# 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:

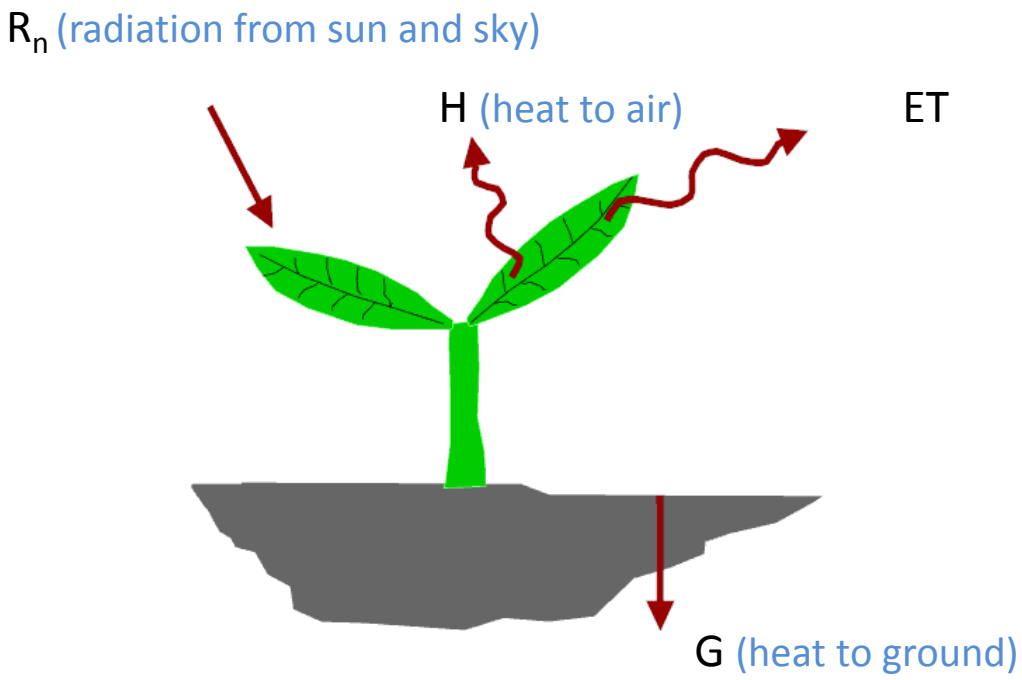
## Mapping EvapoTranspiration at High Resolution with Internalized Calibration

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

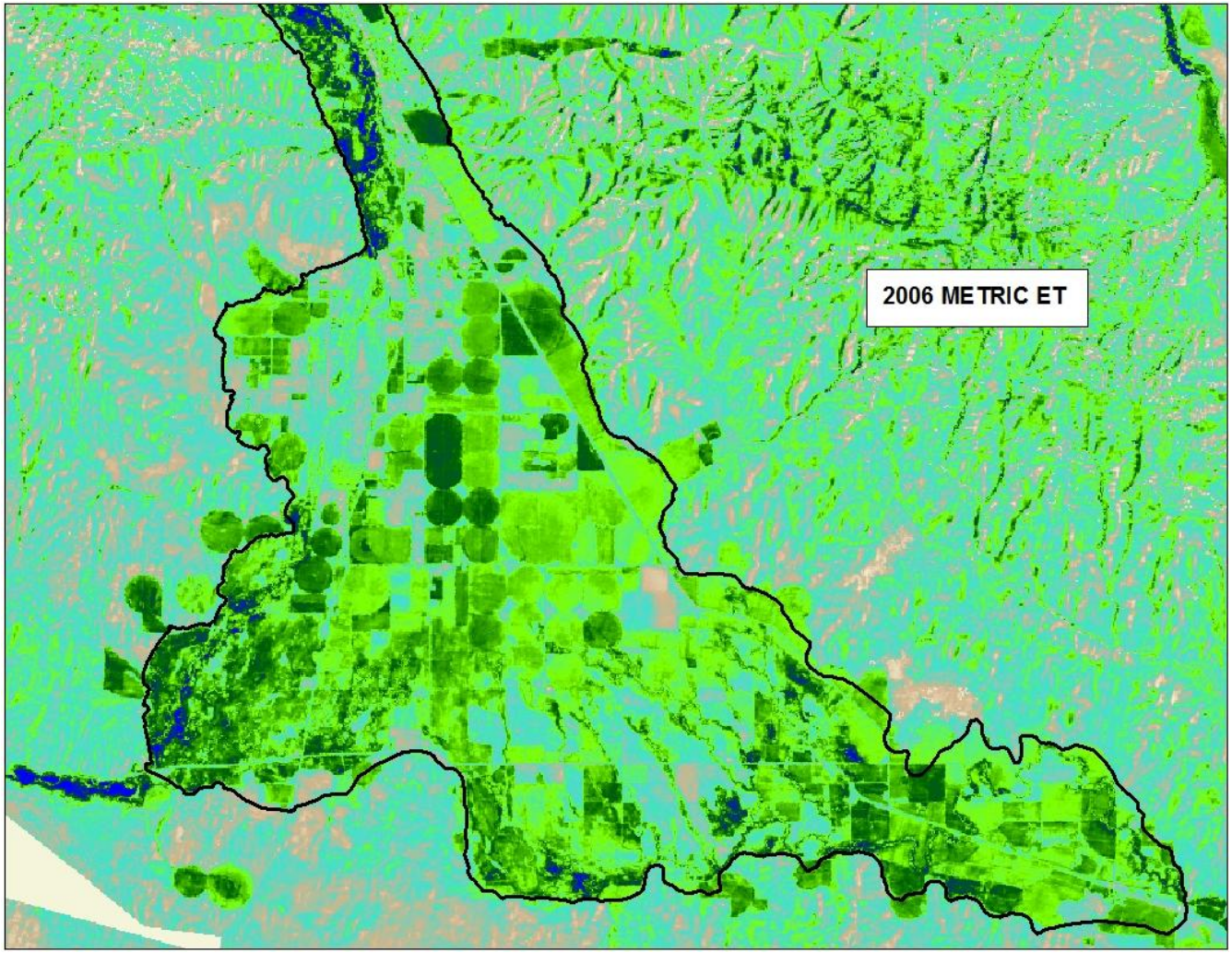
- Uses Satellite-based Red, Near IR, and Thermal IR data.
- Completes the Energy Balance for Each Pixel.
- ET is calculated as a residual of the energy balance.

