Satellite Mapping of Crop Coefficients and Crop Water Requirements in California

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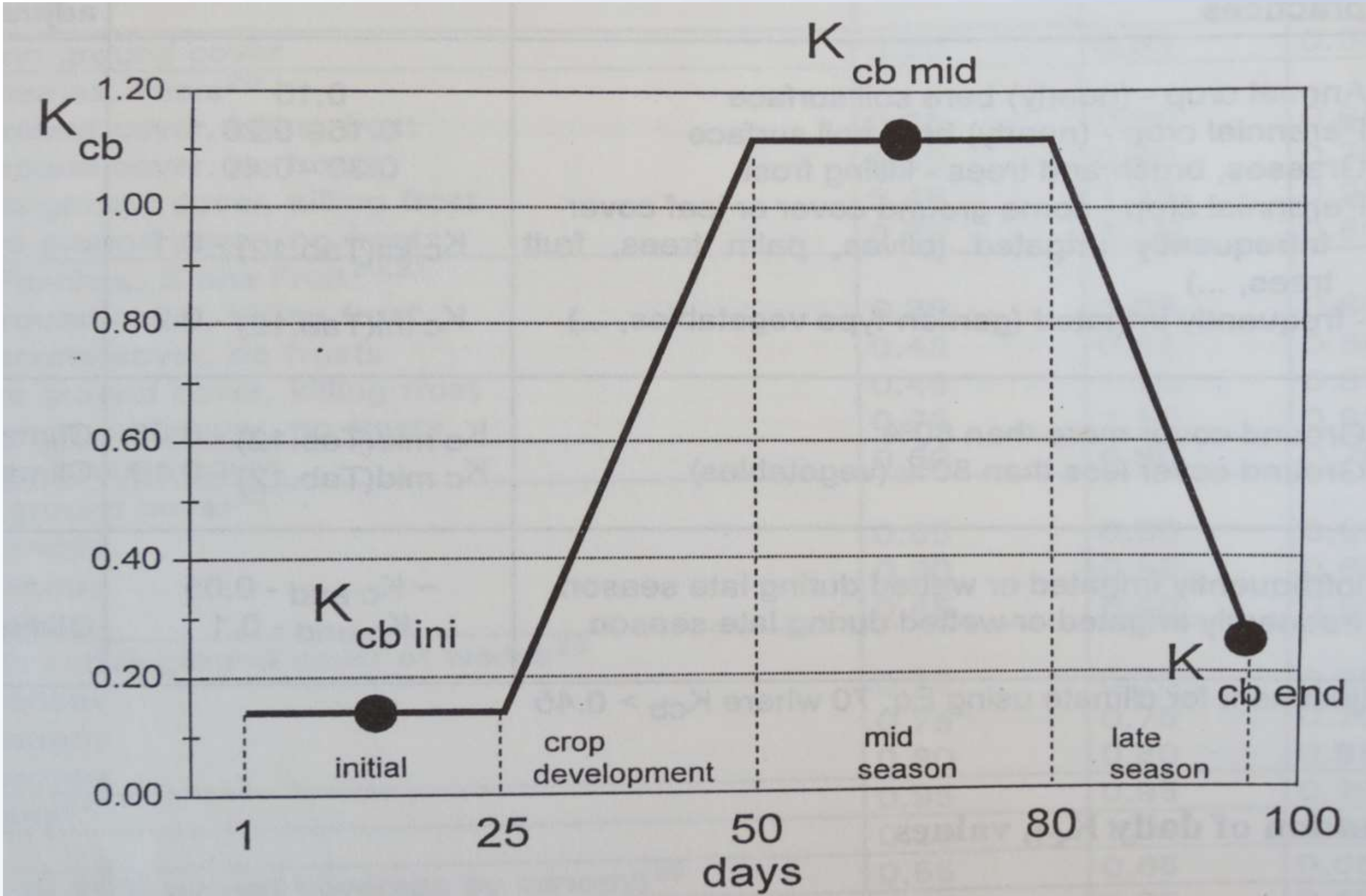
CA Dept. of Water Resources

