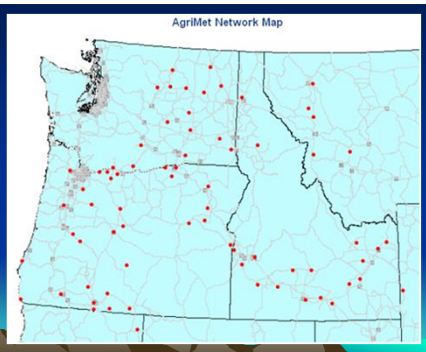


AgriMet System

The AgriMet system is a cooperative agricultural weather station network, managed and operated by the U.S. Bureau of Reclamation, dedicated to agricultural crop water use estimation.

www.usbr.gov/pn/agrimet/

www.usbr.gov/pn/agrimet/



ET

Evapotranspiration is an energy limited process. The energy for the latent heat of evaporation comes from two sources: solar radiation (heat function) and advective energy transfer (wind function)

Combination Equation

Evapotranspiration models that take into account both radiation energy and advective energy are called combination equations. The classical combination equation is the Penman Equation. AgriMet uses a variant of the Penman equation.

1982 Kimberly-Penman Equation

The equation used by AgriMet is:

Latent Energy — Radiant Energy — Advective Energy

$$\lambda \cdot ET_r = \frac{\Delta}{\Delta+\gamma}(R_n - G) + \frac{\gamma}{\Delta+\gamma} \cdot 6.43 \cdot W_f(e_s - e_a)$$

$$\frac{\Delta}{\Delta+\gamma} + \frac{\gamma}{\Delta+\gamma} = 1 \qquad \frac{\Delta}{\Delta+\gamma} \approx 0.75$$

1982 Kimberly-Penman Equation Wind Function

The wind function characterizes the effects of wind in the advection (motion of the atmosphere) of sensible heat for ET and is calculated as:

$$W_f = a_w + b_w \cdot U_2$$

1982 Kimberly-Penman Equation Wind Function

The empirical coefficients are calibrated for the effect that surrounding rangeland is wetter earlier in the year and has less advection of sensible heat than later in the year.

$$a_w, b_w = f(day\ of\ year)$$

Reference Crop ET

The Kimberly-Penman equation estimates evapotranspiration for a alfalfa crop (ET_r) that is well-watered with 12 to 20 in of top growth which is denoted as ET_r

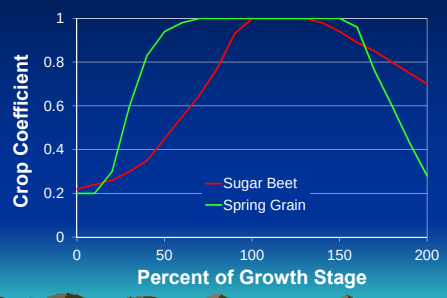
Crop ET

Estimated crop evapotranspiration, which is denoted as ET_c, is calculated as:

$$ET_c = K_c \cdot ET_r$$

where K_c is the crop coefficient.

Normalized Crop Coefficient

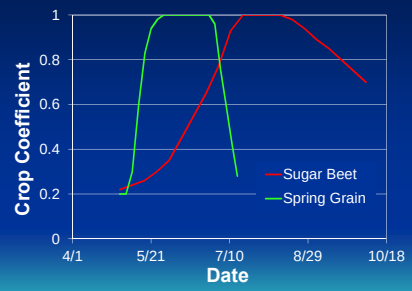


Normalized Crop Coefficient

Spring Grain

Growth Stage (%)	Crop Coefficient	Growth Stage Indicators
0	0.20	Emergence
.....	.....	
70	1.00	Full Canopy
.....	.....	
100	1.00	Heading
.....	.....	
200	0.28	Leaves and Stem Dead

Scaled Crop Coefficient



Soil Water Budget

Using terminology of DEQ Guidance the soil water budget is:

$$IR_{net} = CU - (PPT_e + Carryover\ SM) + LR$$

where IR_{net} is net irrigation requirement, CU is crop consumptive use (ET), PPT_e is effective precipitation SM is soil moisture and LR is the leaching requirement.