$$ET = R_n - G - H$$



# 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.

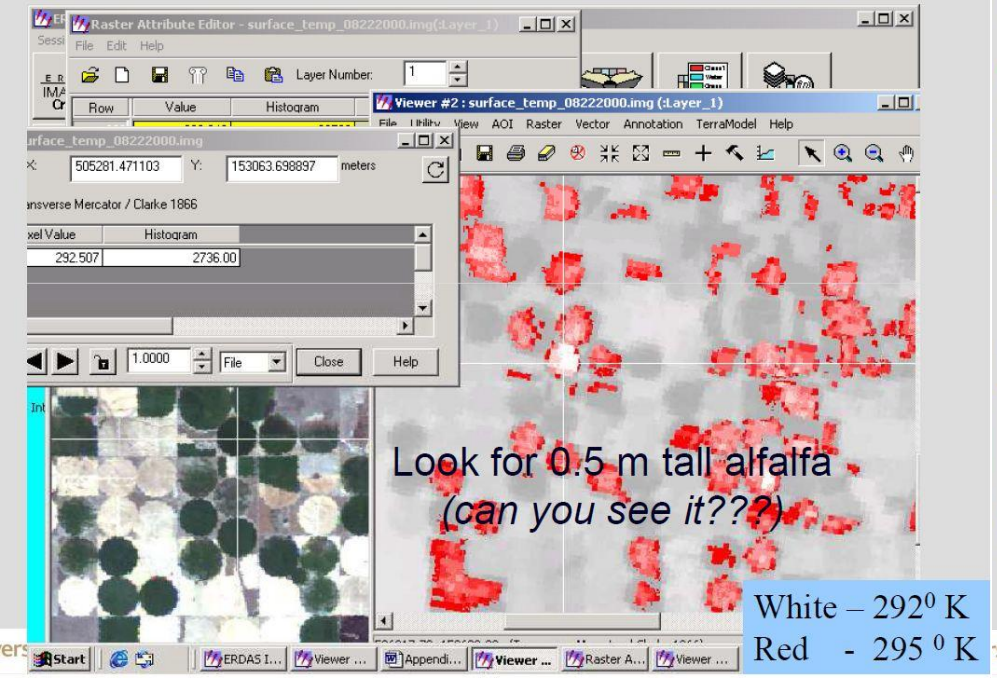
•**Cold Pixel**: a wet, well-irrigated crop surface with full cover. Temperature of land surface is approximately equal to air temperature.

