Big Wood Groundwater Model Development: Options for Estimating Evapotranspiration and Precipitation

Mike McVay June 6, 2013

DRAFT

Options for Estimating Evapotranspiration (ET)

- Many ways of estimating ET.
- We have access to two very defensible methods.
  - We have guidance on the use of both methods

- ETIdaho
- METRIC^{tm}

- Both methods have been developed by Dr. Richard Allen and his group at the University of Idaho Research and Extension Center at Kimberly, ID. Both were developed in cooperation With IDWR.

METRIC:

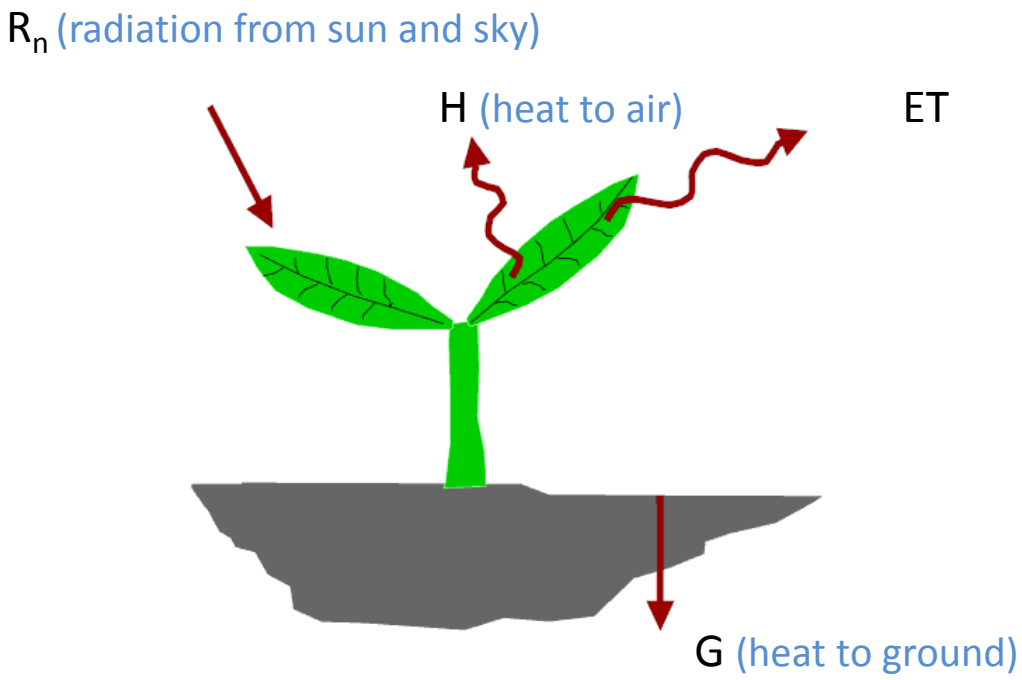
Mapping EvapoTranspiration at High Resolution with Internalized Calibration

METRIC is an energy-based method for estimating ET that is tied-down and partly calibrated using ground-based reference ET (from weather data).

How METRIC Works

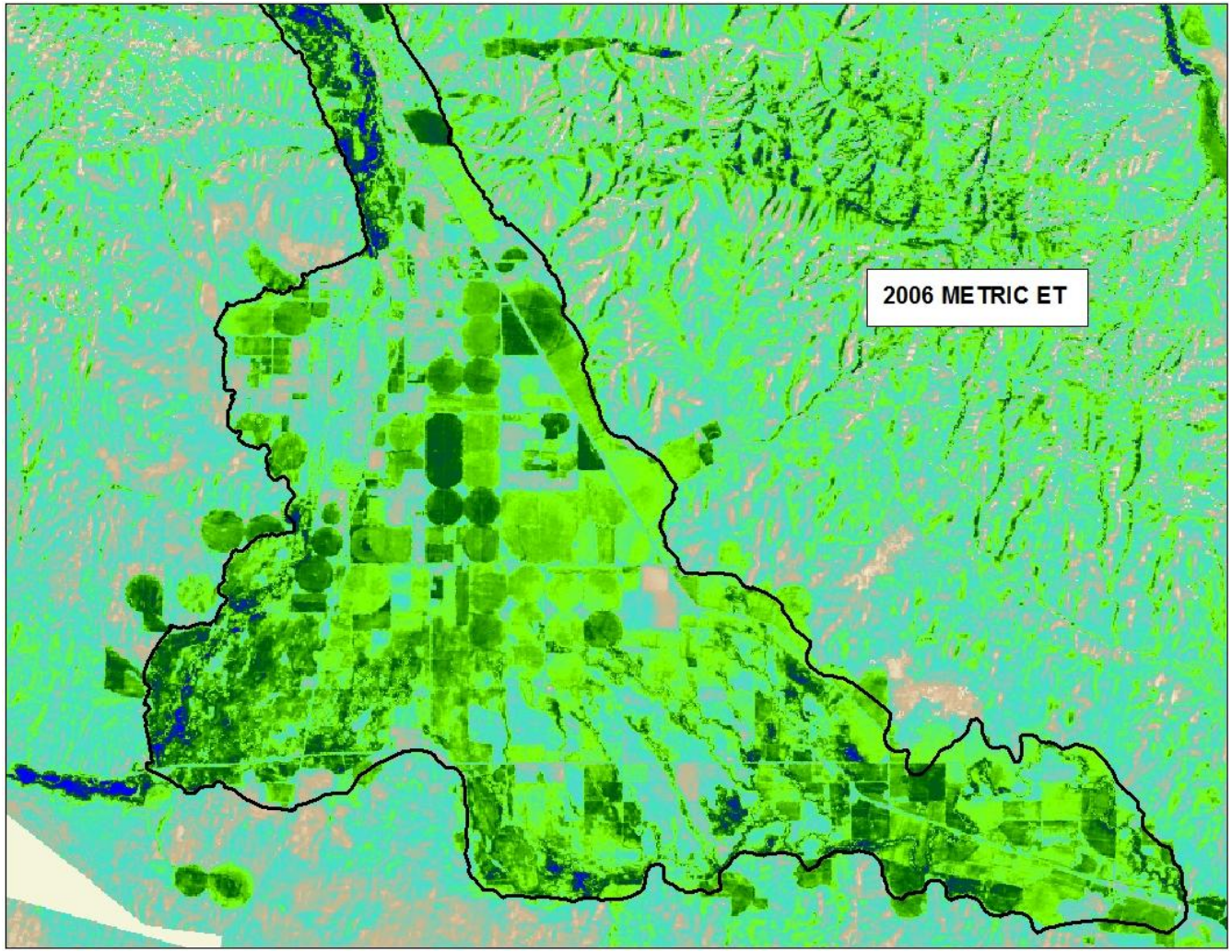
- Uses Satellite-based Red, Near IR, and Thermal IR data.
- Completes the Energy Balance for Each Pixel.
- ET is calculated as a residual of the energy balance.

$$ET = R_n - G - H$$



How METRIC Works

METRIC uses 30 m Landsat images to calculate ET at the time the satellite passes over.



How METRIC Works

•Energy balance form a satellite is neat, but it needs to be “trained’ to conditions on the ground.