U.S. Council on Irrigation and Drainage
Colorado ET Workshop 2016

Ft. Collins, CA
13 October 2016

Crop Coefficients: FAO-56



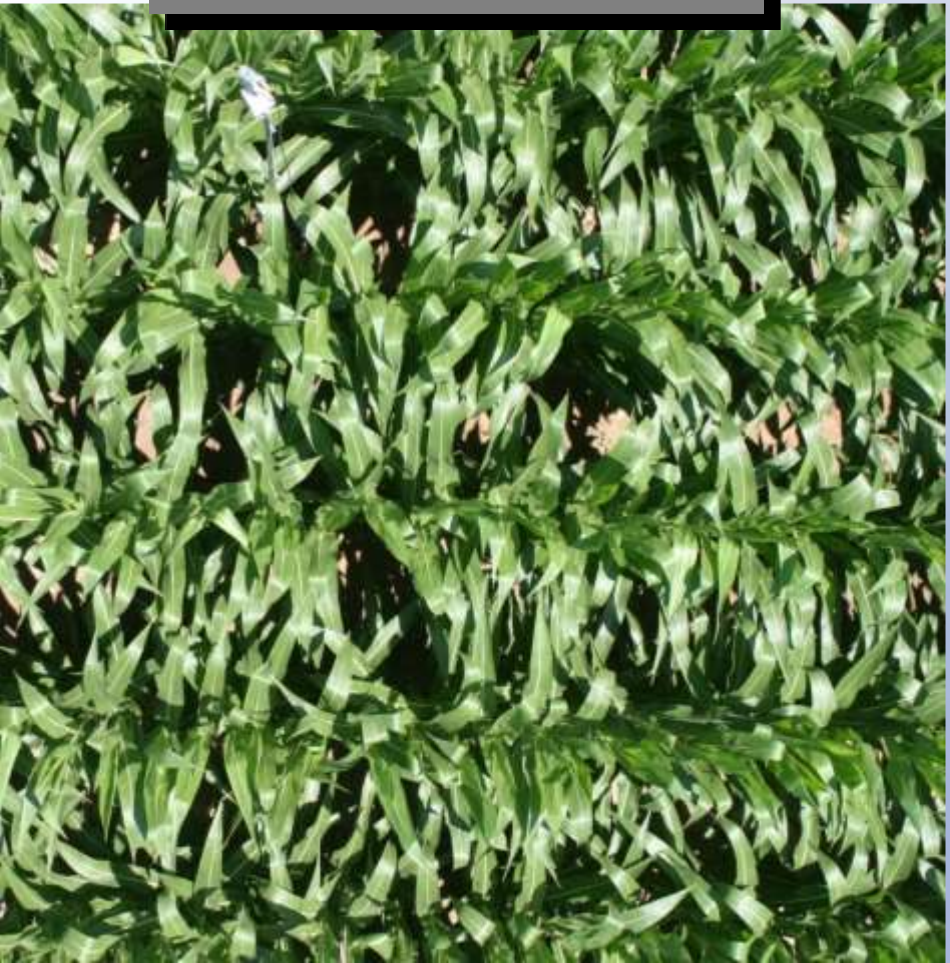



Annual Crops

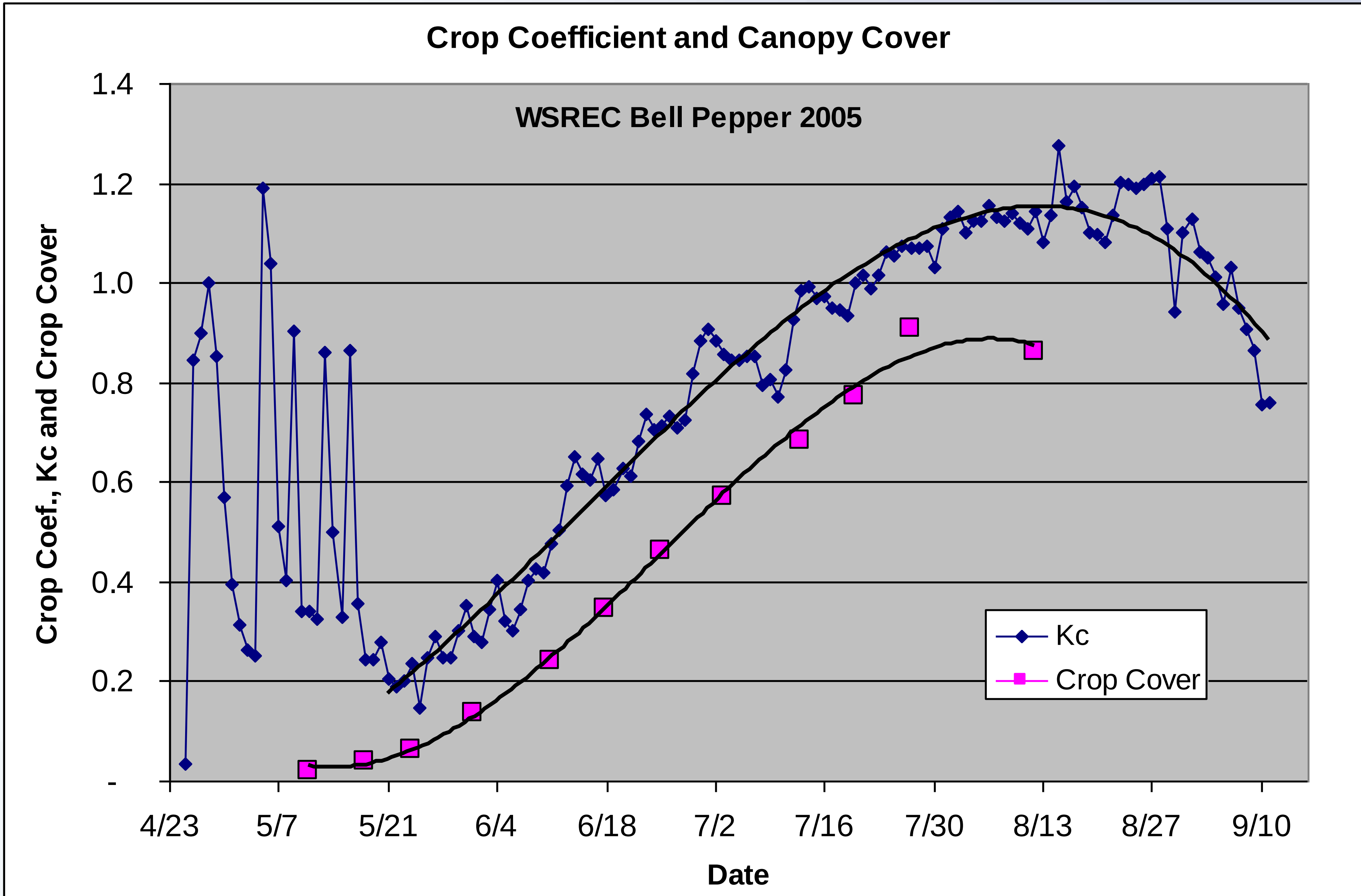
Vineyards

Ground Cover: LIRF Corn 7/31/2008

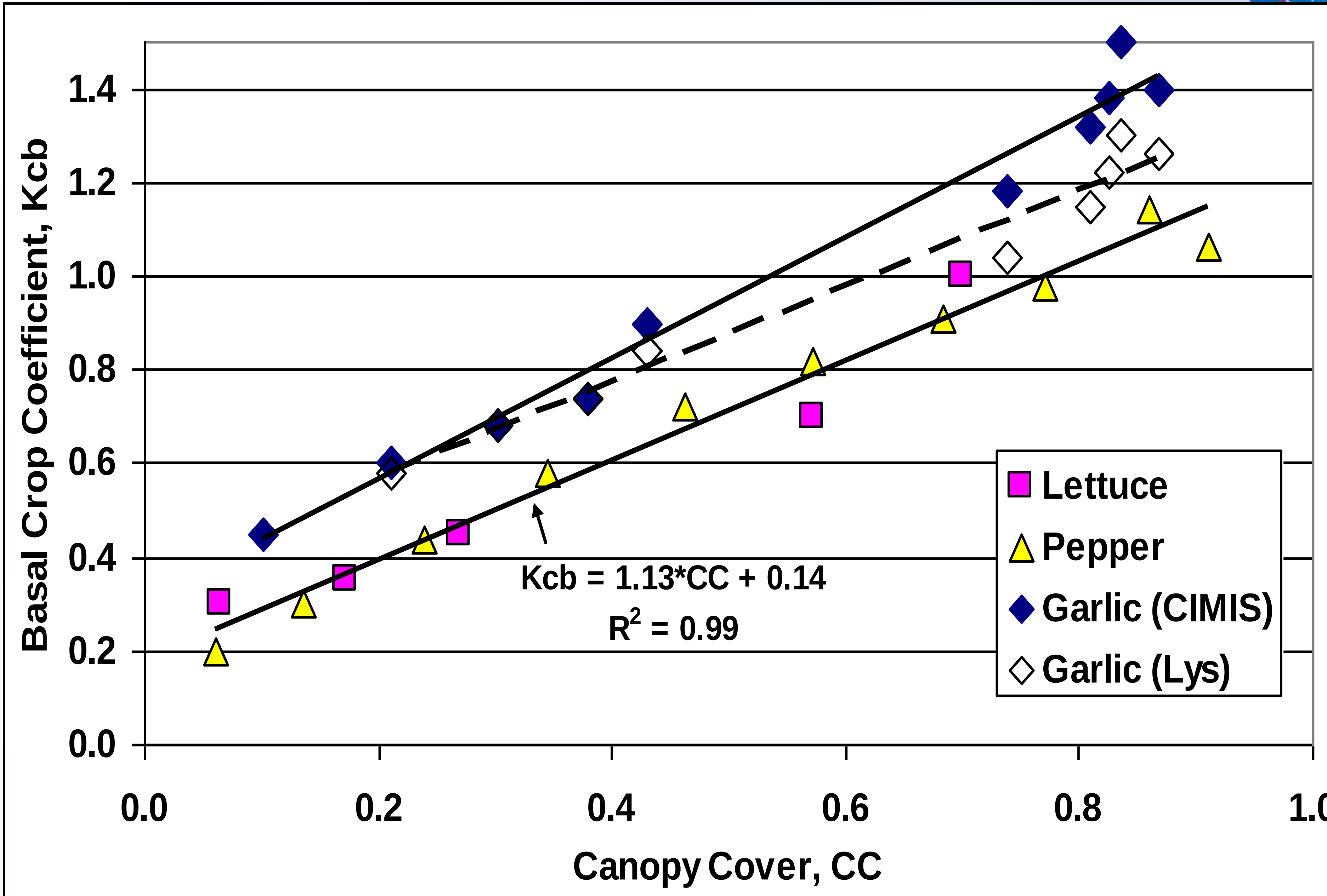
Tmnt 1: 91%



Tmnt 6: 63%



Crop Coefficient and Canopy Cover
WSREC Bell Pepper 2005
Crop Coef., Kc and Crop Cover
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-
4/23
5/7
5/21
6/4
6/18
7/2
7/16
7/30
8/13
8/27
9/10
Date
Kc
Crop Cover



Basal Crop Coefficient, Kcb
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Canopy Cover, CC
Kcb = 1.13*CC + 0.14
R2 = 0.99
Lettuce
Pepper
Garlic (CIMIS)
Garlic (Lys)

Irrig Sci (2009) 28:17–34
DOI 10.1007/s00271-009-0182-z

ORIGINAL PAPER

Estimating crop coefficients from fraction of ground cover and height

