Comparison of Daily ET Estimates for Sprinkler-Irrigated Sugar Beets from a Cloud-based Irrigation Scheduling Tool and Remote Sensing

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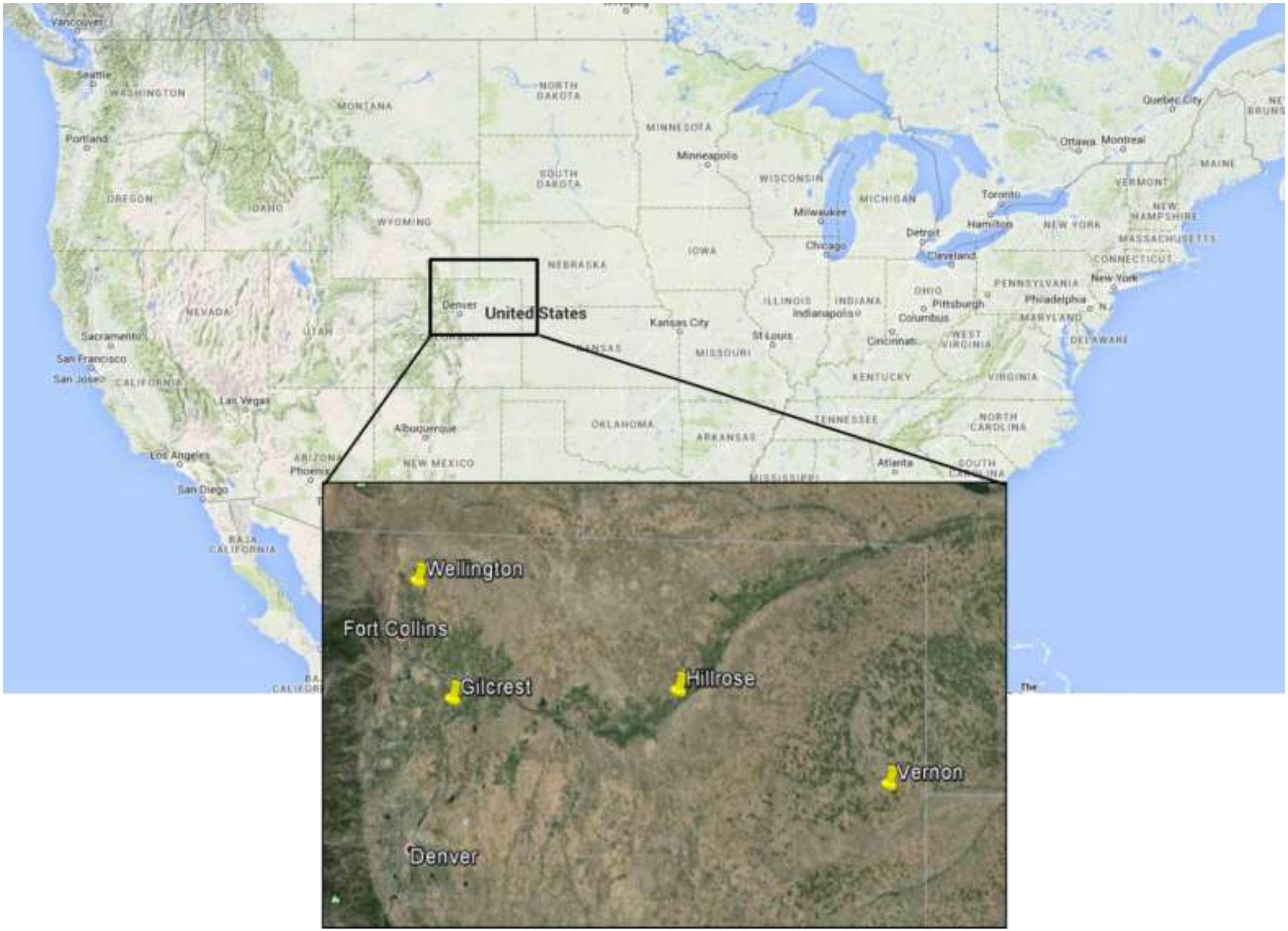
Objectives

- Compare daily sugar beet ET_c estimated using the K_{cr} approach and remote sensing
- Evaluate the feasibility of incorporating remotely-sensed ET_c into daily soil water balance calculations of a cloud-based irrigation scheduler