•METRIC uses two “anchor” pixels to fix boundary conditions for the energy balance and to internally calibrate.

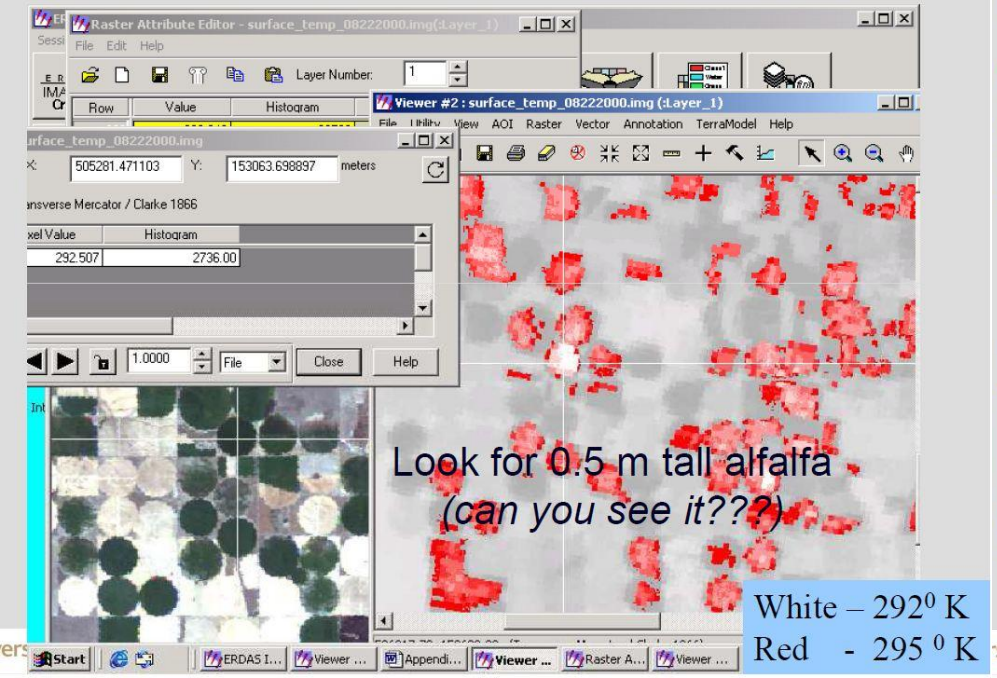
•**Cold Pixel**: a wet, well-irrigated crop surface with full cover. Temperature of land surface is approximately equal to air temperature.

•**Hot Pixel**: a dry, bare agricultural field. ET is approximately zero.

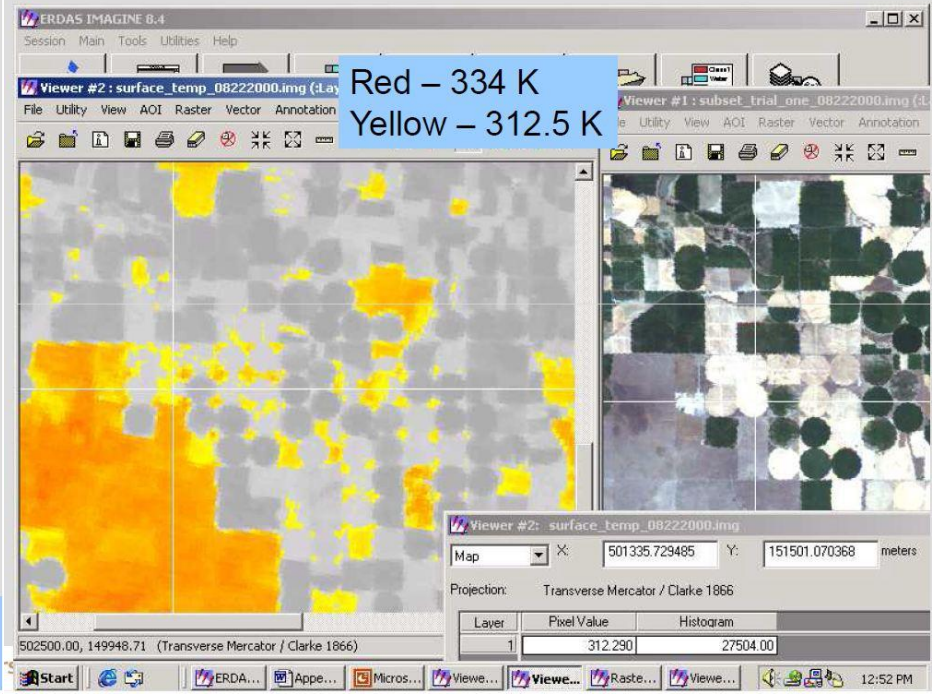
How METRIC Works

Selecting the hot and cold pixels requires the most experienced operators.