Richard G. Allen · Luis S. Pereira

Received: 13 May 2009 / Accepted: 15 July 2009 / Published online: 16 September 2009

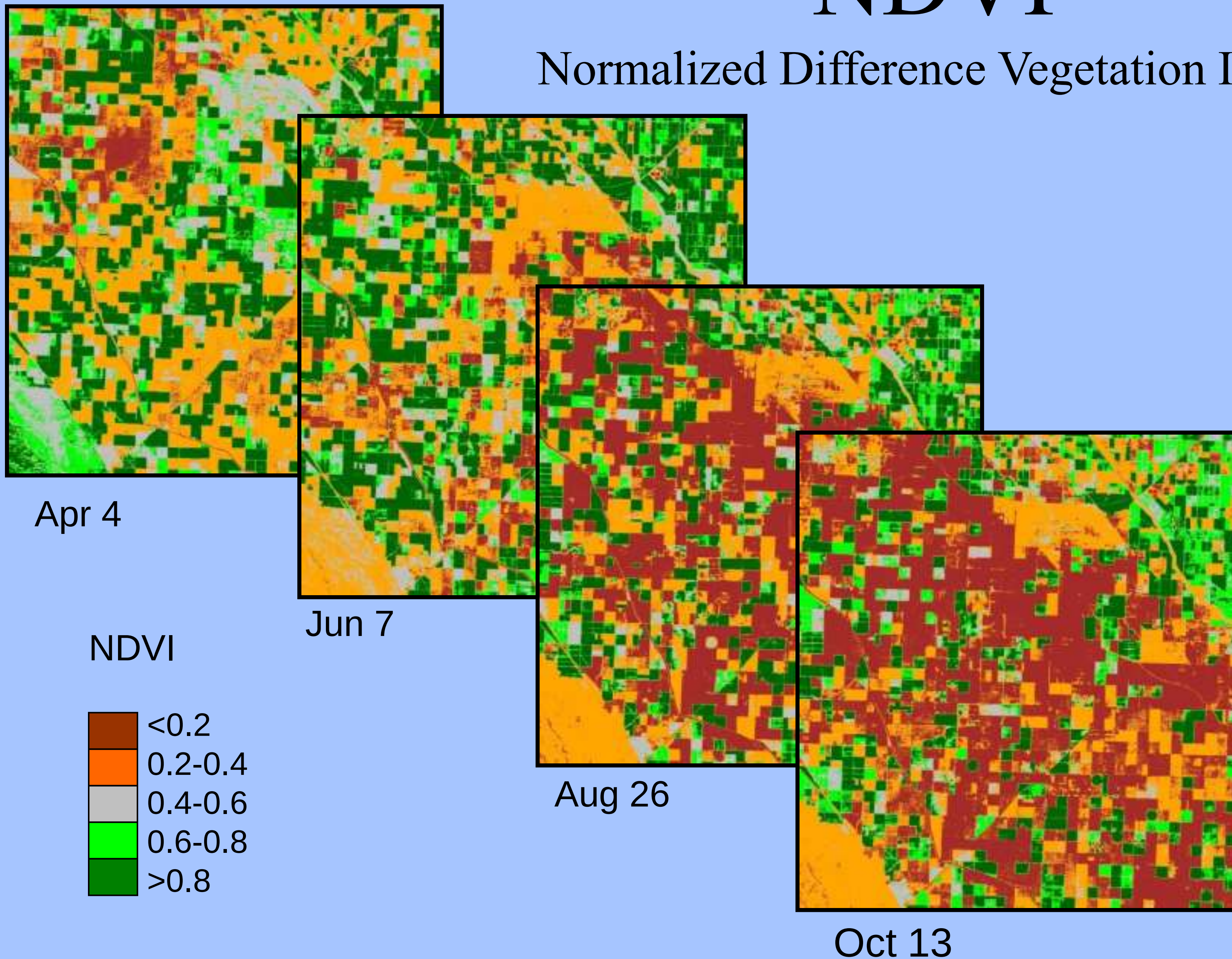
Abstract The FAO-56 procedure for estimating the crop coefficient K_c as a function of fraction of ground cover and crop height has been formalized in this study using a density coefficient K_d. The density coefficient is multiplied by a basal K_c representing full cover conditions, $K_{cb\ full}$, to produce a basal crop coefficient that represents actual conditions of ET and vegetation coverage when the soil surface is dry. $K_{cb\ full}$ is estimated primarily as a function of crop height. $K_{cb\ full}$ can be adjusted for tree crops by multiplying by a reduction factor (F_r) estimated using a mean leaf stomatal resistance term. The estimate for basal