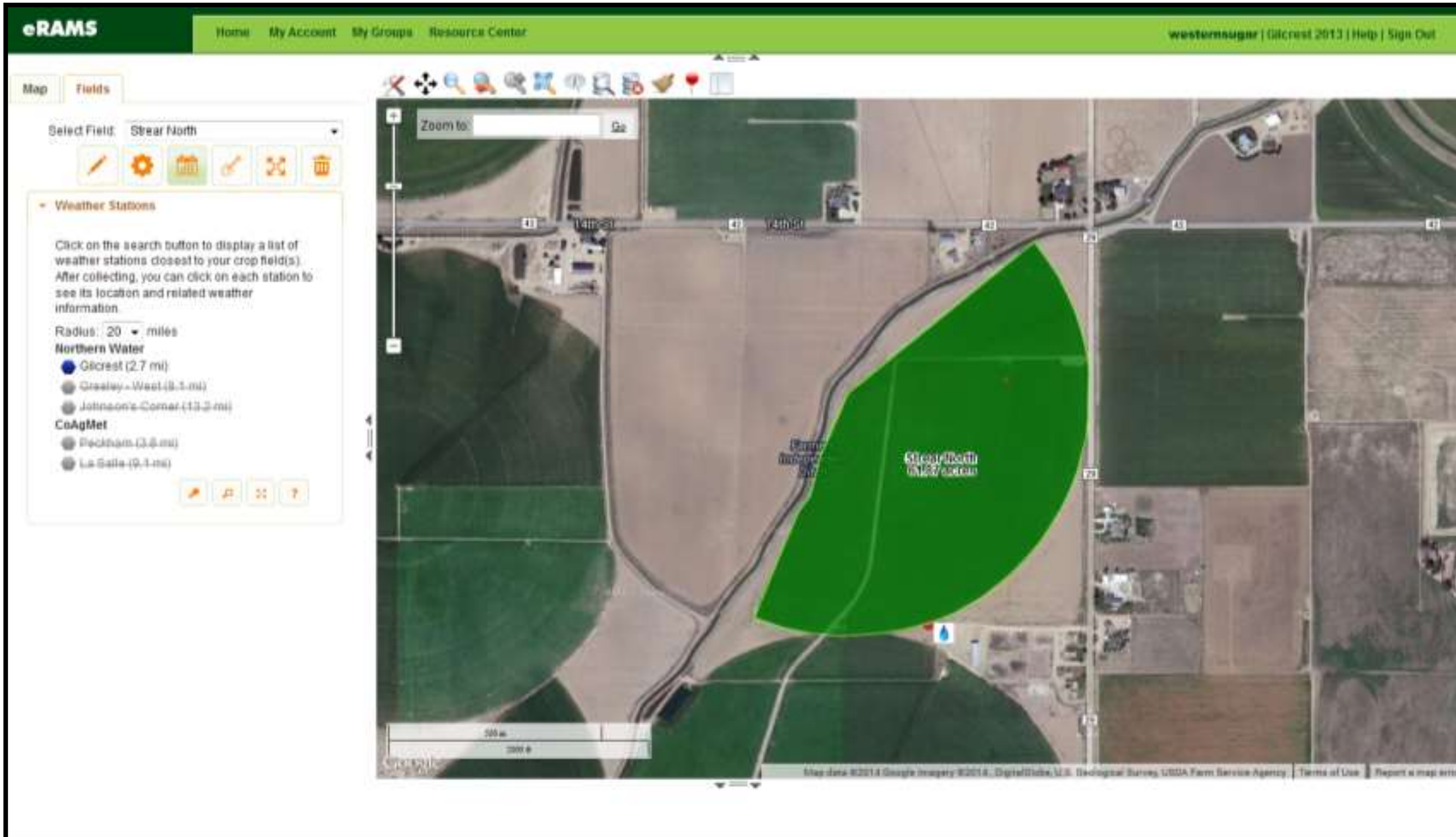
Locations of sugar beet fields



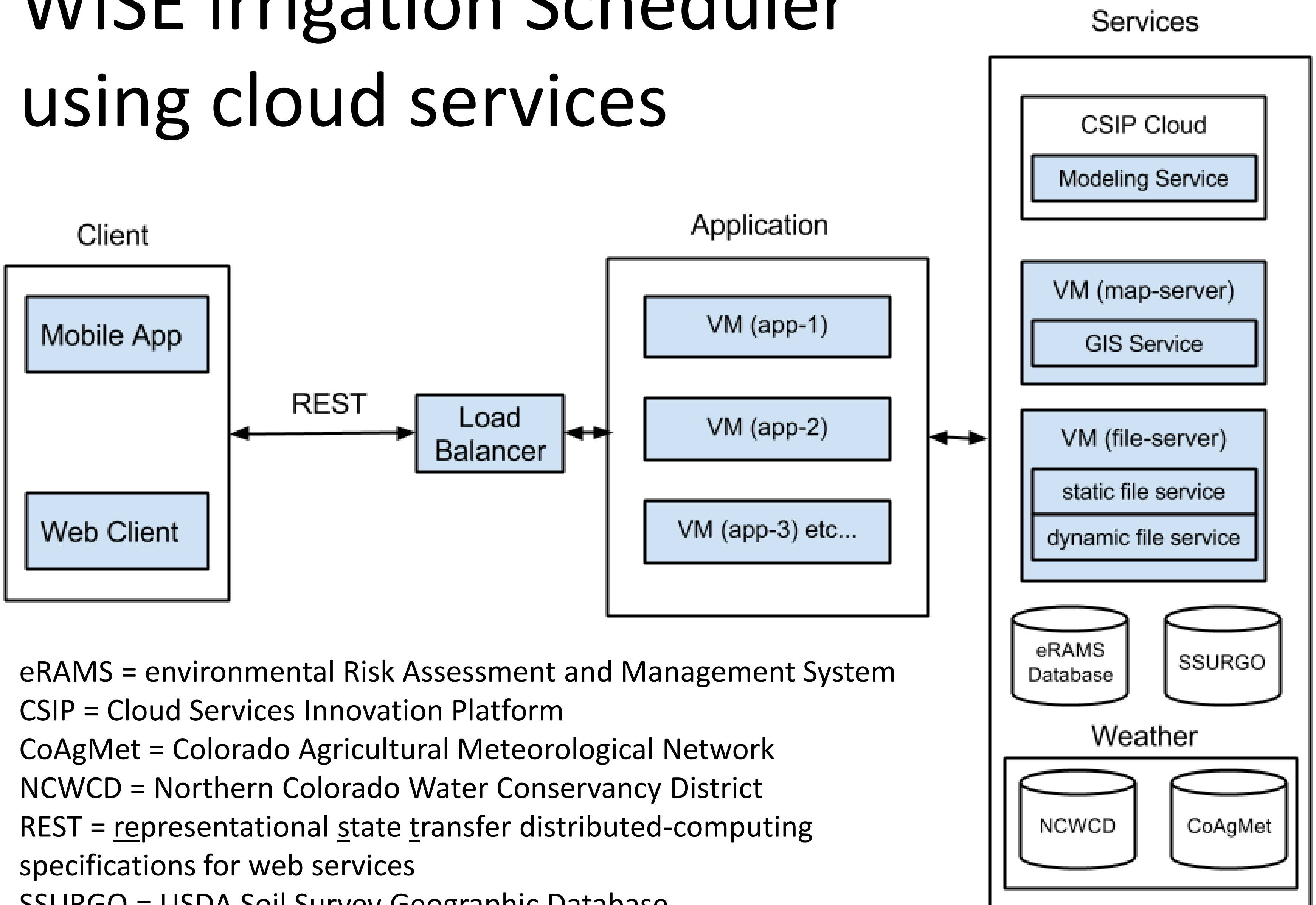

LAI-2000
Plant Canopy Analyzer

Water Irrigation Scheduler for Efficient Application

WISE



WISE Irrigation Scheduler using cloud services



eRAMS = environmental Risk Assessment and Management System
CSIP = Cloud Services Innovation Platform
CoAgMet = Colorado Agricultural Meteorological Network
NCWCD = Northern Colorado Water Conservancy District
REST = representational state transfer distributed-computing specifications for web services
SSURGO = USDA Soil Survey Geographic Database
VM = virtual machine