Selecting the "Cold" Pixel



Selecting the "Hot" Pixel

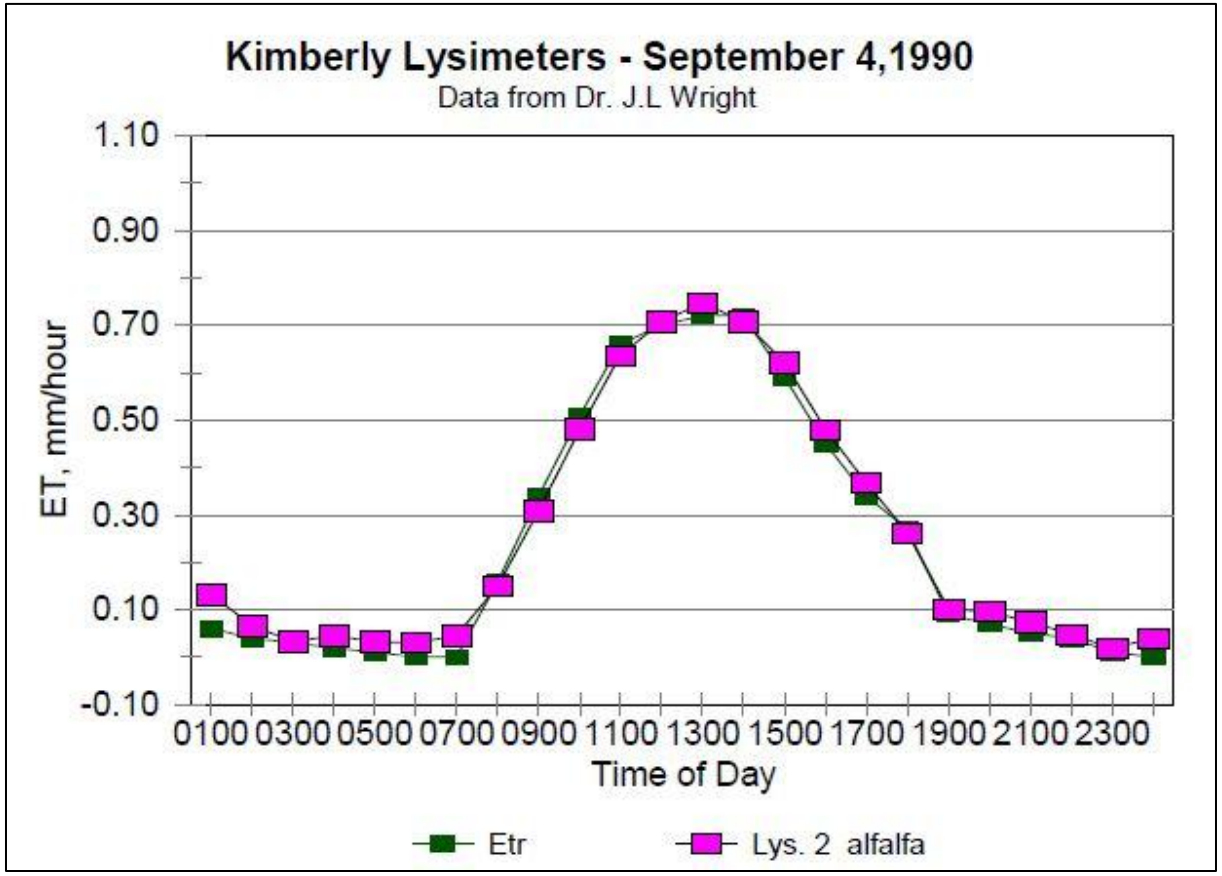


How METRIC Works

- One of the important features of METRIC is the use of Reference ET (ET_r) – calculated at ground-based weather stations.

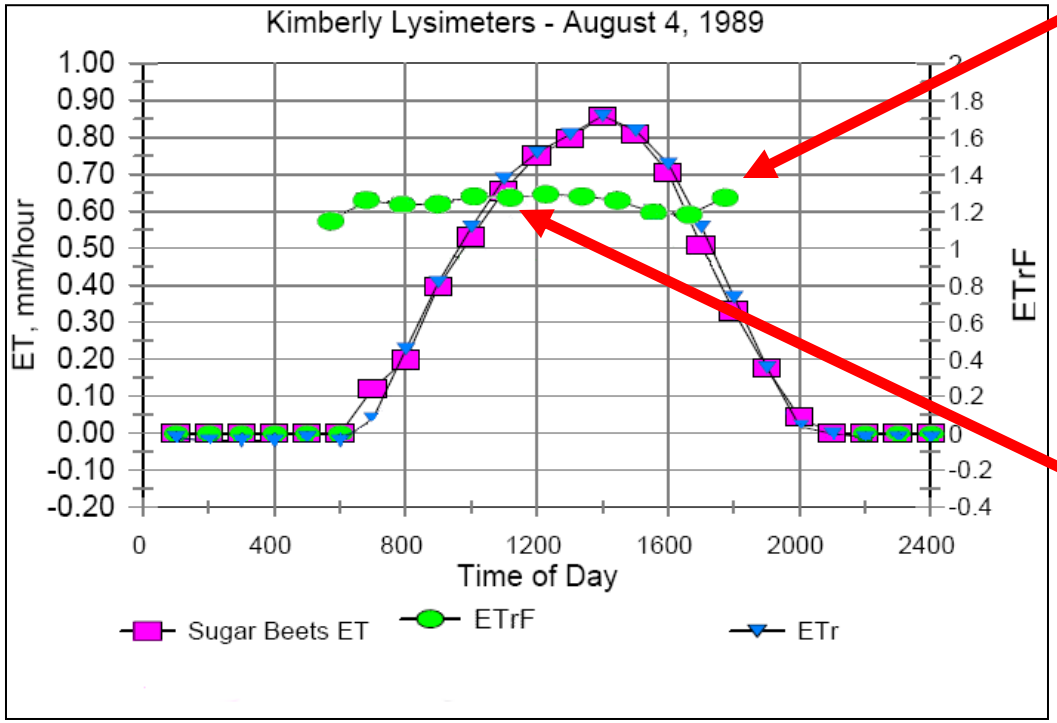
ET_r is the amount of ET from an extensive surface of standardized reference crop – we use alfalfa in Idaho.

ET_r is used to calibrate the "cold" pixel - ET at the cold pixel is approximately $1.05*ET_r$.



How METRIC Works

ET_r is used to extrapolate to 24-hr ET.



$ET_rF = ET / ET_r$

ET_rF at 11am

24-Hour ET Computation

$$ET_{24} = (ET_rF_{11am})\ (24\text{-hour } ET_r)$$

Note that ETrF is the same as Kc

How METRIC Works

Seasonal Evapotranspiration ($ET_{seasonal}$)

- Interpolate ET_rF between images (after cloud masking) (same principle as in constructing a crop coefficient curve. Preferrably, a curvilinear interpolation is used to better simulate the gradual development of vegetation and/or gradual drying of soil).

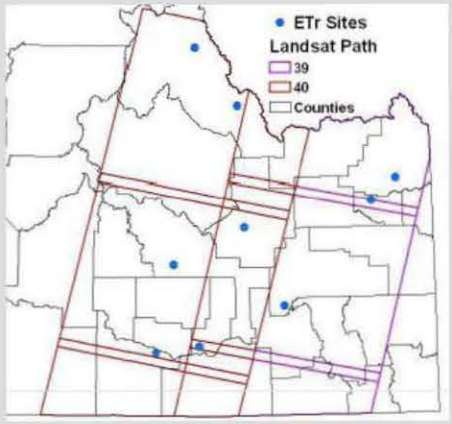
- Assume ET for area of interest changes in proportion to change in ET_r

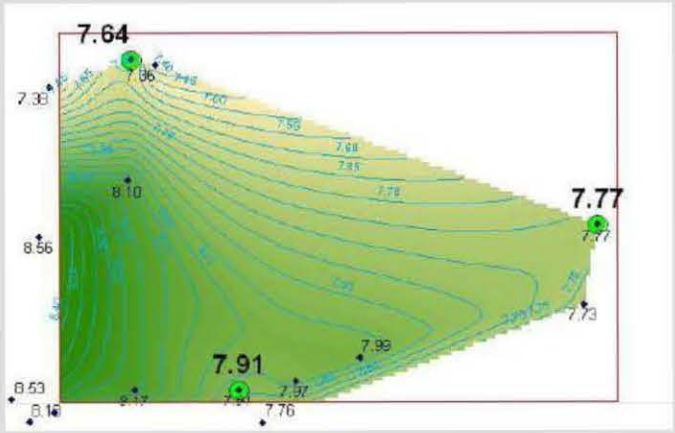
In current applications of METRIC, we strongly recommend:

- 1. use a single value for ET_r during METRIC calibration and determination of ET_rF for the image (because the calibration of a and b is closely tied to the singular ET_rF and wind speed)
- 2. use an ET_r "surface" derived from multiple weather stations, if available, when computing ET for intervening days (to account for variable weather and ET_r across the image)