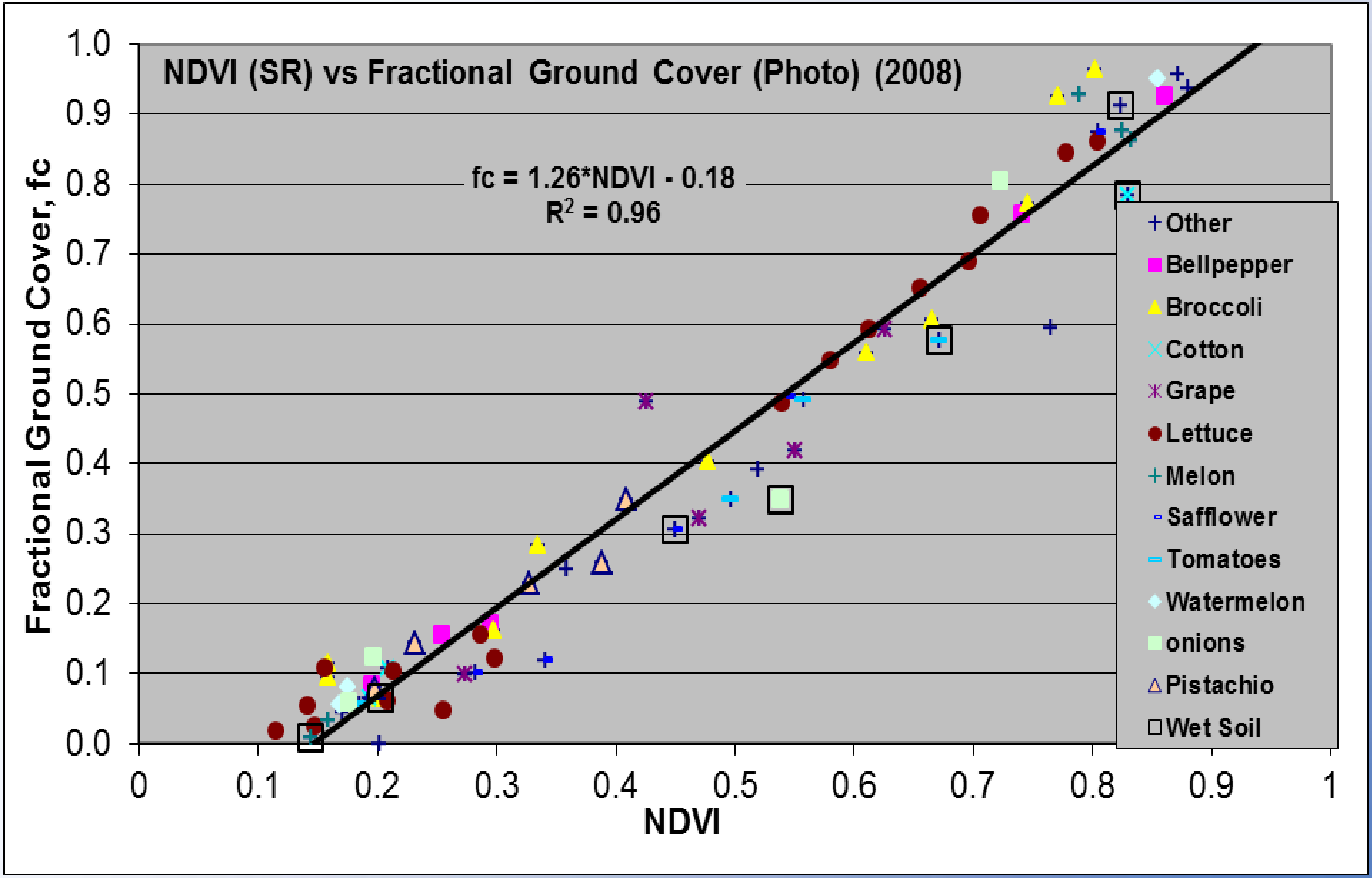
Introduction

The two-step crop coefficient (K_c) × reference evapotranspiration (ET_{ref}) method has been a successful and dependable means to estimate evapotranspiration (ET) and crop water requirements. The method utilizes weather data to estimate ET for a reference condition and multiplies that estimate by a crop coefficient that represents the relative rate of ET from a specific crop and condition to that of the reference. The reference condition is generally ET from a clipped, cool season, well-watered grass (ET_o) or from a

NDVI

Normalized Difference Vegetation Index





NDVI (SR) vs Fractional Ground Cover (Photo) (2008)
fc = 1.26*NDVI - 0.18
R2 = 0.96
Fractional Ground Cover, fc
NDVI
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Other
Bellpepper
Broccoli
Cotton
Grape
Lettuce
Melon
Safflower
Tomatoes
Watermelon
onions
Pistachio
Wet Soil

Development of Reflectance-Based Crop Coefficients for Corn

Christopher M. U. Neale, Walter C. Bausch, Dale F. Heermann

ASSOC. MEMBER ASAE | ASSOC. MEMBER ASAE | MEMBE ASAE

ABSTRACT

Concurrent measurements of reflected canopy radiation and the basal crop coefficient (K_{cb}) for corn were conducted throughout a season in order to develop a reflectance-based crop coefficient model. Reflectance was measured in Landsat Thematic Mapper bands TM3 (0.63 - 0.69 um) and TM4 (0.76 - 0.90 um) and used in the calculation of a vegetation index called the normalized difference (ND). A linear transformation of the ND was used as the reflectance-based crop coefficient (K_{cr}). The transformation equates the ND for dry bare soil and the ND at effective cover, to the basal crop coefficient for dry soil evaporation and at effective cover, respectively. Basal crop coefficient values for corn were obtained from daily evapotranspiration measurements of corn and alfalfa, using hydraulic weighing lysimeters. The Richards growth curve function was fitted to both sets of data. The K_{cb} values were determined to be within −2.6% and 4.7% of the K_{cr} values. The date of effective cover obtained from the K_{cb} data was within four days of the date on which the ND curve reached its maxima according to the Richards function. A comparison of the K_{cr} with basal crop curves from the literature for several years of data indicated good agreement. Reflectance-based crop coefficients are sensitive to periods of slow and fast growth induced by weather conditions, resulting in a real time coefficient, independent from the traditional time base parameters based on the day of planting and effective cover.

INTRODUCTION

Crop coefficients and calculated reference crop

soil conditions from those under which they were developed. However, these coefficients provide an inexpensive and practical method for estimating actual crop ET throughout a growing season with reasonable accuracy for scheduling irrigations.

The use of reflected canopy radiation to obtain a real time reflectance-based basal crop coefficient for corn has previously been studied by Neale and Bausch (1983) and Bausch and Neale (1987). Those studies compared Wright's (1982) basal crop coefficient for corn with a transformation of the normalized difference (Deering et al., 1975), calculated using remotely sensed reflected canopy radiation data obtained throughout a growing season. One hypothesis in those comparisons was that the normalized difference curve reached its maxima close to the date of effective cover on the basal crop coefficient curve. However, no evapotranspiration data were available at that time to estimate basal crop coefficients.

The objective of this paper is to show the feasibility of using remote sensing methodology to estimate crop coefficients for corn by comparing simultaneous field estimates of corn basal crop coefficients and reflectance-based crop coefficients. A comparison of the reflectance-based crop coefficients with coefficients from the literature will also be made for several years of data.