WISE Irrigation Schedule

Estimation of crop evapotranspiration (ET_c) (alfalfa reference, no water stress)

$$ET_c = ET_r \times K_{cr}$$

where

ET_r = reference crop ET (tall reference like alfalfa)

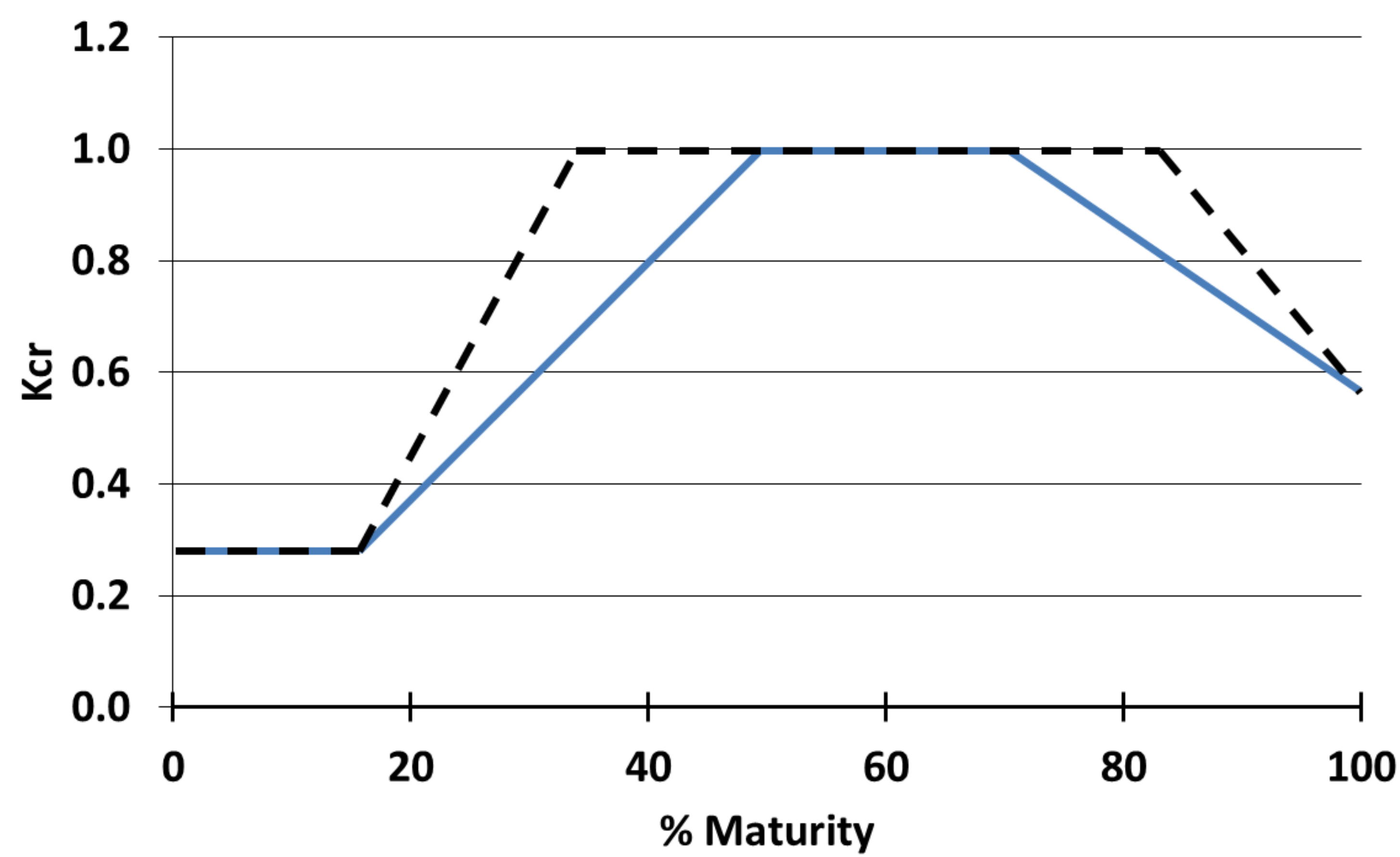
= the ET rate from a **uniform surface** of **dense**, actively growing vegetation (**hypothetical crop**) having specified height (**50 cm or 20 inches** for alfalfa) and surface resistance (to vapor transport), **not short of soil water**, and representing an **expanse of at least 100 m** (328 ft) of the same or similar vegetation (ASCE-Standardized Reference ET equation)