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

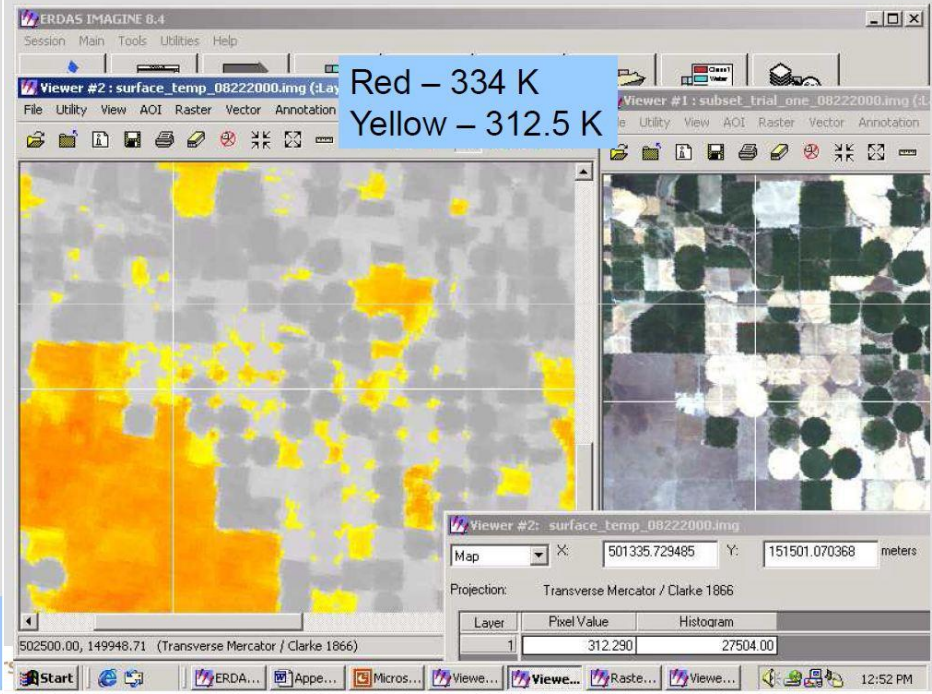
# How METRIC Works

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

## Selecting the "Cold" Pixel




## Selecting the "Hot" Pixel

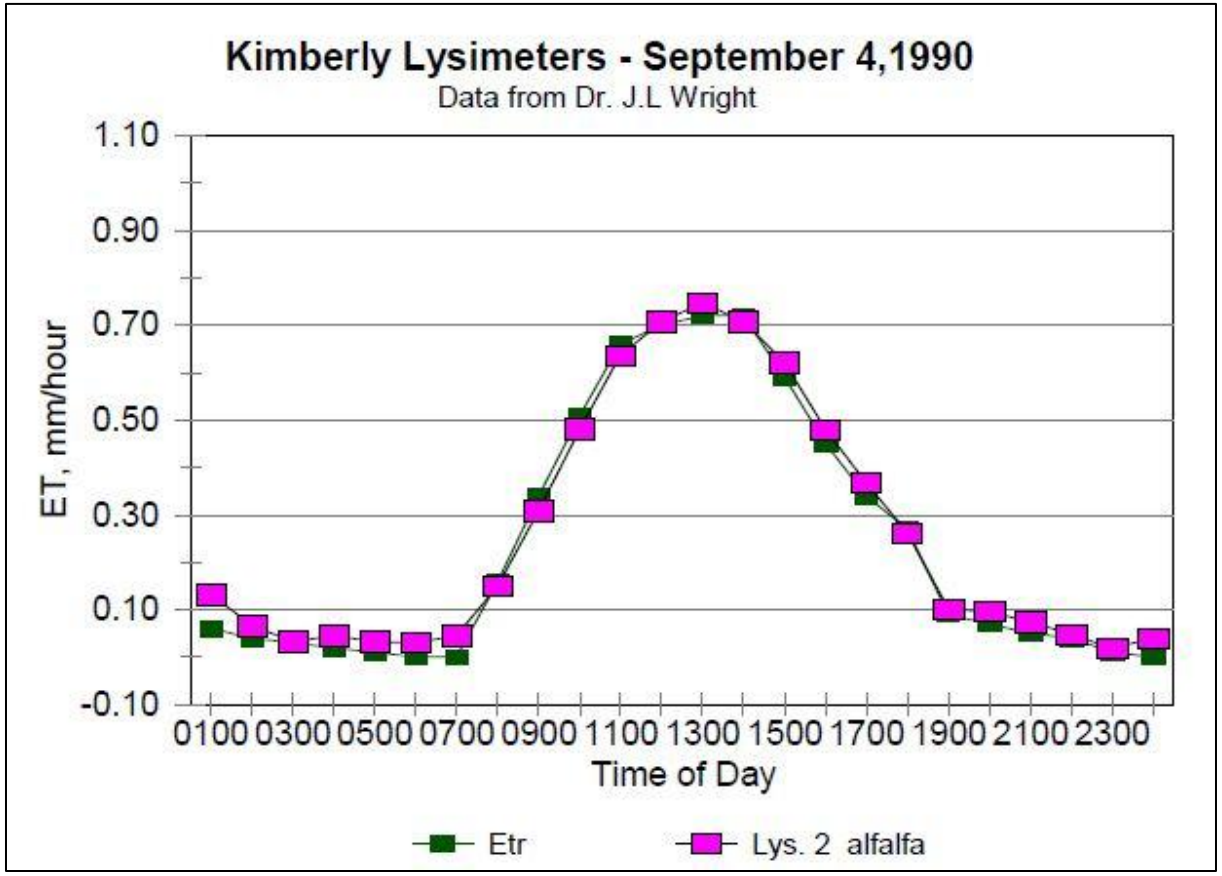


# How METRIC Works

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

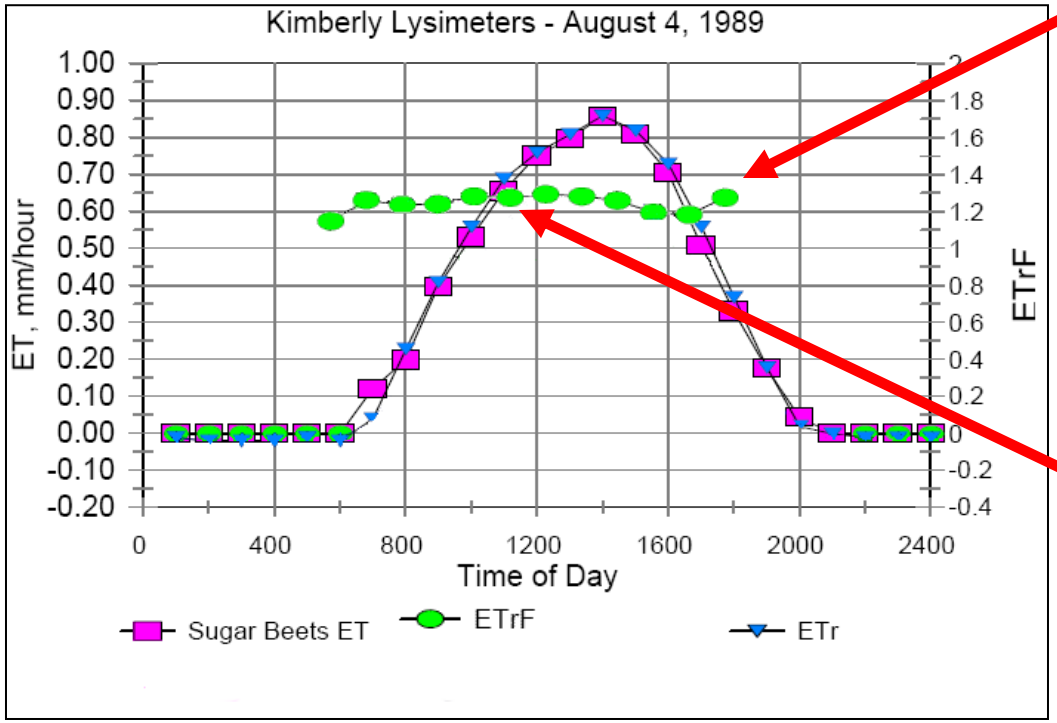