Irrigation Water Req't

Using terminology of DEQ Guidance, the irrigation water requirement is:

$$IWR = \frac{IR_{net}}{E_i}$$

where IWR is irrigation water requirement and E_i is irrigation application efficiency.

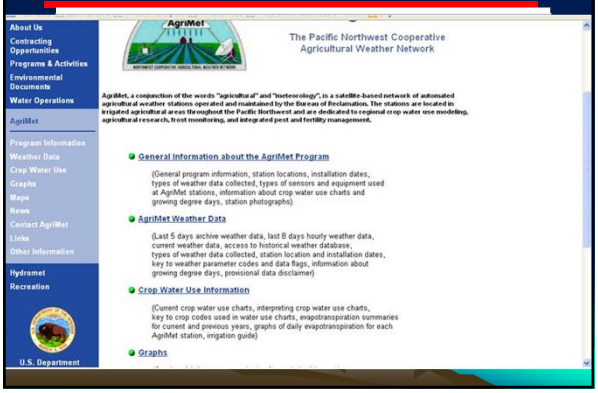
Hydraulic Loading Rate Management

Daily maximum hydraulic loading rate can be determined using a running cumulative seasonal water balance:

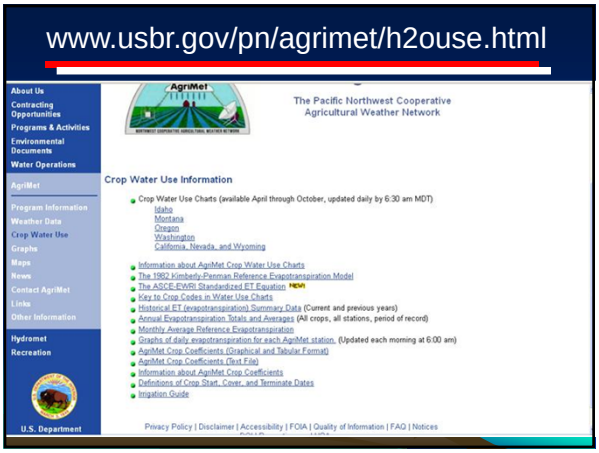
$$IWR_j = \frac{\sum_{j-1} ET - \sum_{j-1} PPT_e}{E_i} - \sum_{j-1} Irrigation + \frac{\sum_j LR}{E_i}$$

where *j* is day of the growing season from start of crop growth and IWR_j is maximum application depth on day *j*.