K_{cr} = crop coefficient based on tall (alfalfa) reference

$$= \frac{ET_c}{ET_r}$$

Sugar beet K_{cr} values

K_{cr} values for the original and modified curves.			
Curve	% Maturity	K_c	K_c Value
Original			
Cutoff 1	15	Initial	0.26
Cutoff 2			
Cutoff 3			
Cutoff 1			
Cutoff 2			
Cutoff 3			



Estimation of crop evapotranspiration (ET_c) (with water stress)

$$ET_c = ET_r \times K_{cr} \times K_s$$

where K_s is a water stress coefficient (0 to 1)

$$K_s = \frac{(\max d_{PAW}) - D}{(1 - MAD) * (\max d_{PAW})}$$

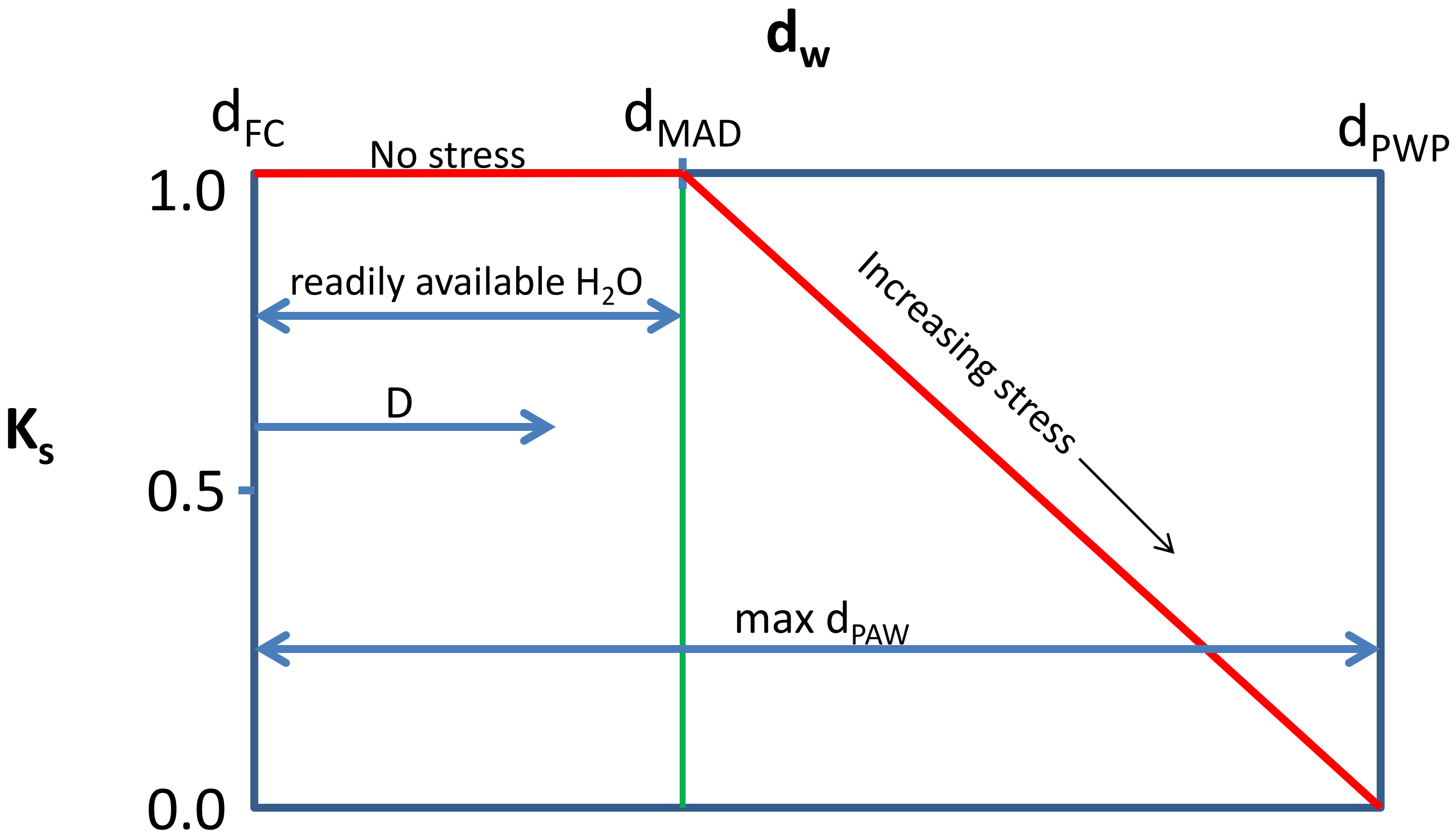
$\max d_{PAW}$ = maximum depth of plant available water; $d_{FC} - d_{PWP}$

D = soil water deficit; $d_{FC} - d_w$

MAD = management allowed depletion (decimal fraction)

Note: K_s should be set equal to 1 if $D < d_{MAD}$. A K_s of 1 means that there is no water stress. The K_s will work with both alfalfa or grass references and crop coefficients.