$ET_r$ is the amount of ET from an extensive surface of standardized reference crop – we use alfalfa in Idaho.

$ET_r$ 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).

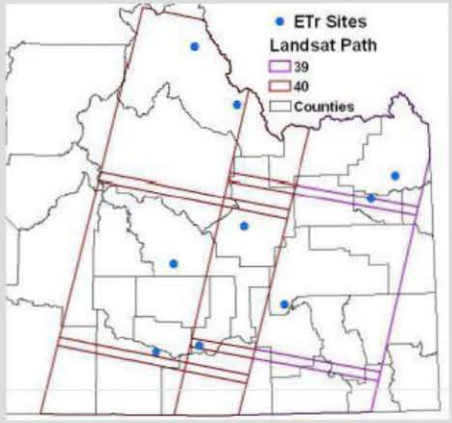
- Assume ET for area of interest changes in proportion to change in $ET_r$

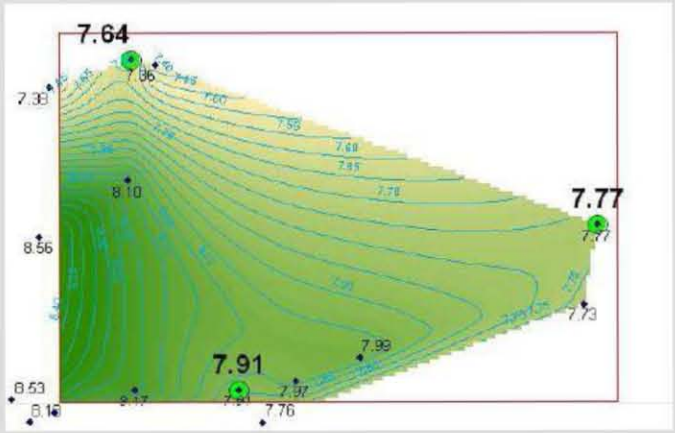
In current applications of METRIC, we strongly recommend:

- 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)

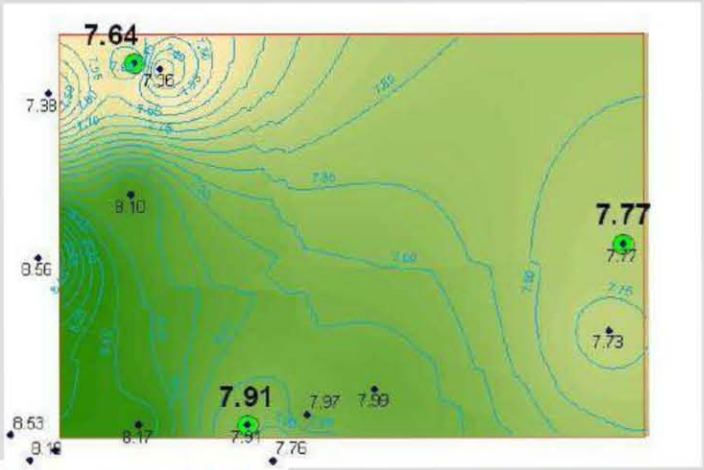
# How METRIC Works

## Spatial Interpolation of $ET_r$ for Use with METRIC $ET_rF$

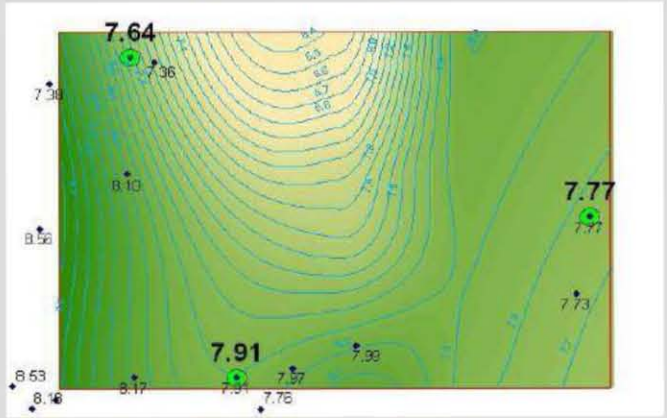



Natural neighbor interpolation



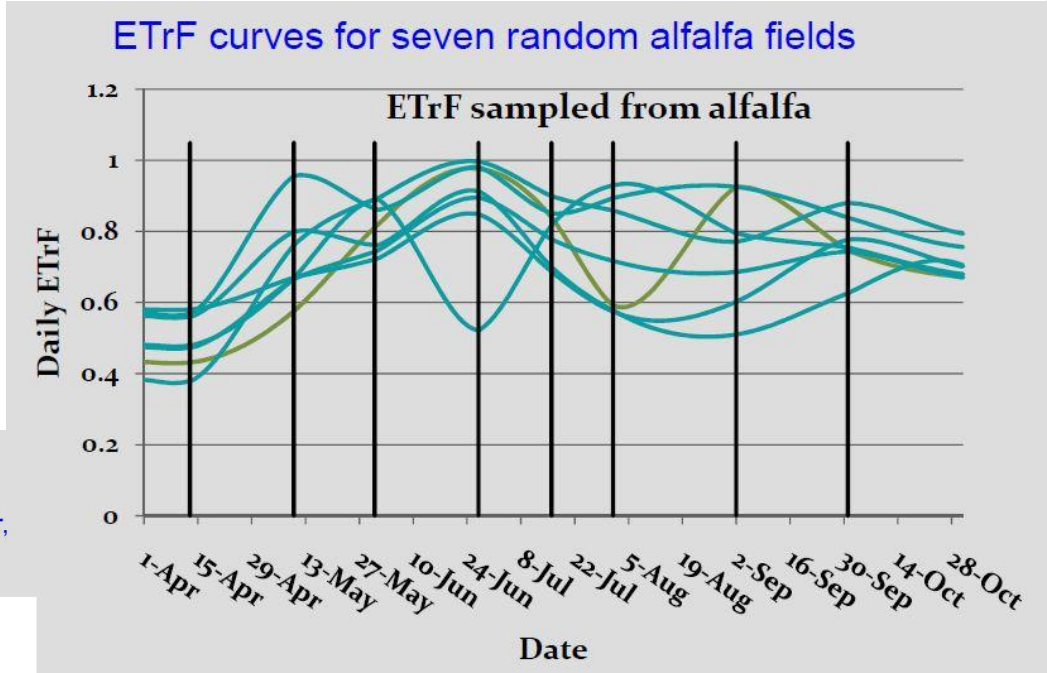

Inverse distance weighted interpolation