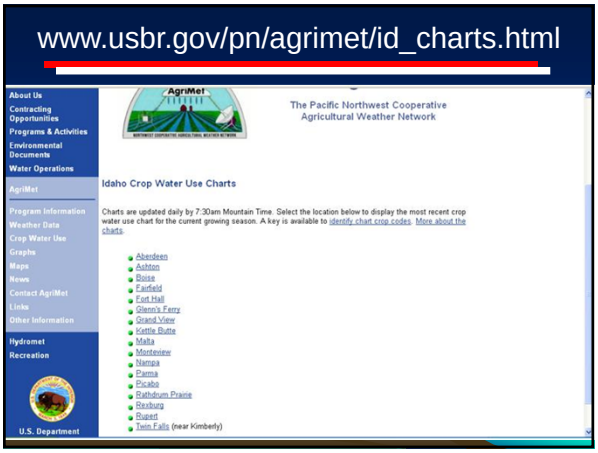
www.usbr.gov/pn/agrimet/



www.usbr.gov/pn/agrimet/h2ouse.html



www.usbr.gov/pn/agrimet/id_charts.html



www.usbr.gov/pn/agrimet/chart/nmpich.txt

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*****************************************************************
*                                                               *
*  ESTIMATED CROP WATER USE - Apr 17, 2012   NMPI                *
*                                                               *
*****************************************************************
*           *         DAILY          *     *     *     *     *  *  *
*           * CROP WATER USE-(IN) * DAILY*     *     *  7  *  14 *
* CROP START*  PENMAN ET  -  Apr  * FORE *COVER* TERM* SUM  * DAY* DAY *
*       DATE*--------------------* CAST * DATE* DATE*  ET  * USE* USE *
*           *  13   14   15   16  *     *     *     *     *  *  *
*-----------*--------------------*------*-----*-----*-----*----*----*
* ETr  02/15* 0.18 0.25 0.25 0.09 * 0.20 *02/15*10/10*  7.2 * 1.3* 2.5 *
*-----------*--------------------*------*-----*-----*-----*----*----*
* ALFP 03/15* 0.14 0.20 0.20 0.07 * 0.16 *05/15*10/10*  2.5 * 1.0* 1.8 *
*-----------*--------------------*------*-----*-----*-----*----*----*
* ALFM 03/15* 0.14 0.20 0.20 0.07 * 0.16 *05/15*10/10*  2.5 * 1.0* 1.8 *
*-----------*--------------------*------*-----*-----*-----*----*----*
* PAST 03/10* 0.11 0.16 0.16 0.06 * 0.13 *05/05*10/10*  2.5 * 0.8* 1.5 *
*-----------*--------------------*------*-----*-----*-----*----*----*
* LAWN 03/10* 0.14 0.20 0.20 0.07 * 0.16 *04/25*10/10*  3.3 * 1.0* 2.0 *
*-----------*--------------------*------*-----*-----*-----*----*----*
* WGRN 02/15* 0.18 0.25 0.25 0.09 * 0.20 *05/05*07/05*  5.8 * 1.2* 2.5 *
*-----------*--------------------*------*-----*-----*-----*----*----*
* SGRN 03/15* 0.12 0.18 0.18 0.07 * 0.14 *06/10*07/25*  1.9 * 0.8* 1.4 *
*-----------*--------------------*------*-----*-----*-----*----*----*
* SGRN 04/05* 0.04 0.05 0.06 0.02 * 0.04 *06/20*08/05*  0.4 * 0.3* 0.4 *
*****************************************************************
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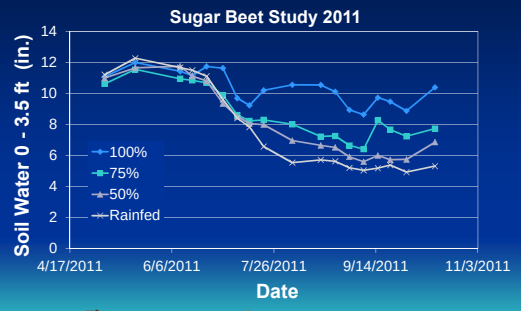
Numerical Example

Location: Treasure Valley LR = 0
Center Pivot System E_i = 0.9
Water Application Depth = 0.6

Date	ET	∑ET	∑PPTe	∑(ET-PPT$_e$)/E$_i$	∑Irrig	IWR	Irrig
	in.	In.	in.	in.	in.	in.	in.
4/12	0.14	1.89	0.0	2.10	1.8	0.30	
4/13	0.14	2.03	0.0	2.26	1.8	0.46	
4/14	0.20	2.23	0.0	2.48	1.8	0.68	0.6
4/15	0.20	2.43	0.0	2.70	2.4	0.30	
4/16	0.07	2.50	0.07	2.70	2.4	0.30	

Effectiveness



Visual Confirmation

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Summary

The AgriMet system provides data that can be used to determine hydraulic loading rates for wastewater land application systems in a relatively simple and effective manner.

Potential Issues

1. Lack of AgriMet station near wastewater land application site.
2. Lack of crop coefficient curve.

Alfalfa vs. Grass Reference Crop ET

Two reference crop definitions are in use in various parts of the world. Caution must be exercised not to mix grass-based crop coefficient values with alfalfa reference ET and vise versa.

Crop Coefficient Conversion

$$K_{c(grass)} = K_{ratio} \cdot K_{c(alfalfa)}$$

where K_{ratio} ranges from 1.0 to 1.3, depending upon climate; 1.05 for humid, calm conditions, 1.2 for semi-arid, moderately windy conditions, and 1.35 for arid, windy conditions.