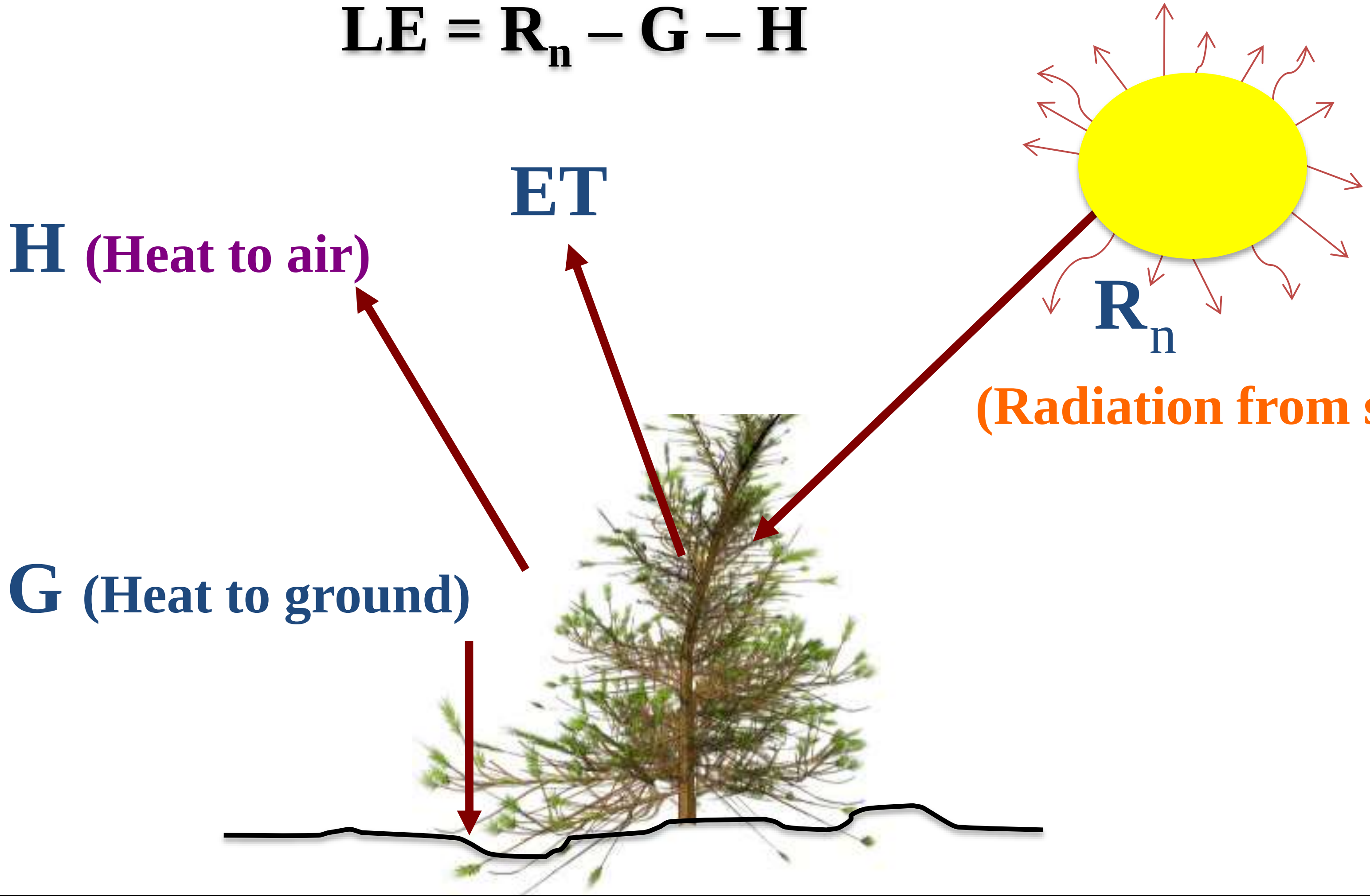
Water stress coefficient, K_s
(shown as the red line)



Remote Sensing of Evapotranspiration (ReSET)

Using Surface Energy Balance ET is calculated as a "residual" of the energy balance

$$LE = R_n - G - H$$



Description of Energy Balance Models

The use of the energy balance equation:

$$R_n = LE + G + H$$

Net Radiation (R_n), Soil Heat Flux (G), Sensible Heat Flux (H), and Latent Energy consumed by ET (LE).

Model R_n, G and H, then determining LE as a residual.

$$LE = R_n - G - H$$

LE and EF Calculation

- Using LE the evaporative fraction (EF) is calculated:

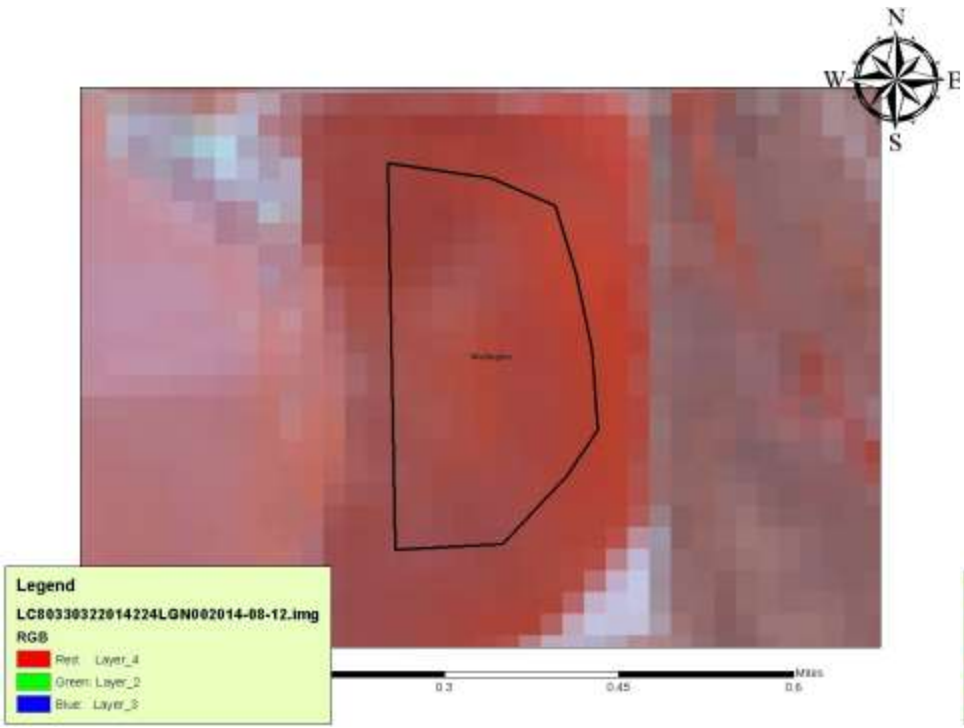
$$EF = LE/(R_n - G)$$ Evap./Available energy