BACKGROUND

Agronomic Variables and Evapotranspiration

Specific factors that influence evapotranspiration of plants include plant species, percent canopy cover, plant population, row spacing and orientation, rooting depth and extent, stage of growth, light reflection, and soil moisture availability (Gates and Hanks, 1967). Penman

Satellite Irrigation Management Support Project: TOPS - SIMS

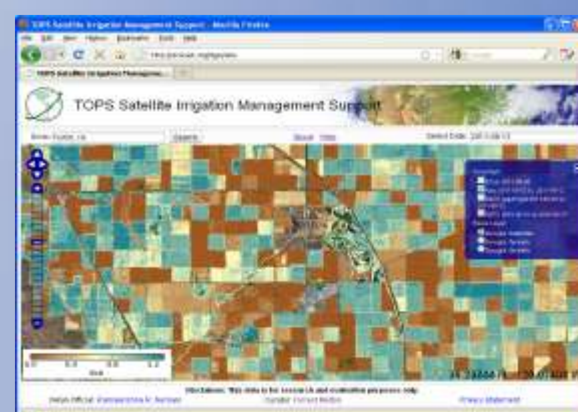
Processing Steps

- At sensor radiance
- LEDAPS
- Surface reflectance
- NDVI
- Fractional ground cover
- K_{cb}
- $ET_{cb} = K_{cb} * ET_{ref}$

Satellite

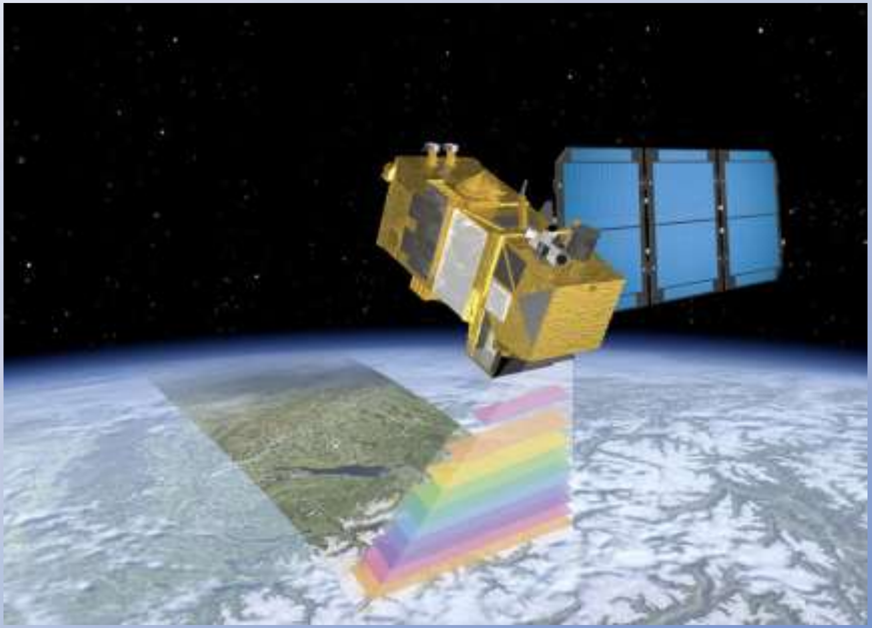
ET Weather Station

Processor



Web browser

Satellite Data



Landsat (TM / ETM+ / OLI)
30m / 0.25 acres
Overpass every 8-16 days

Sentinel-2A
20m / 0.1 acres
Sentinel 2B launch in 2017

Satellite Irrigation Management Support Project: TOPS - SIMS

Processing Steps

- At sensor radiance
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- K_{cb}
- $ET_{cb} = K_{cb} * ET_{ref}$

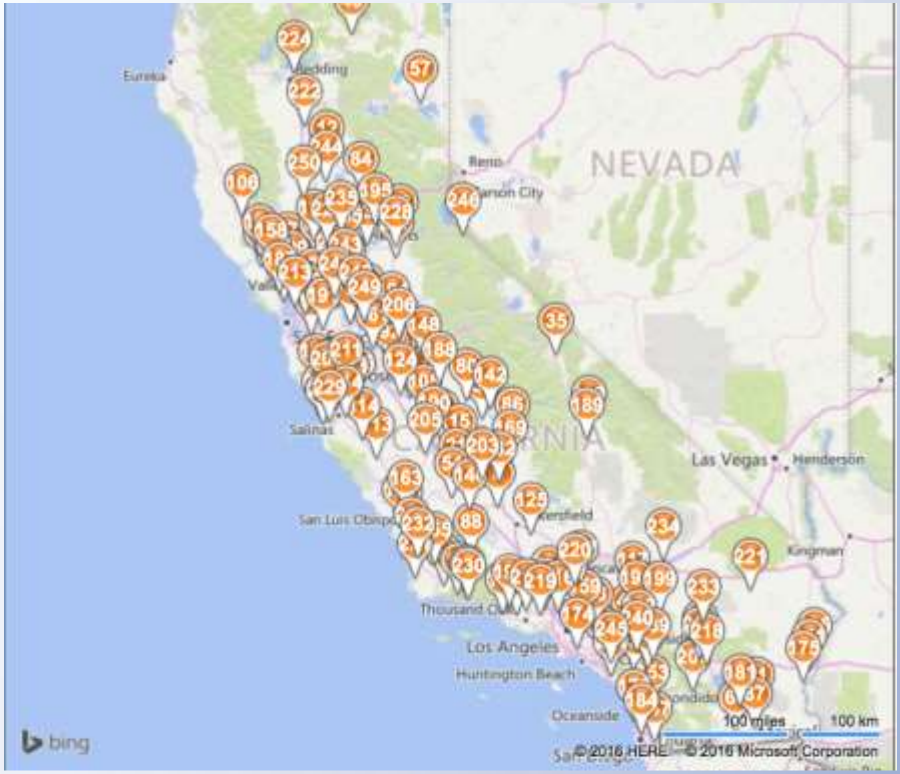
Satellite

ET Weather Station

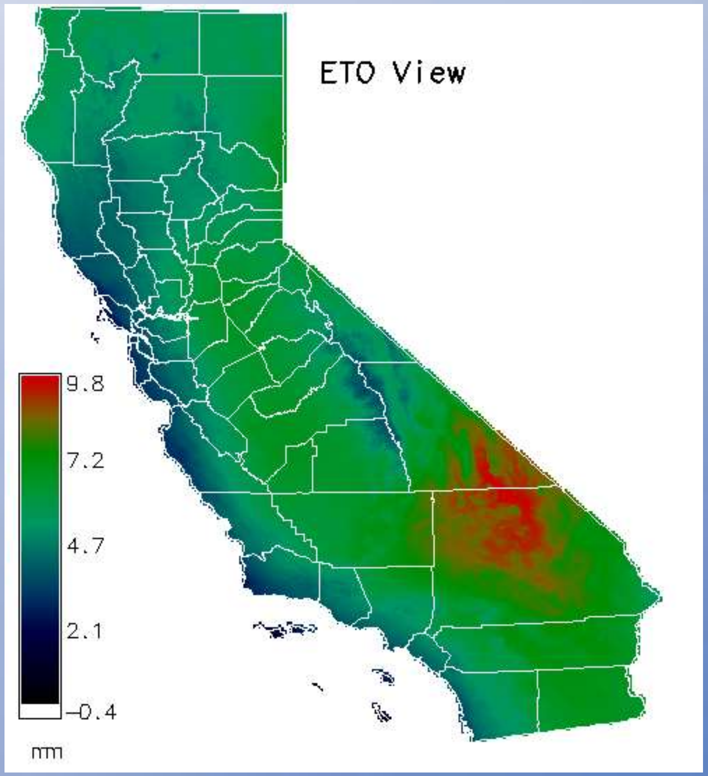
Processor

Web browser

ET_{ref}: CIMIS / Spatial CIMIS



CIMS Station Data, 1982 to present



Spatial CIMIS, 2003 to present

Satellite Irrigation Management Support Project: TOPS - SIMS

Processing Steps

- At sensor radiance
- LEDAPS
- Surface reflectance
- NDVI
- Fractional ground cover
- K_{cb}
- $ET_{cb} = K_{cb} * ET_{ref}$