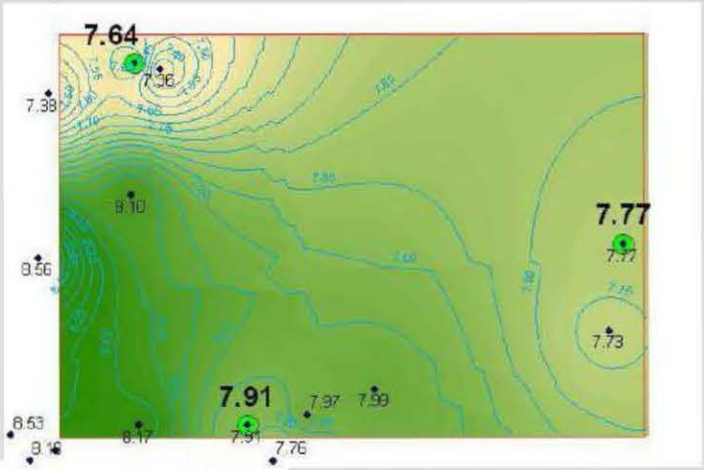
How METRIC Works

Spatial Interpolation of ET_r for Use with METRIC ET_rF

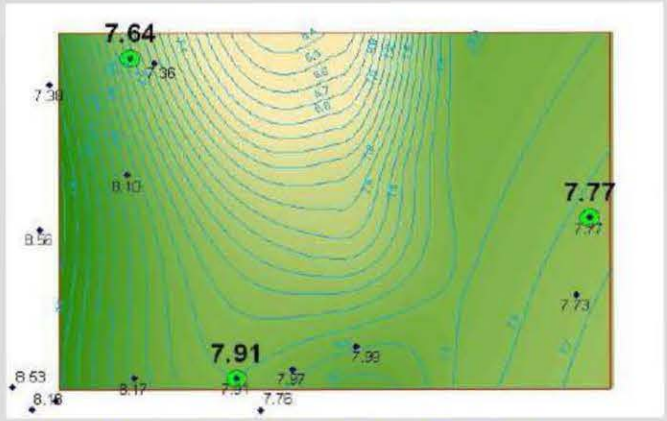




Natural neighbor interpolation



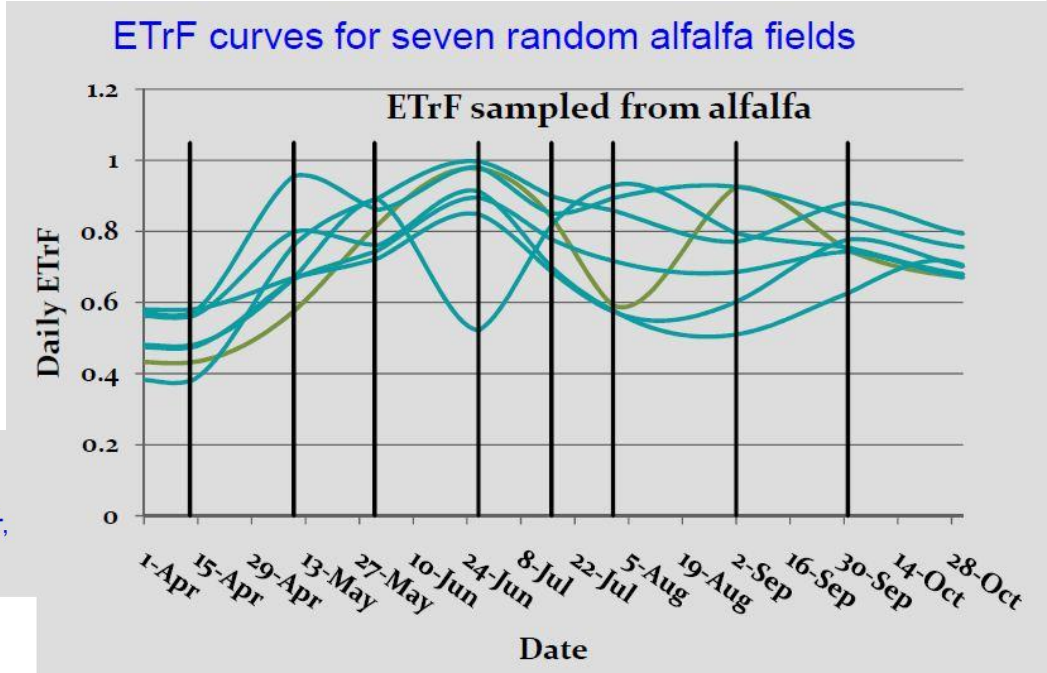
Inverse distance weighted interpolation



Regularized spline interpolation

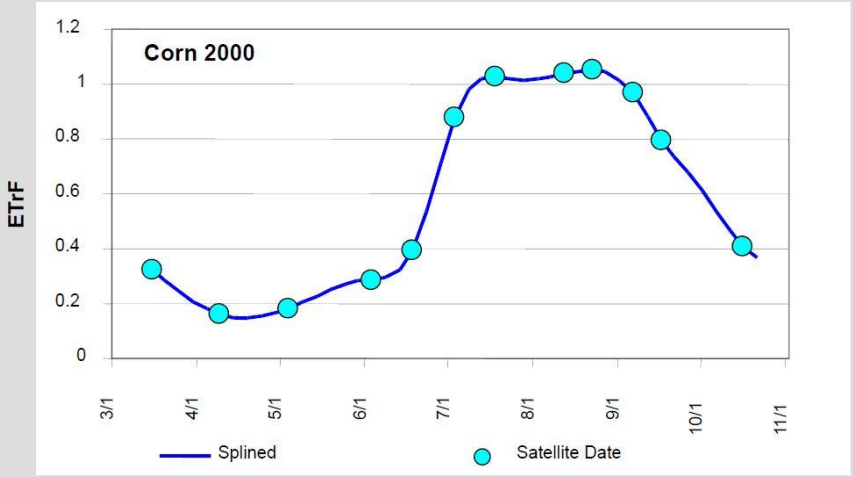
How METRIC Works

An interpolation (spline) is applied to estimate ETrF over time..