Regularized spline interpolation

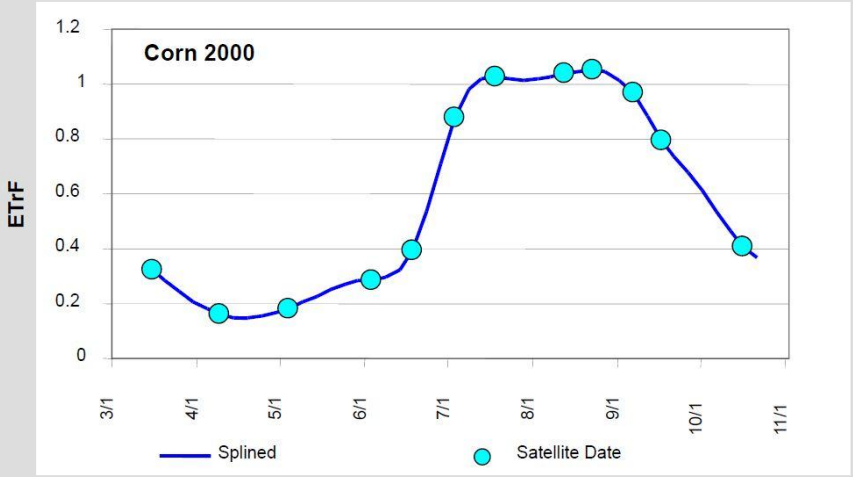
# How METRIC Works

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




**Using a Cubic Spline to obtain Monthly ETrF**

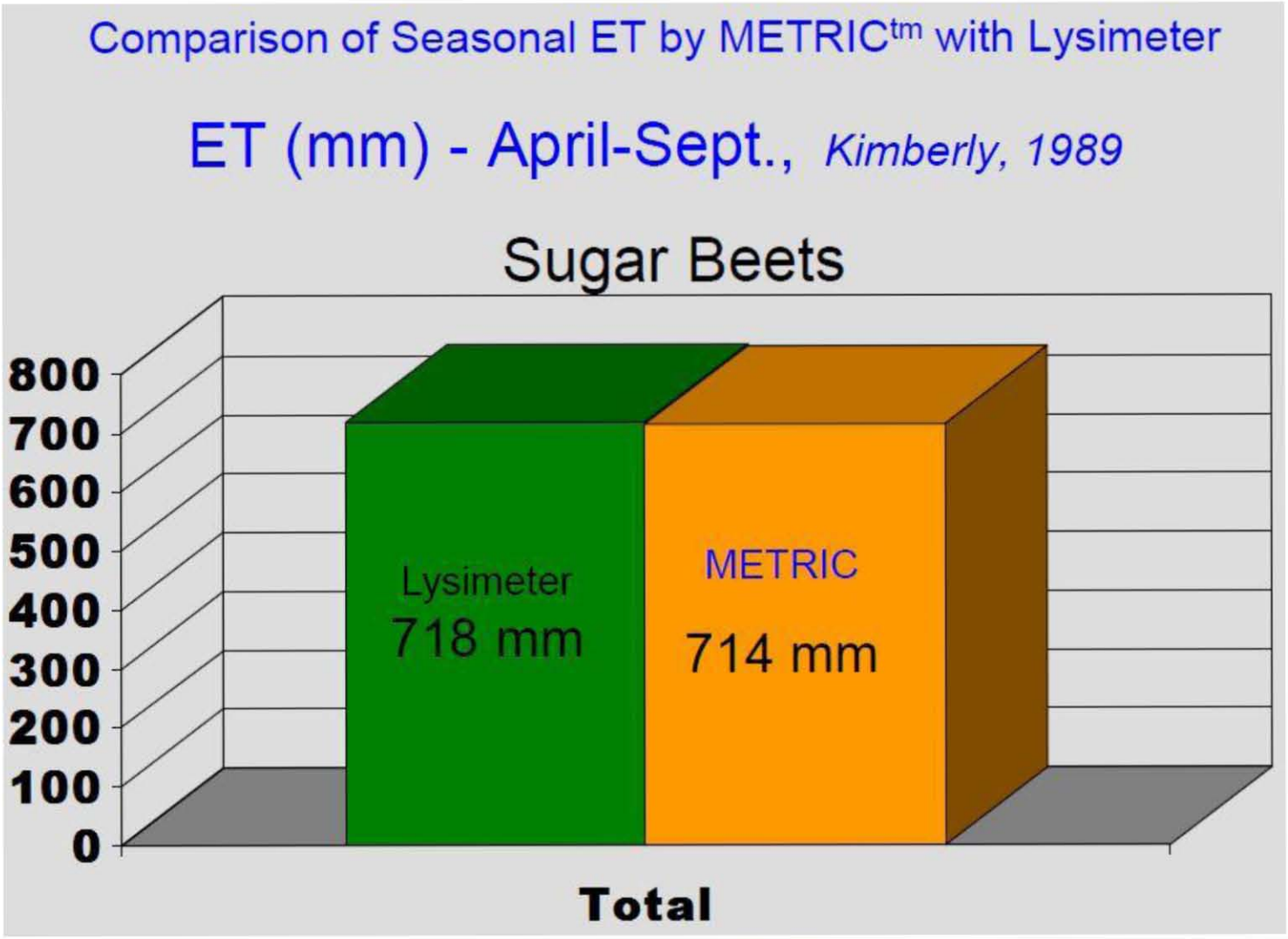
The ETrF curve represents the ET behavior of a pixel, relative to ETr, during the growing season