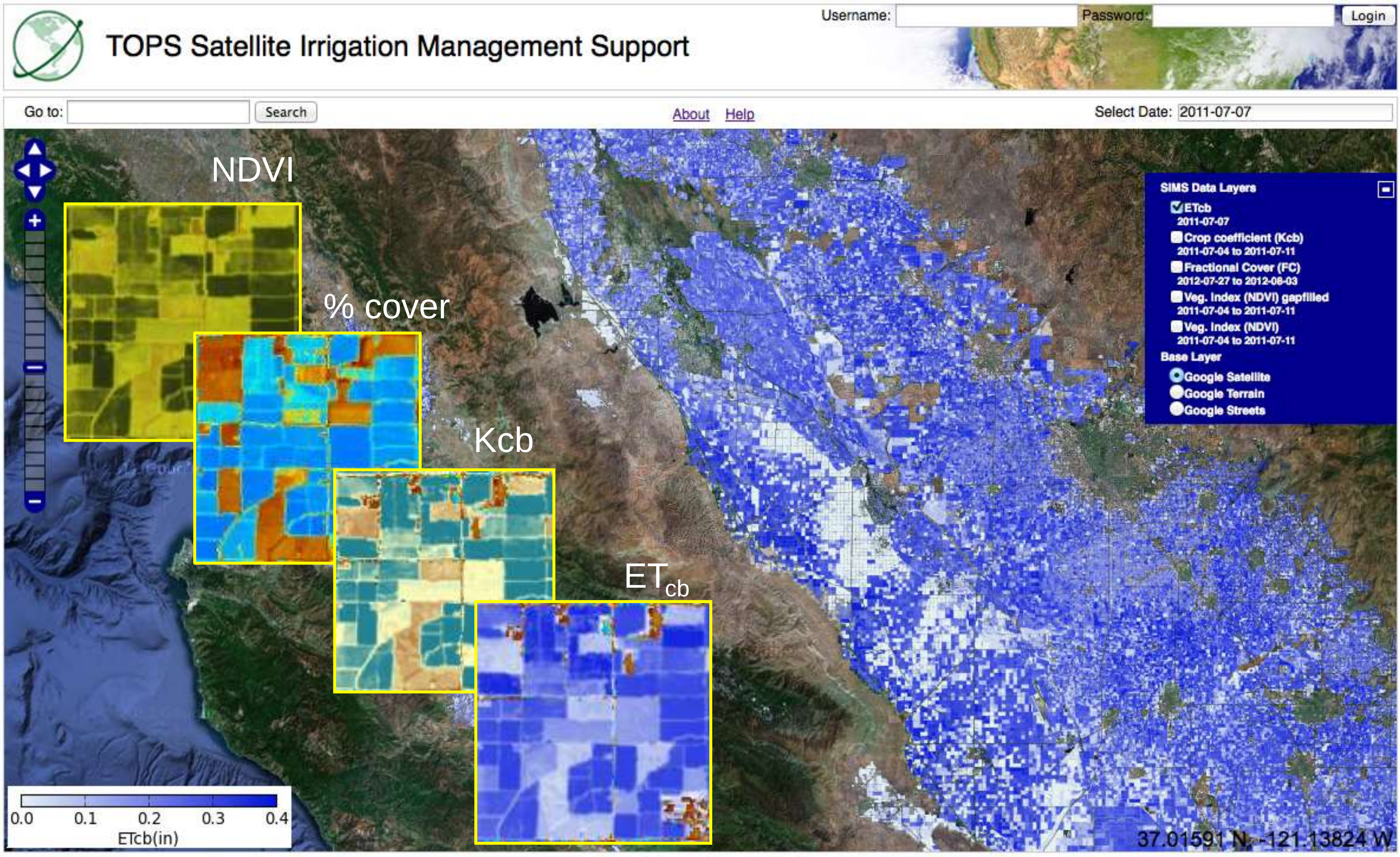
Satellite

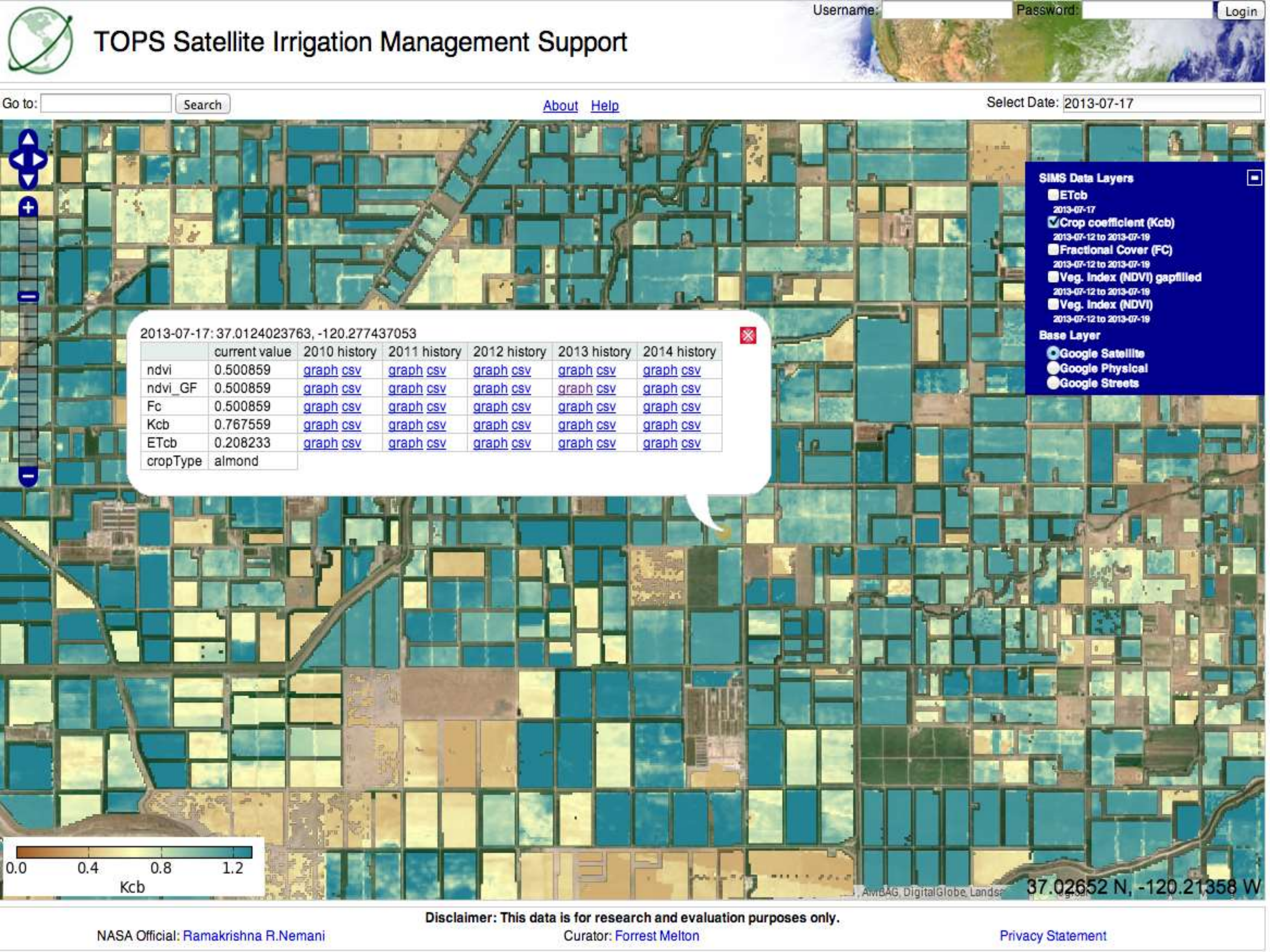
ET Weather Station

Processor

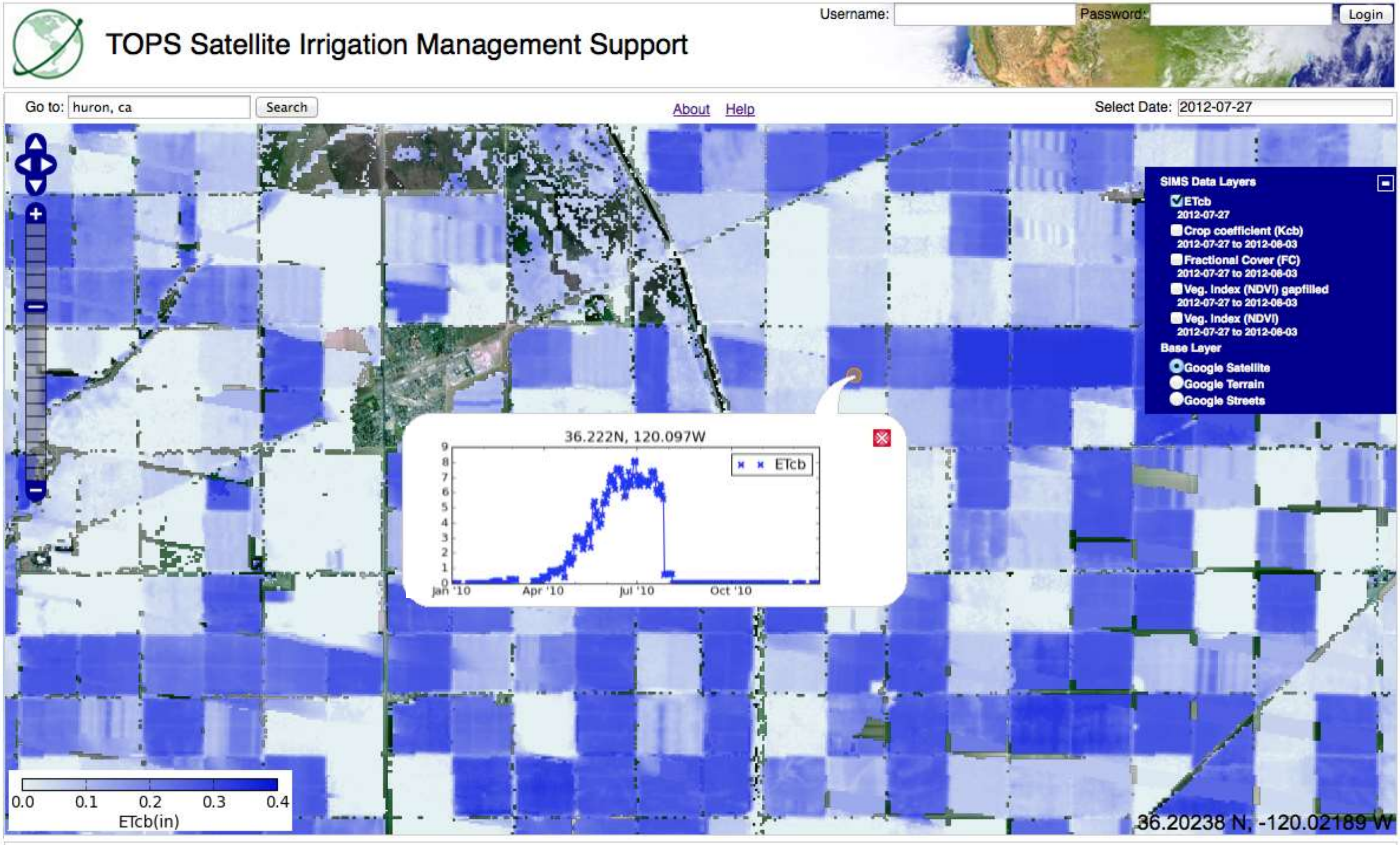
Web browser

Satellite Irrigation Management Support (SIMS) Web Services




TOPS Satellite Irrigation Management Support
Username: Password: Login
Go to: Search
About Help
Select Date: 2013-07-17
2013-07-17: 37.0124023763, -120.277437053
current value | 2010 history | 2011 history | 2012 history | 2013 history | 2014 history
ndvi | 0.500859 | graph csv | graph csv | graph csv | graph csv | graph csv
ndvi_GF | 0.500859 | graph csv | graph csv | graph csv | graph csv | graph csv
Fc | 0.500859 | graph csv | graph csv | graph csv | graph csv | graph csv
Kcb | 0.767559 | graph csv | graph csv | graph csv | graph csv | graph csv
ETcb | 0.208233 | graph csv | graph csv | graph csv | graph csv | graph csv
cropType | almond
SIMS Data Layers
ETcb
2013-07-17
Crop coefficient (Kcb)
2013-07-12 to 2013-07-19
Fractional Cover (FC)
2013-07-12 to 2013-07-19
Veg. Index (NDVI) gapfilled
2013-07-12 to 2013-07-19
Veg. Index (NDVI)
2013-07-12 to 2013-07-19
Base Layer
Google Satellite
Google Physical
Google Streets
0.0 0.4 0.8 1.2
Kcb
37.02652 N, -120.21358 W
Disclaimer: This data is for research and evaluation purposes only.
NASA Official: Ramakrishna R.Nemani
Curator: Forrest Melton
Privacy Statement