Using a Cubic Spline to obtain Monthly ETrF

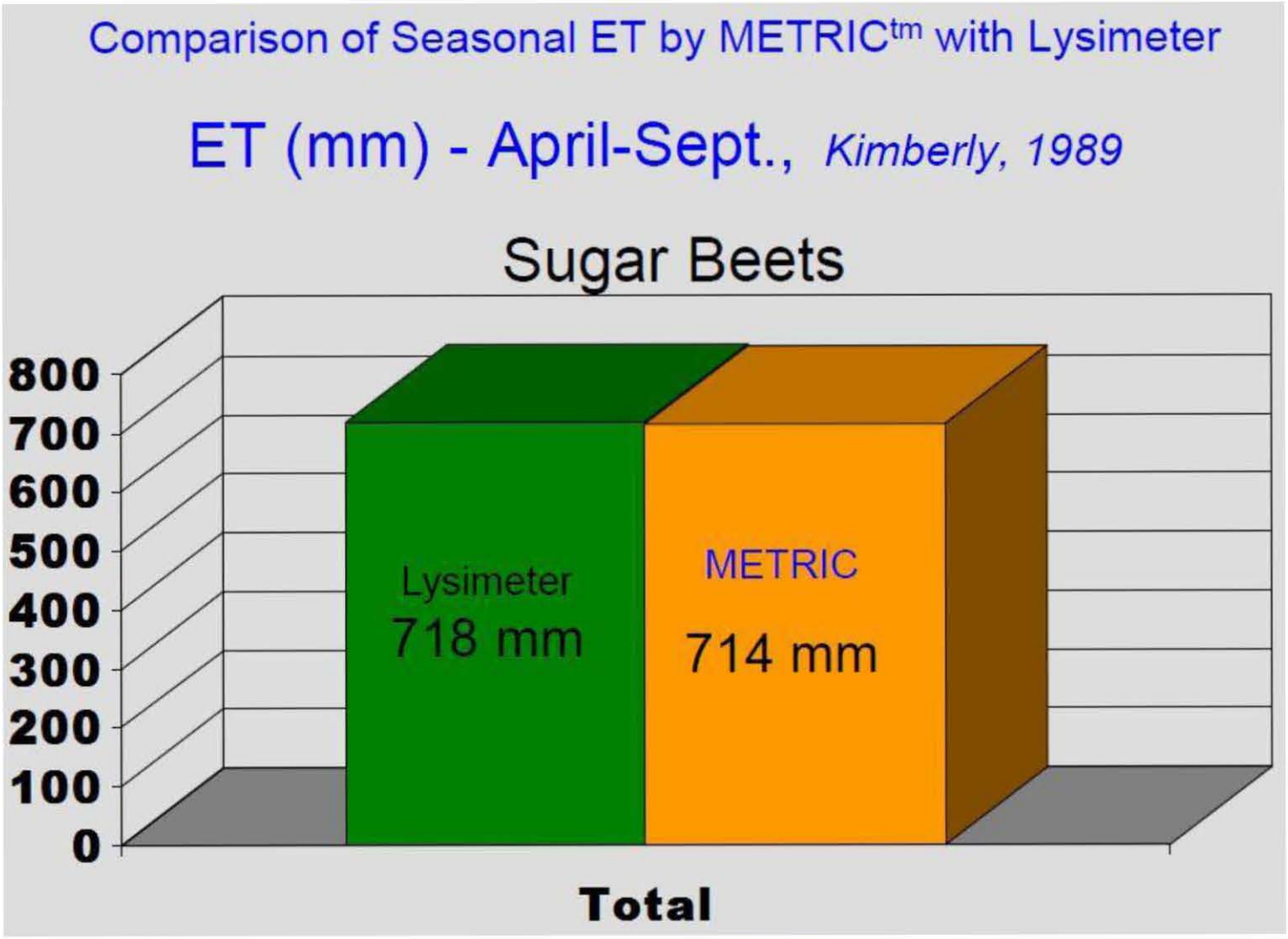
The ETrF curve represents the ET behavior of a pixel, relative to ETr, during the growing season



The interpolation is applied at each pixel to get ETrF (relative to ETr) across the entire image.

How METRIC Works

Dailey ET is computed from ETrF and summed to Monthly and Seasonal ET.



Benefits of using METRIC

- ET via satellite can provide dependable (accurate) information.
- ET can be determined remotely.
- ET can be aggregated over time and space.
- ET is tied down using reference ET. Provides consistency with ETIdaho method.
- Energy Balance is applied at each pixel (30 m) to map spatial variation.
- Areas where ET is reduced (water stress, pests, etc.) are identified.
- No ground data (at the field) is required.
- Valid for natural vegetation.
- ET estimate has an error of +/- 10-15% of true ET, if done well.
  - We have the experts processing METRIC.

ETIdaho

- Uses the ASCE standardized Penman-Monteith method.
- Is a reference equation that calculates actual ET for a given crop (ET_c) by using Crop Coefficients (K_c) and Reference ET (Et_R).

$$ET_c = K_c * ET_R$$

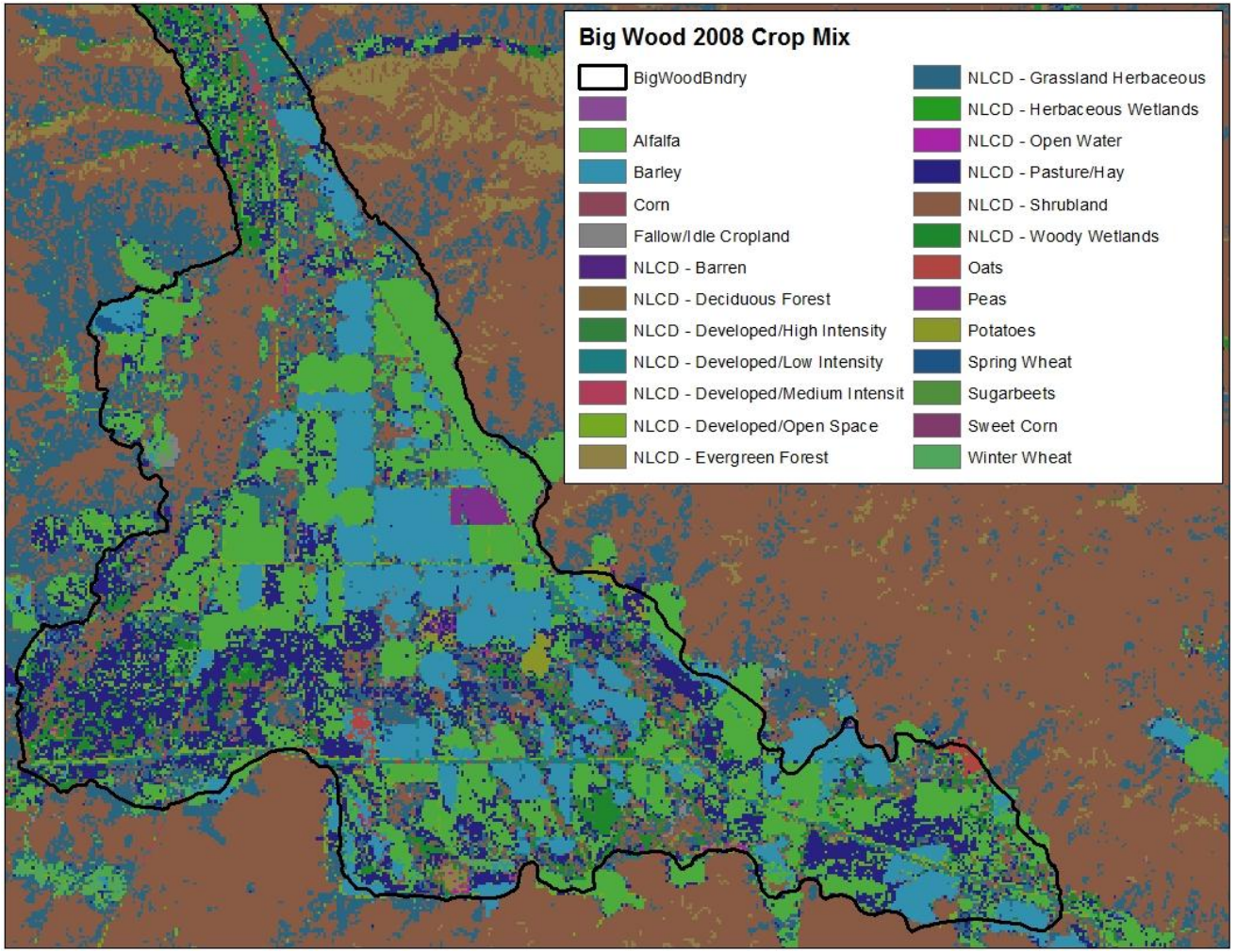
- The Crop Coefficient is actually a dual coefficient that considers both the crop ET and the effect that irrigation and precipitation have on evaporation from the soil surface.
- ETIdaho catalogues ET_c for various crop types at numerous weather stations.
- We need to classify and quantify the crops in the Big Wood valley.
- ET over an area has an error of +/- 10-15% of true ET...IF DONE WELL*

ETIdaho and Crop Mix

- To use ETIdaho, we need to identify the crop mix.
- We have reasonable GIS coverage for 2007-2010.
- Other years we have to rely on the county crop mix as reported in the NASS.
- Crops are often omitted from the reported mix due to privacy concerns.