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 ($Et_R$).

$$ET_c = K_c * ET_R$$

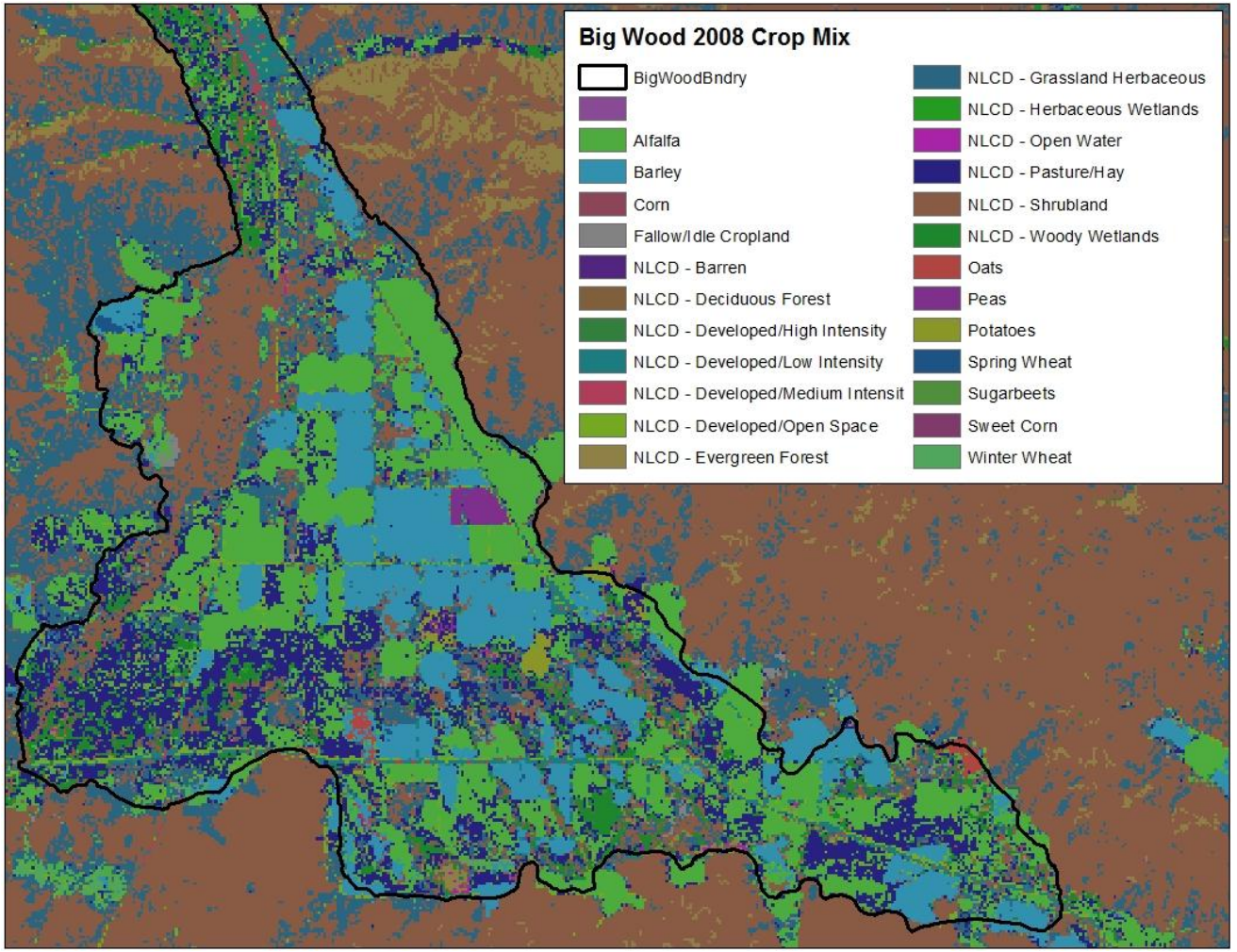
- The Crop Coefficient is actually a dual coefficient that considers both the crop ET and the effect that irrigation and precipitation have on evaporation from the soil surface.
- ETIdaho catalogues $ET_c$ for various crop types at numerous weather stations.
- We need to classify and quantify the crops 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.