Satellite Irrigation Management Support (SIMS) Web Services



Accuracy Assessment Field Campaign

Inflow

Soil Water

Deep Perc

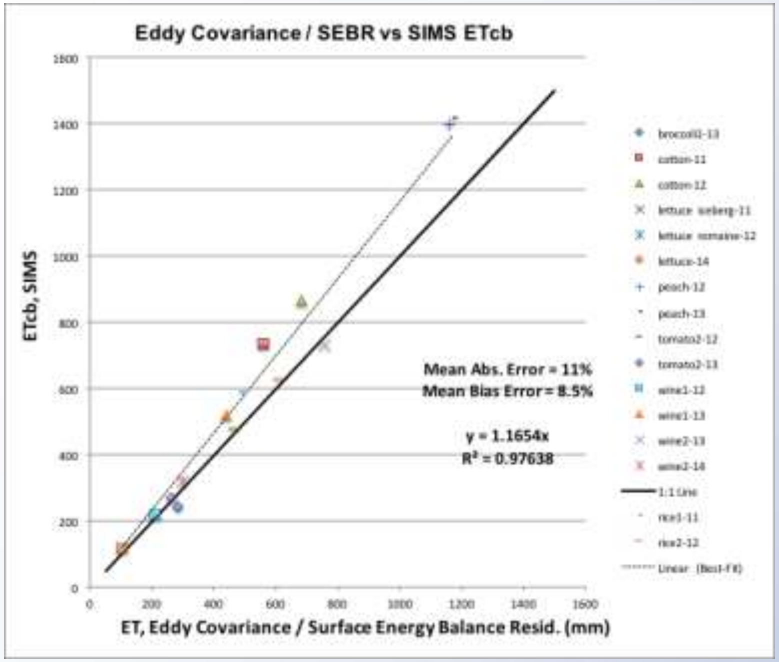
Eddy Covariance

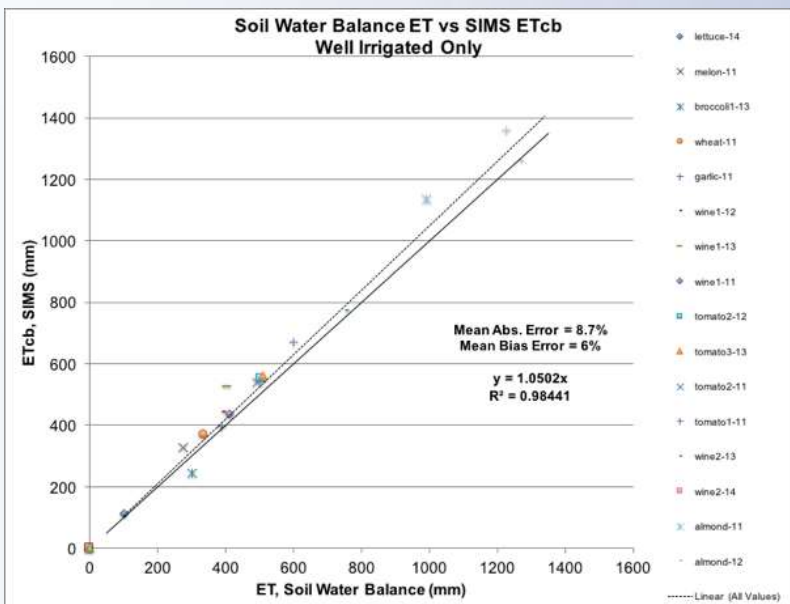
Water Balance and SEB

15 crops

30 sites

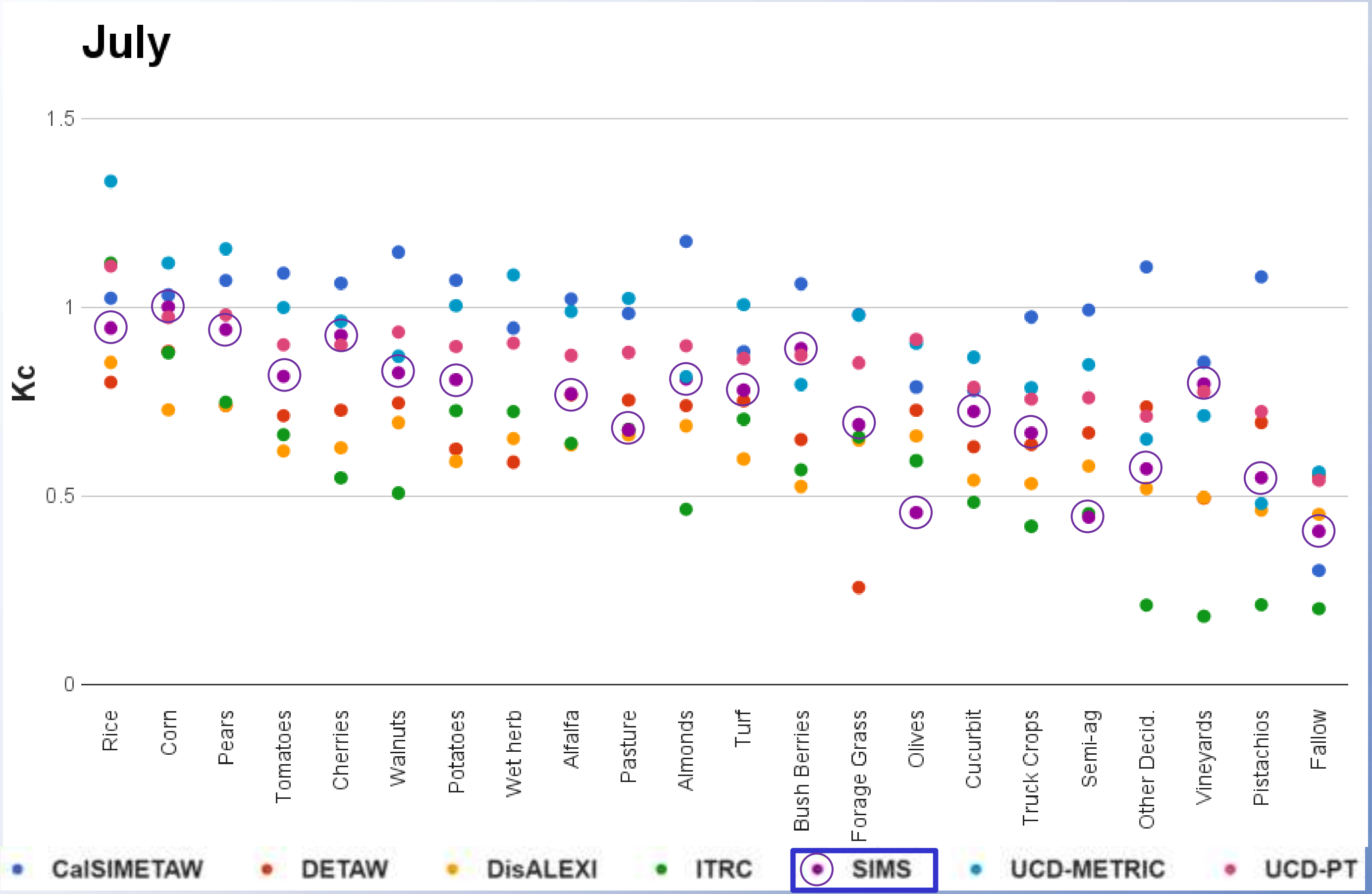
SIMS Accuracy Assessment





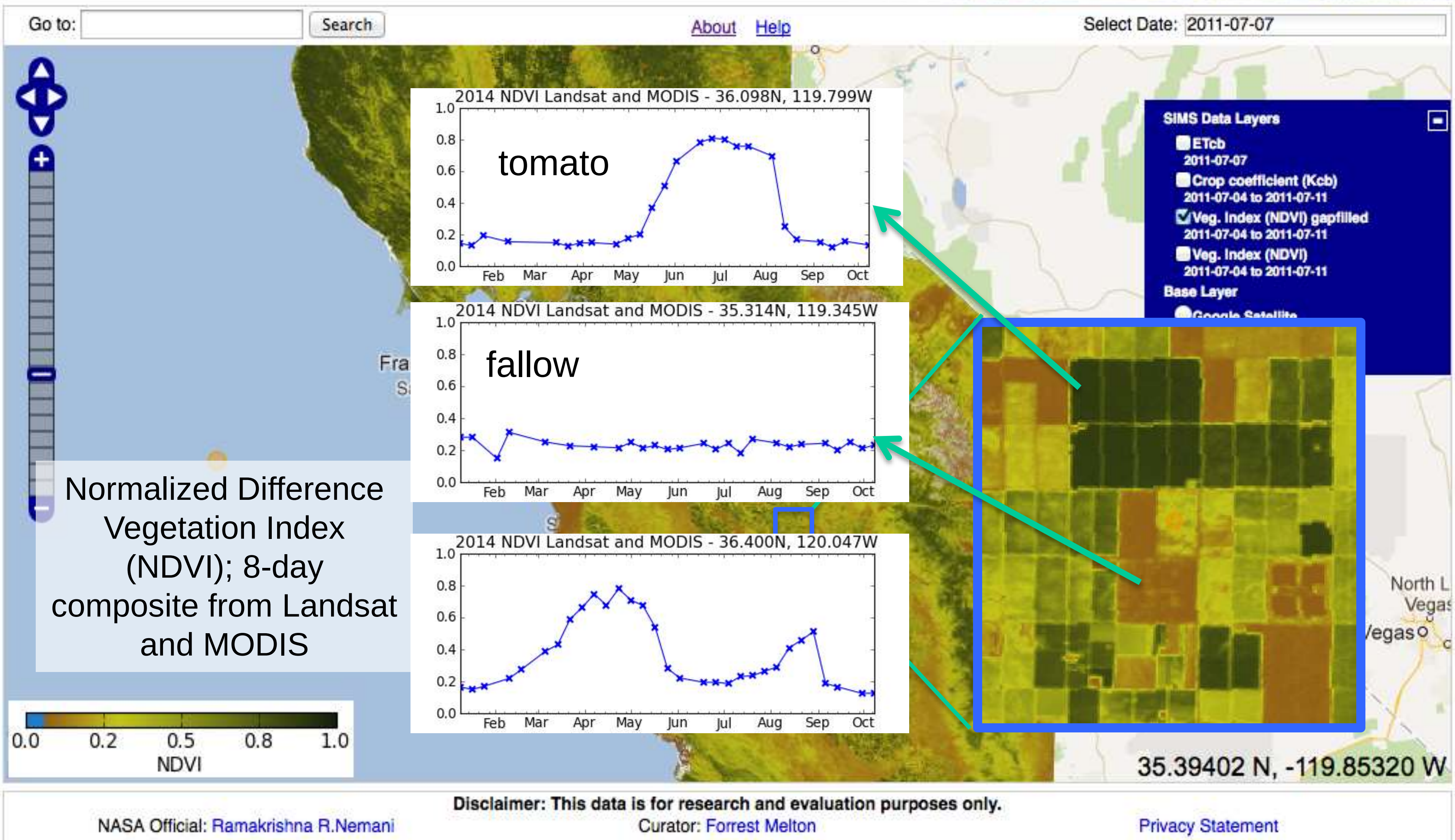
- Field validation campaign completed in partnership with partner growers, CA DWR, CSU Fresno, USDA ARS and UC Davis.
- Data collected for 15 crops at 30 sites using eddy covariance, surface energy balance residual, soil moisture sensor networks.
- Results highly encouraging for seasonal and daily comparisons.
  - 11% mean absolute error for seasonal ETcb vs measured ETa (via eddy covariance / surface energy balance residual; n = 12)
  - 14.2% mean absolute error for seasonal ETcb vs measure ETa (via soil water balance; n = 23) → reduced to 8.7% for well-irrigated crops only (n = 16)

Average Observed ET_{rf} by Crop Type for CA Delta



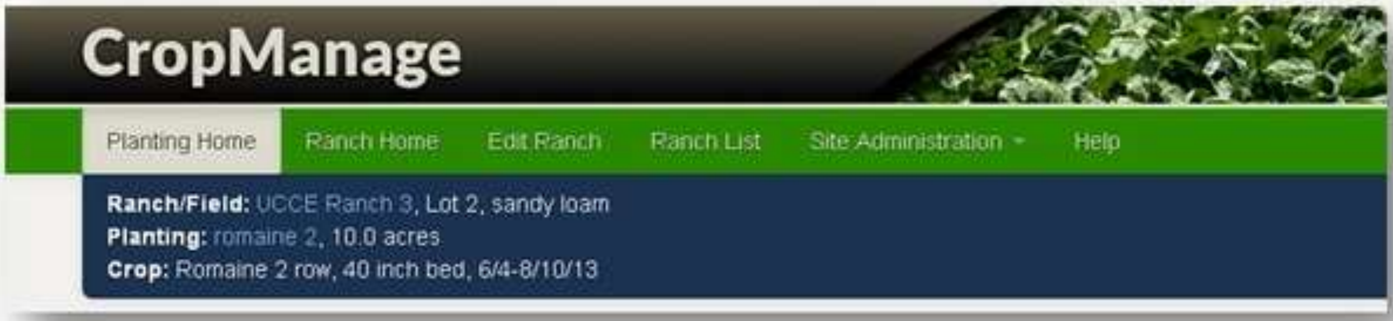
- SIMS close to median of model ensemble for most crop types
- SIMS close to mid-point between two versions of METRIC run by two different expert groups (ITRC and UC Davis)

Monitoring Crop Development



Southern San Joaquin Valley, CA, Field Boundary Polygons

Application Program Interface (API)
for Integration with Other Irrigation Management Software



Irrigation Summary

Show / Hide Columns | Reset Column Order | Show Previous Columns | Show Next Columns

Water Date	Irrigation Method	Recommended Irrigation Interval (days)	Recommended Irrigation Amount (inches)	Recommended Irrigation Time (hours)	Irrigation Water Applied (inches)	Kc	Canopy Cover (%)	Average Reference ET (inches/day)	Total Crop ET (inches)
6/4/13	Germination Sprinkler	N/A	N/A	N/A	0.75 in	0.00	0	0.00	0.00
6/5/13	Germination Sprinkler	1.6	0.22 in	0.72 hrs	0.45 in	1.00	0	0.14	0.14
6/7/13	Germination Sprinkler	1.9	0.36 in	1.18 hrs	0.30 in	0.70	0	0.17	0.23
6/9/13	Germination Sprinkler	1.7	0.39 in	1.29 hrs	0.45 in	0.70	0	0.18	0.25
6/12/13	Sprinkler	3.1	0.28 in	0.95 hrs	0.30 in	0.48	1	0.15	0.21
6/16/13	Sprinkler	2.9	0.40 in	1.33 hrs	0.45 in	0.37	1	0.20	0.30
Totals			1.64 in	5.47 hrs	2.70 in				1.13 in