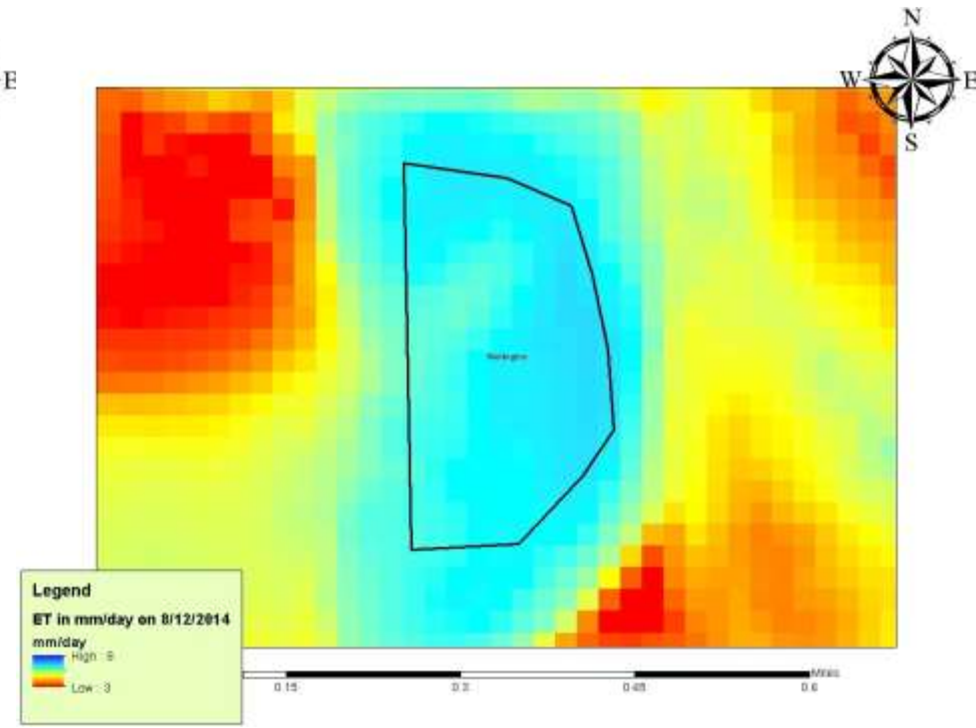
- It assumes that this fraction remains constant throughout the day, therefore can be used in determining daily ET as shown below:

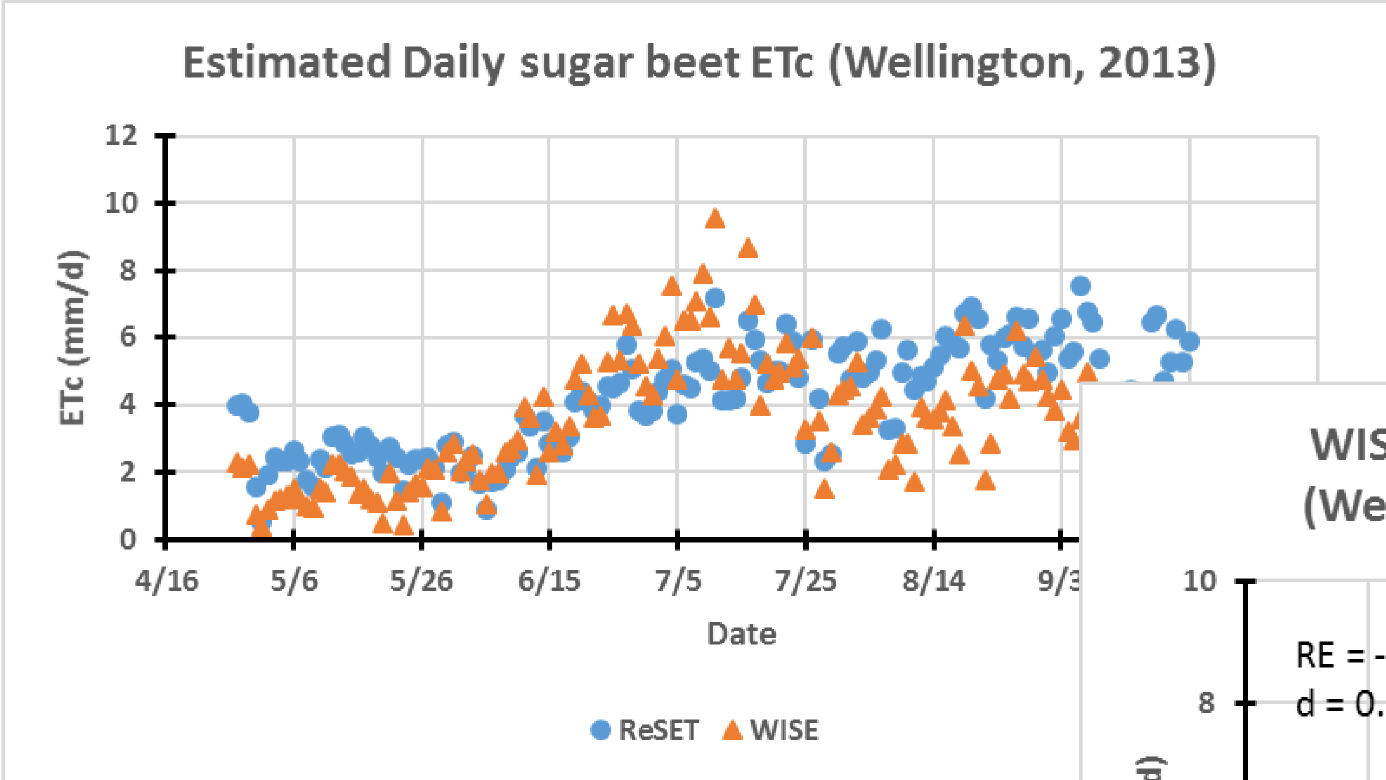
$$ET_{24} = 86{,}400 * EF * (R_{n24} - G_{24})/ \lambda_v$$