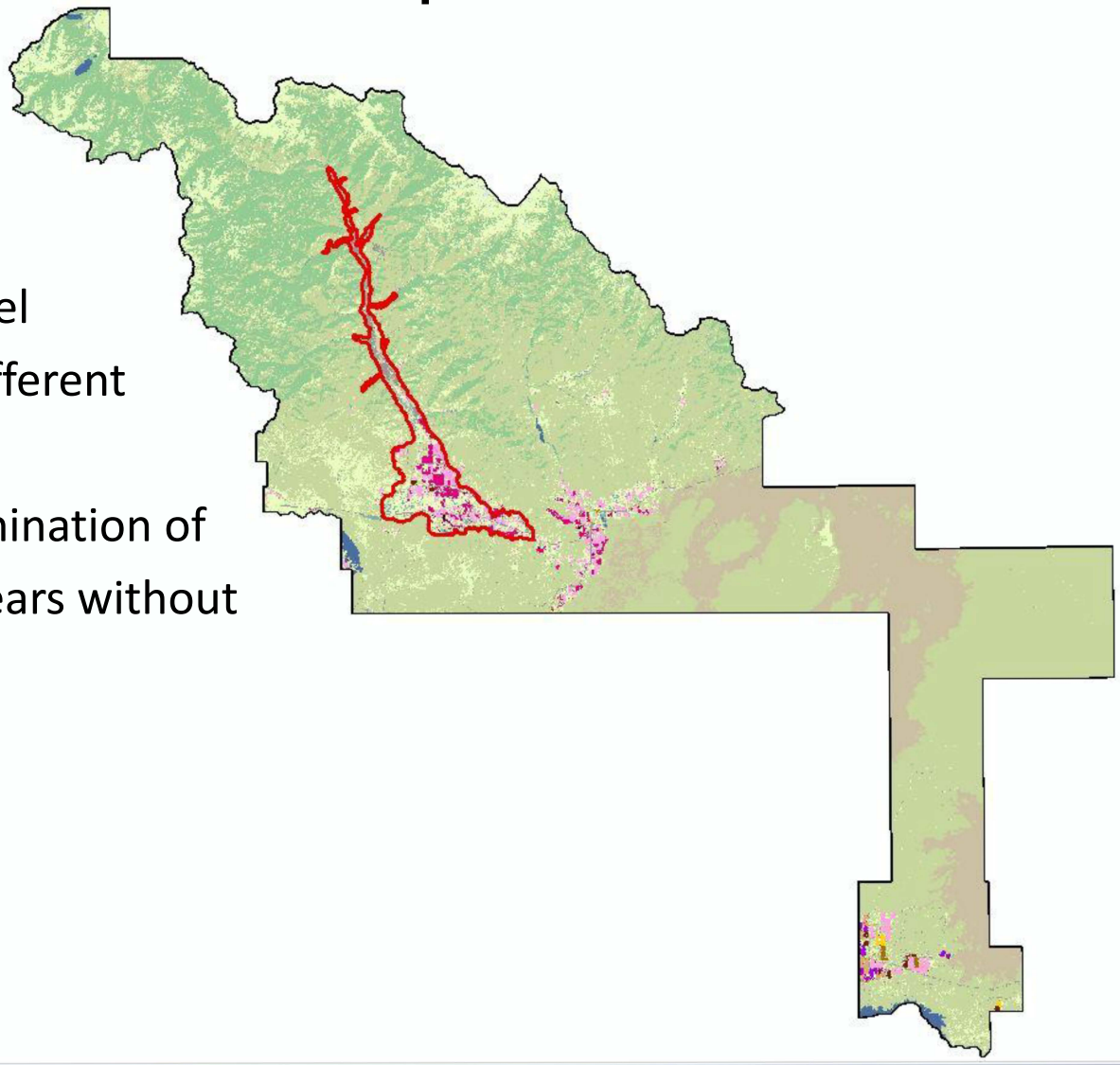
ETIdaho and Crop Mix

We have good GIS Crop Mix Coverage for 2007,2008, 2009 and 2010.



ETIdaho and Crop Mix

- Blaine County has two distinct and very different agricultural areas.
- The mix outside of the model boundary is substantially different than in the Big Wood area.
- This complicates the determination of crop mix for the model in years without GIS coverage.



ETIdaho and Crop Mix

Crop Mix determination is further complicated by Incomplete reporting.

Spring Wheat Acres Planted by County, Idaho, 2002-2011

County and District	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
North					*Acres*					
Benewah	11,500	8,000	10,200	9,900	9,100	7,000	6,300	9,000	8,200	1/
Boundary	7,600	8,200	8,700	9,000	7,800	5,600	5,800	5,500	4,500	4,500
Clearwater	2,600	2,300	3,500	3,000	3,500	3,400	1/	3,300	1/	1,400
Idaho	16,000	13,000	23,000	25,000	20,100	18,000	24,000	28,500	30,500	15,700
Kootenai	4,800	4,500	3,600	3,000	2,800	3,500	1/	4,500	1/	4,900
Latah	24,000	24,000	25,000	25,000	26,500	28,000	30,500	35,500	34,500	27,200
Lewis	18,500	12,000	20,000	18,500	24,600	21,500	16,500	14,500	21,000	11,200
Nez Perce	20,000	22,000	21,000	18,600	21,600	23,000	22,500	22,200	17,000	1/
Other Counties	1/	1/	1/	1/	1/	1/	8,400	1/	9,300	26,100
District	105,000	94,000	115,000	112,000	116,000	110,000	114,000	123,000	125,000	91,000
Southwest										
Ada	2,000	1,400	2,600	2,300	1,000	1/	1/	1/	2,600	3,300
Canyon	3,800	4,400	3,700	6,700	5,000	1/	1/	1/	3,900	6,500
Elmore	4,600	1,600	1,900	5,800	4,500	2,800	1/	1/	1/	1/
Gem	1/	1/	1/	500	1/	1/	1/	1/	1/	1/
Owhyee	1,800	1/	4,000	2,800	5,300	2,200	4,800	1/	1/	1/
Payette	1/	700	1/	2,200	1/	500	700	1/	1,300	1/
Washington	1,000	2,300	1,800	2,700	2,200	2,200	2,100	2,200	1/	1/
Other Counties	800	2,600	1,000	1/	1,000	5,300	17,400	17,800	11,200	16,200
District	14,000	13,000	15,000	23,000	19,000	13,000	25,000	20,000	19,000	26,000
South Central										
Blaine	700	1/	1/	1/	1/	1/	1/	1/	1/	2,000
Camas	1,200	1/	1/	1/	1/	1/	1/	2,100	2,800	1/
Cassia	25,300	27,000	28,000	23,300	24,500	1/	1/	20,700	23,600	25,700
Gooding	1,700	2,700	3,700	1,600	1,300	1/	4,000	1,700	1/	3,600
Jerome	5,300	4,700	7,500	5,200	4,000	1/	6,400	6,100	7,400	1/