New Watering | View Rainfall Data

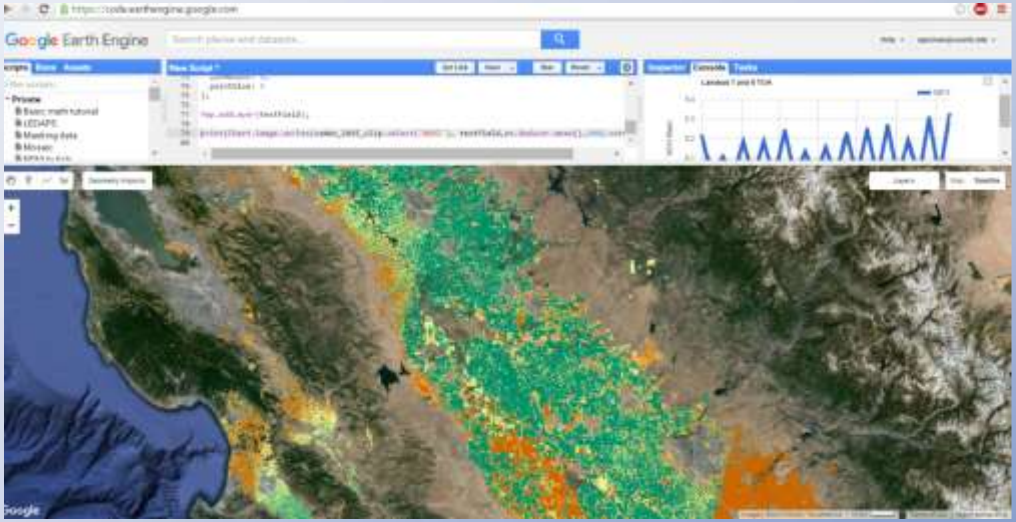
First Previous 1 Next Last

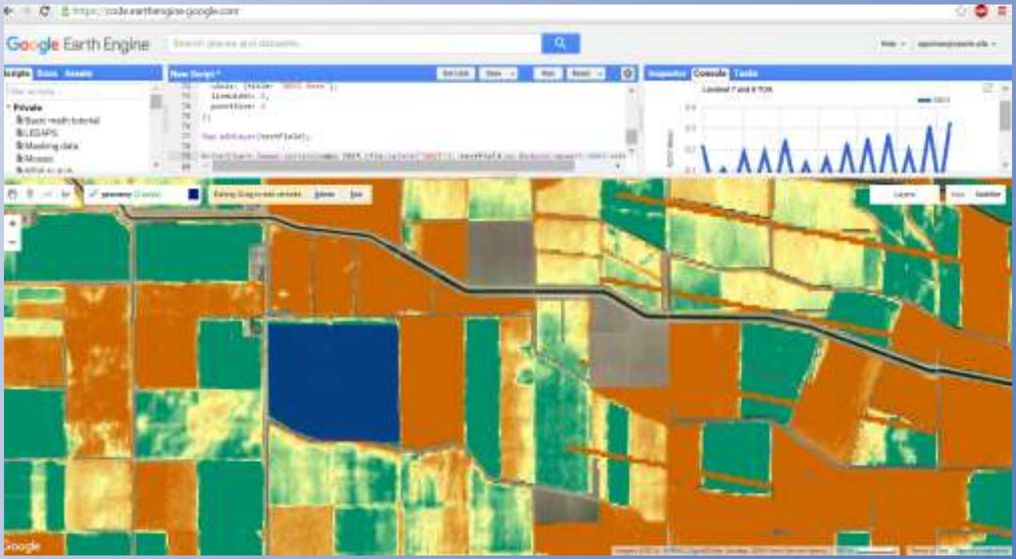
Show All Rows

SIMS Earth Engine Implementation

Advantages:

- Leverage satellite image archives and data services on Google Earth Engine
- Reduce operational costs
- Increase scalability to other regions





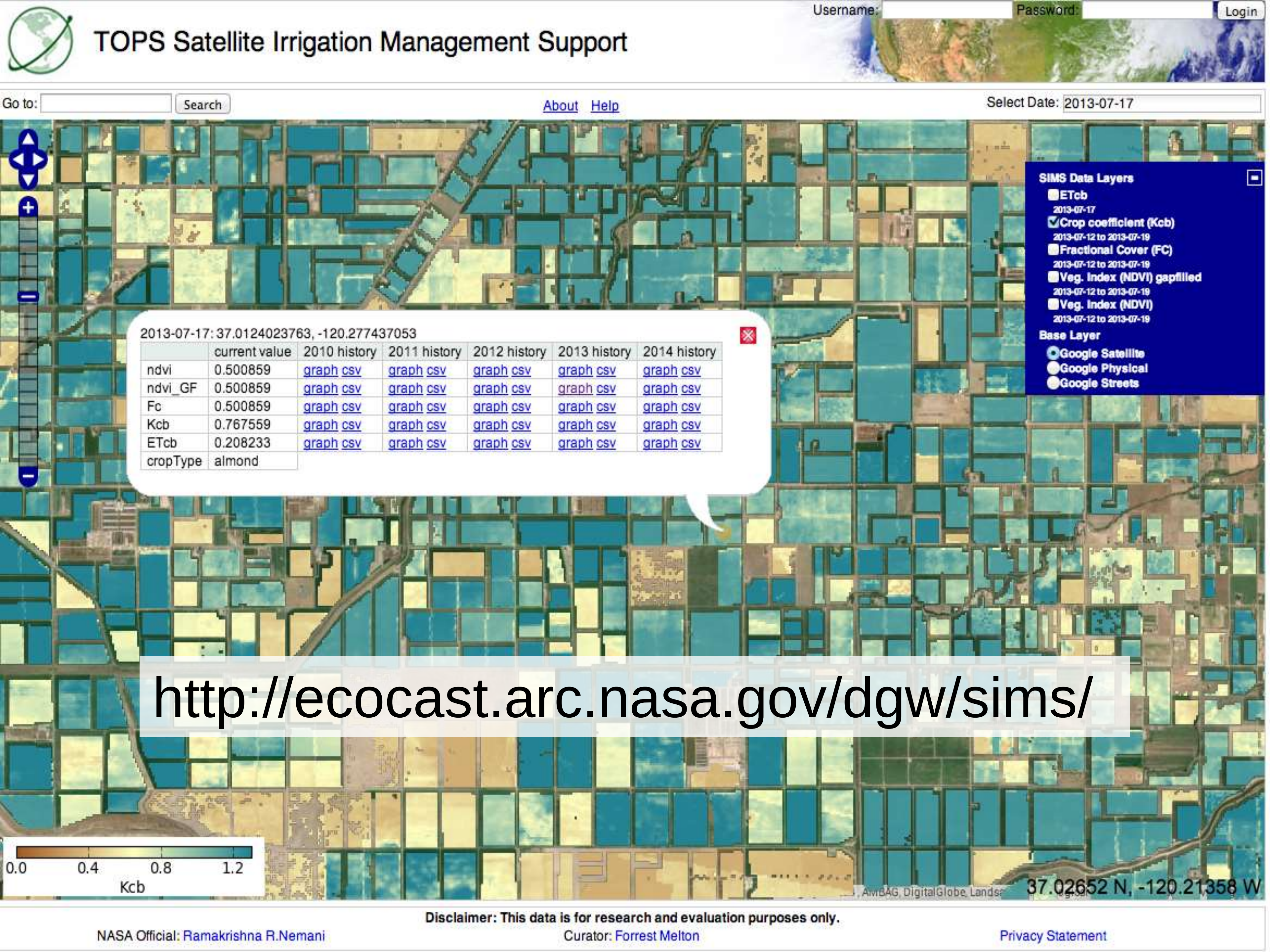
Limitations of the SIMS / Reflectance Approach

- Requires local ET_{ref} (Weather station network)
- Provides ET_{cb} – must add in soil evaporation to get ET_p
- Must estimate crop stress to get ET_a (e.g., via soil water balance)

Advantages of the SIMS / Reflectance Approach

- Reflectance data freely available from multiple satellites (e.g., Landsat 7/8, Sentinel-2A) → operational reliability & data continuity
- Reflectance data available at field scales (30 m)
- Relatively simple calculations - fully automated computations
- NDVI/Fc/K_{cb} interpolates well between point measurements
- Extensible framework for satellite data processing
- ET_{cb} represents biological demand for water by the plant

Combination of energy balance (e.g., METRIC) and reflectance (e.g., SIMS) approaches provides robust, long-term strategy for sustaining operational use.



TOPS Satellite Irrigation Management Support
Username: Password: Login
Go to: Search
About Help
Select Date: 2013-07-17
SIMS Data Layers
ETcb
2013-07-17
Crop coefficient (Kcb)
2013-07-12 to 2013-07-19
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Veg. Index (NDVI) gapfilled
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Veg. Index (NDVI)
2013-07-12 to 2013-07-19
Base Layer
Google Satellite
Google Physical
Google Streets
2013-07-17: 37.0124023763, -120.277437053

	current value	2010 history	2011 history	2012 history	2013 history	2014 history
ndvi	0.500859	graph csv	graph csv	graph csv	graph csv	graph csv
ndvi_GF	0.500859	graph csv	graph csv	graph csv	graph csv	graph csv
Fc	0.500859	graph csv	graph csv	graph csv	graph csv	graph csv
Kcb	0.767559	graph csv	graph csv	graph csv	graph csv	graph csv
ETcb	0.208233	graph csv	graph csv	graph csv	graph csv	graph csv
cropType	almond					

http://ecocast.arc.nasa.gov/dgw/sims/
0.0 0.4 0.8 1.2
Kcb
AMBAG, DigitalGlobe, Landsat
37.02652 N, -120.21358 W
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NASA Official: Ramakrishna R.Nemani
Curator: Forrest Melton
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