- Under calm weather conditions or moderate advection for non-irrigated areas, the assumption of EF being constant can be acceptable.

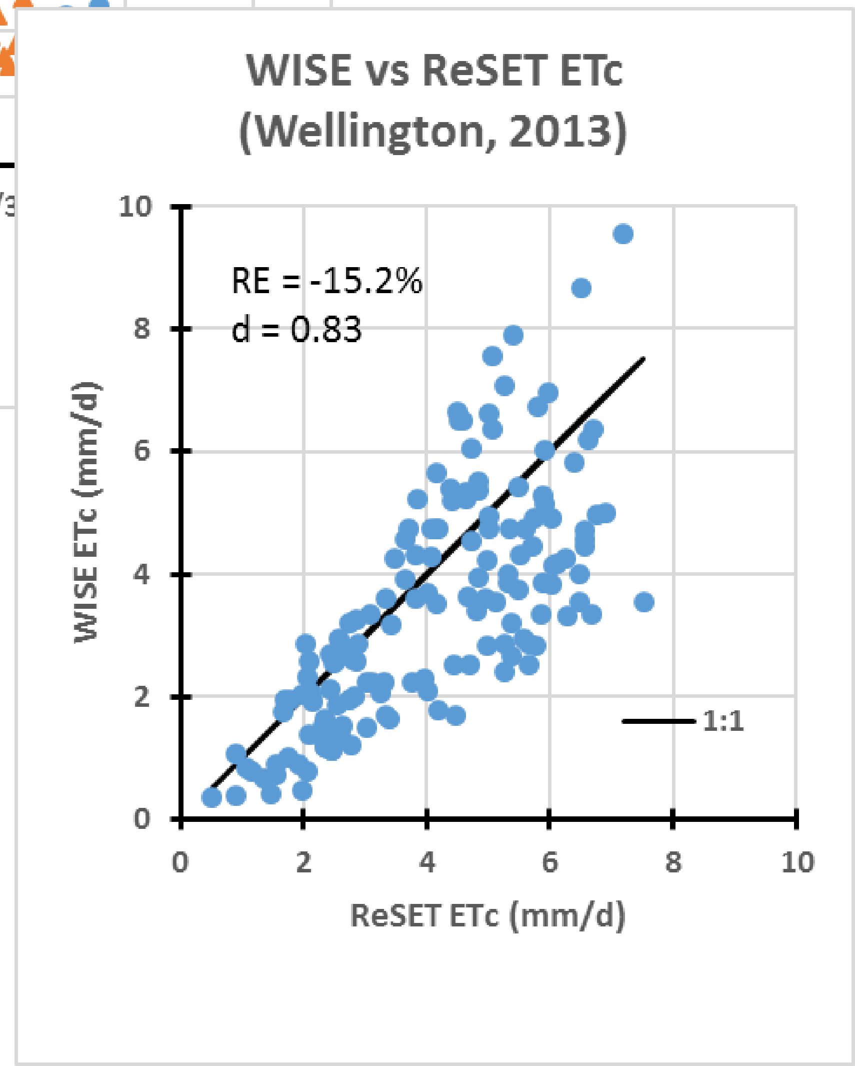
Landsat and ReSET rasters for sugar beet field in Wellington, CO; 8/12/2014