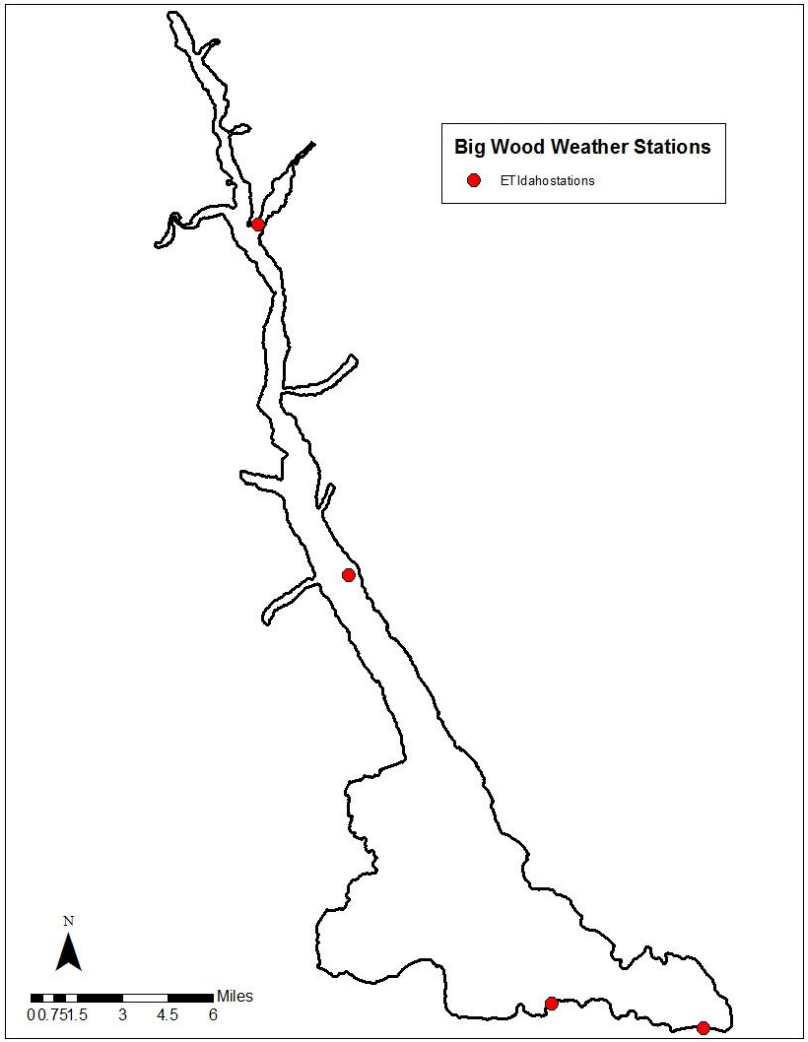
ETIdaho and Weather Data

ETIdaho catalogues actual ET for various crop types at various weather stations.

In the Big Wood model area, ETIdaho calculates ET at Picabo (2 stations) and Hailey (partial 2005 - 2010).

May have necessary weather data at Hailey airport (in log books).

Have weather at Ketchum, and we can apply the ETIdaho calculations at that weather station.



Pros and Cons of ET Estimation Methods

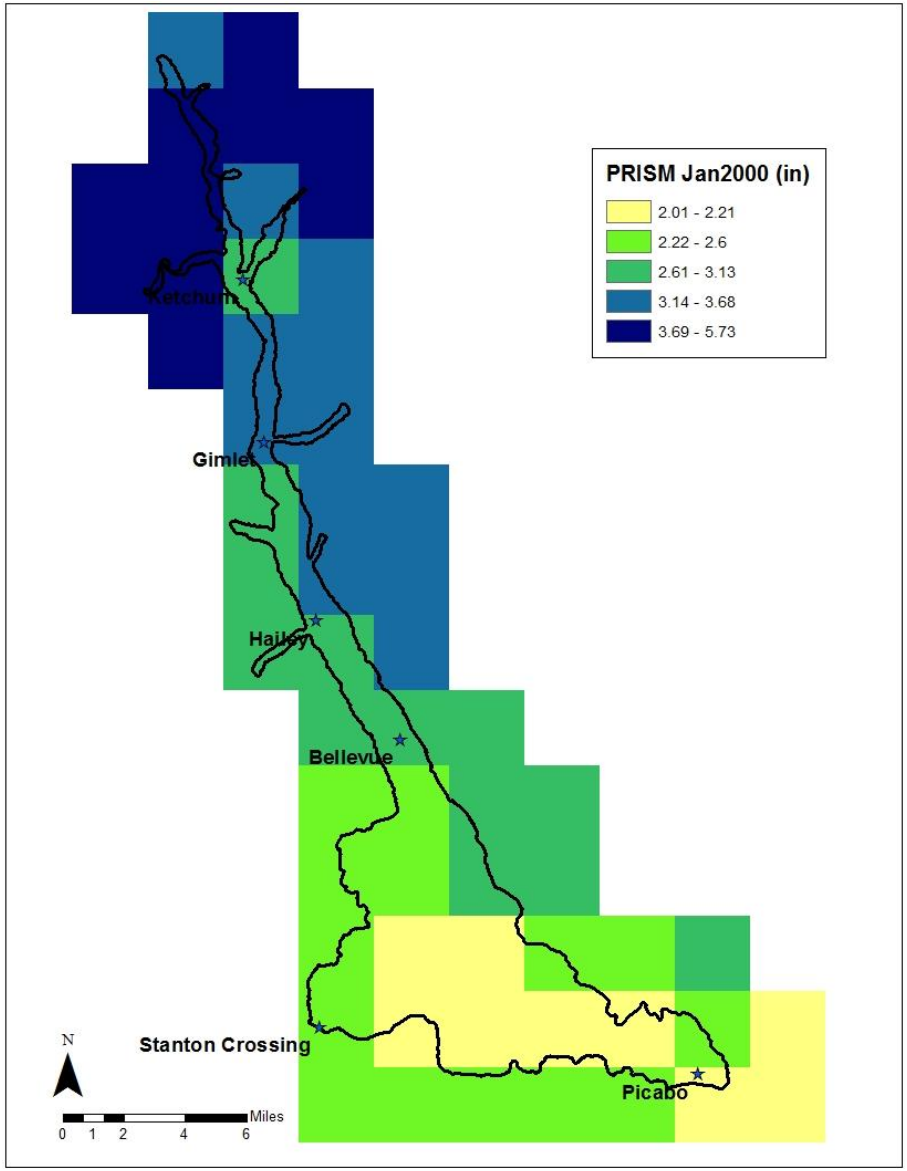
- ETIdaho can estimate ET with +/- 10-15%. IF DONE WELL.
  - Crop classification is difficult.
- ETIdaho gives actual ET for every day.
  - Not very good spatial resolution.
- METRIC can estimate ET with +/- 10-15%. IF DONE WELL.
  - We have the very best METRIC processors.
- METRIC gives spatially accurate estimates of ET.
  - ET calculated instantaneously and distributed over time.
  - Not available for every year.