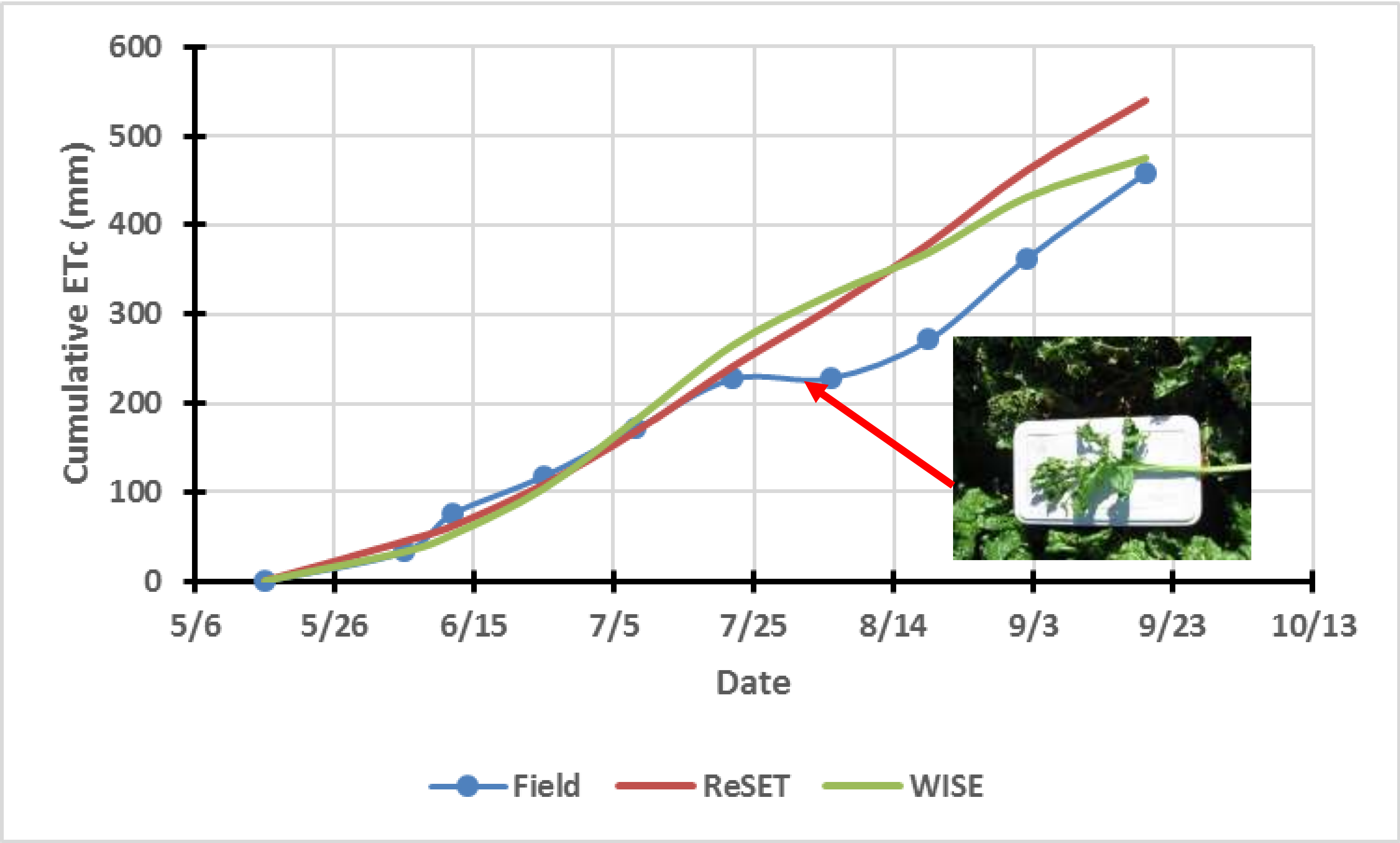


Estimated Daily sugar beet ETc (Wellington, 2013)
ETc (mm/d)
12
10
8
6
4
2
0
4/16
5/6
5/26
6/15
7/5
7/25
8/14
9/3
Date
ReSET
WISE



WISE vs ReSET ETc
(Wellington, 2013)
RE = -15.2%
d = 0.83
WISE ETc (mm/d)
10
8
6
4
2
0
0
2
4
6
8
10
ReSET ETc (mm/d)
1:1

Cumulative sugar beet ET_c Wellington, CO; 2013



Comparative statistics (WISE vs ReSET sugar beet ET_c)

Site	RE (%)	RMSE (mm/d)	d	n	Distance to station (km)
2013					
Gilcrest	-14.0	1.8	0.80	136	4.3
Wellington	-15.2	1.4	0.83	152	10.8
Hillrose	-29.0	2.1	0.79	149	20.3
Vernon	-13.9	1.9	0.79	127	28.2
2014					
Gilcrest	5.1	1.0	0.92	124	4.0
Wellington	-11.5	1.3	0.86	124	12.2
Hillrose	-11.3	1.2	0.87	134	22.0
Vernon	-3.1	1.7	0.85	167	28.2

RE = relative error of mean; RMSE = root mean square error;
d = index of agreement; n = number of days

Summary

- Daily sugar beet ET_c estimated by WISE was 3 to 29% less than that estimated by ReSET, with RMSE ranging from 1.0 to 2.1 mm/d.
- Index of agreement between WISE and ReSET daily ET_c ranged from 0.79 to 0.92.
- Many factors affect the accuracy of estimated ET_c: quality of weather station data; shape of K_{cr} curve; quality of Landsat images; assumptions used in energy balance calculations
- Landsat image processing in ReSET needs to be automated to incorporate estimated ET_c into WISE.

For more information, go to http://wise.colostate.edu/

or see:

Andales, A.A., Bauder, T.A., and Arabi, M. 2014. A Mobile Irrigation Water Management System Using a Collaborative GIS and Weather Station Networks. In: Practical Applications of Agricultural System Models to Optimize the Use of Limited Water (Ahuja, L.R., Ma, L., Lascano, R.; Eds.), Advances in Agricultural Systems Modeling, Volume 5. ASA-CSSA-SSSA, Madison, Wisconsin, pp. 53-84.

Bartlett, A.C., Andales A.A., Arabi, M., Bauder, T.A. 2015. A Smartphone App to Extend Use of a Cloud-based Irrigation Scheduling Tool. Computers and Electronics in Agriculture 111:127-130.

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