Estimating ET for the Big Wood Model

- We believe that METRIC is the best available estimate of ET.
- We have METRIC for the years 1996, 2000, 2002 (partial), 2006 2008, 2009 and 2010 by the end of the year.
- Plan to use METRIC when available and ETIdaho for the remaining Years (1995, 1997, 1998, 1999, 2001, 2002 (partial), 2003, 2004, 2005 and 2007.
- Good reasons to use these in combination.
  - Both methods utilize Reference ET (ET_R).
  - Both methods developed by Dr. Allen

METRIC Keys off of:

- Reflectance of light energy.
- Vegetation Indices.
- Surface Temperature.
- Relative Variation in surface temperature.
- Wind Speed (from weather station).



Precipitation

PRISM: (Precipitation-elevation Regressions on Independent Slopes Model) is a model that uses point precipitation data with DEM to generate monthly and annual gridded precipitation maps.

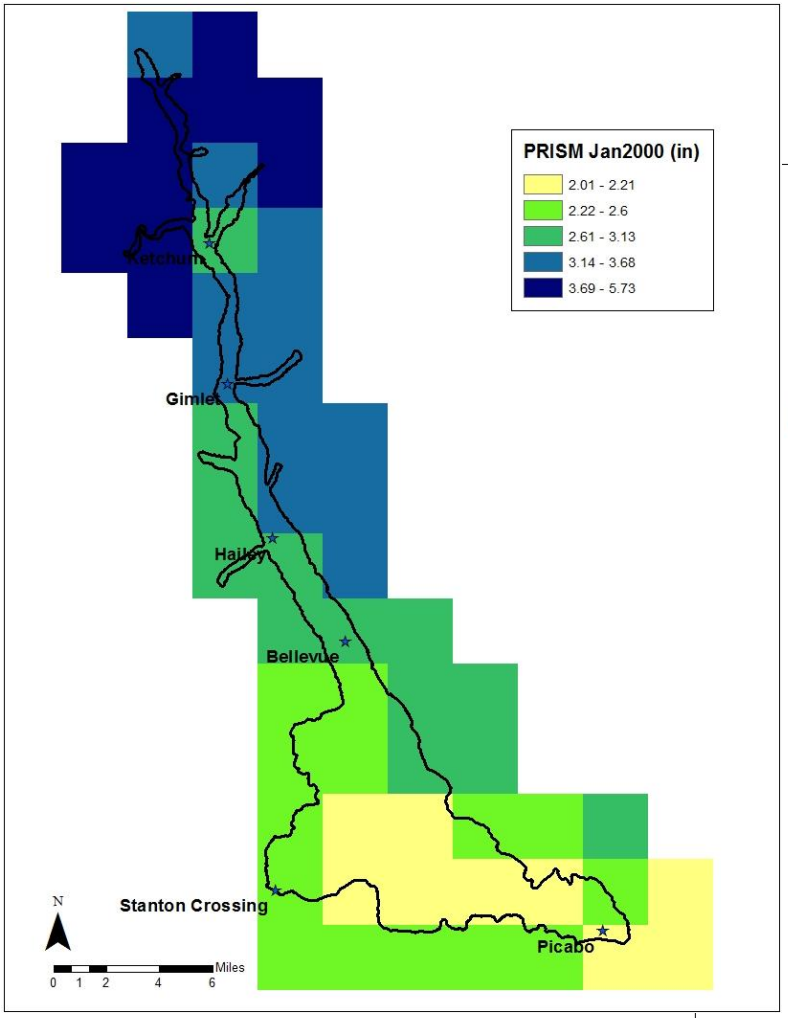
We have Monthly PRISM data; however, spatial resolution (4 km) is problematic in the Big Wood River valley.

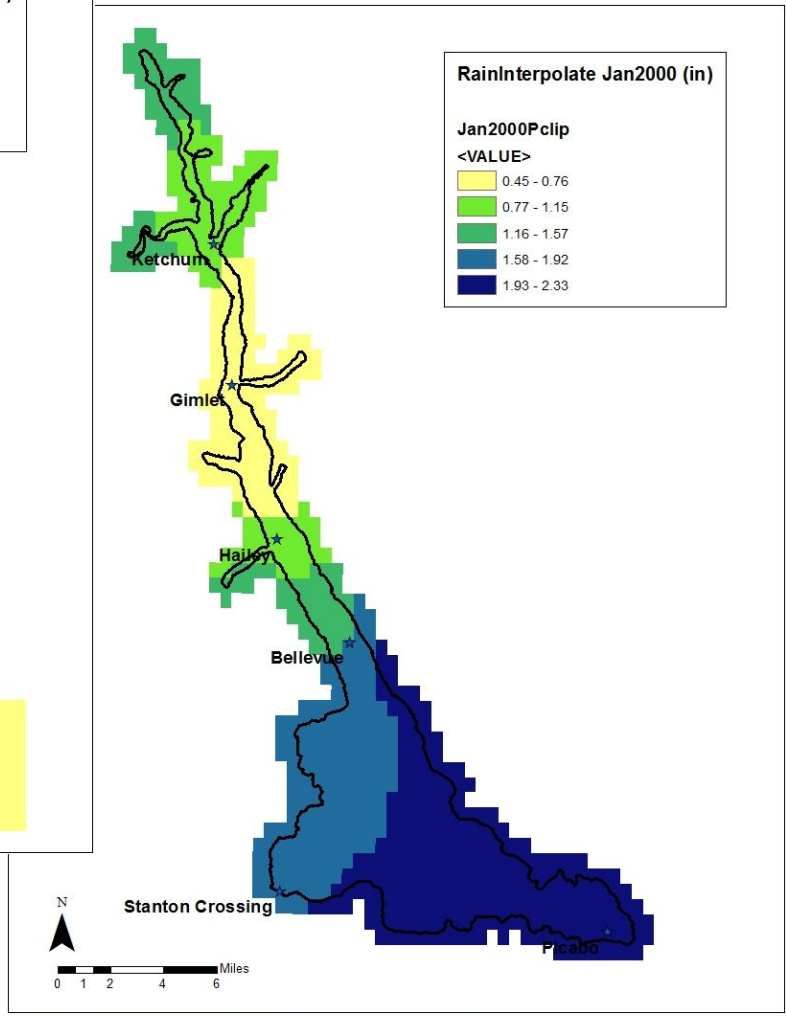
The PRISM Climate Group is located at Oregon State University

Precipitation

We can re-grid the PRISM data to 800m grid. However, this requires AVERAGE monthly data in combination with daily local weather.

This can create substantially different precipitation patterns.





Precipitation

Since we are using ET that is tied to data from local weather stations, it seems appropriate to use the precipitation from the same stations.