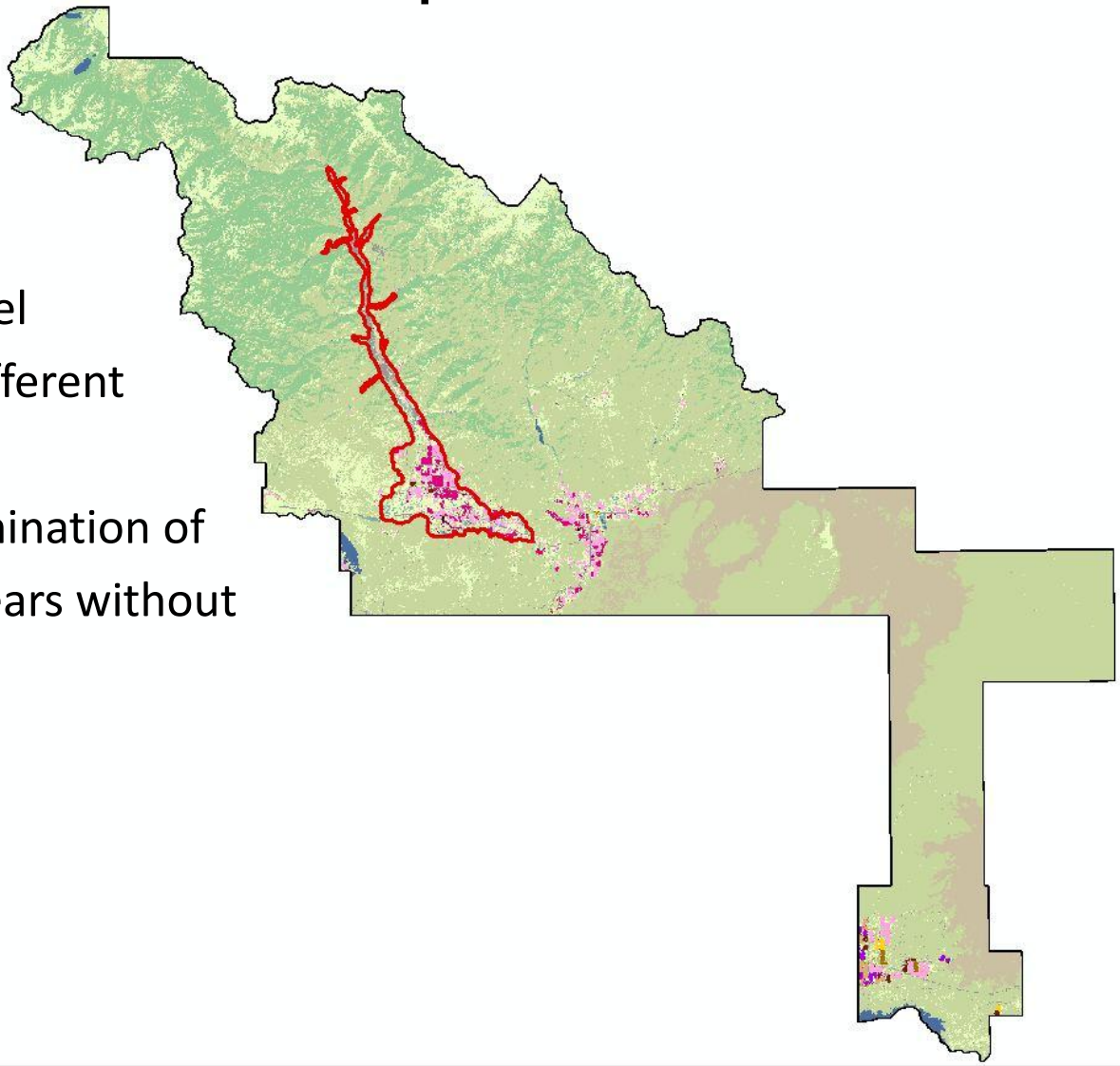
# ETIdaho and Crop Mix

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/ |

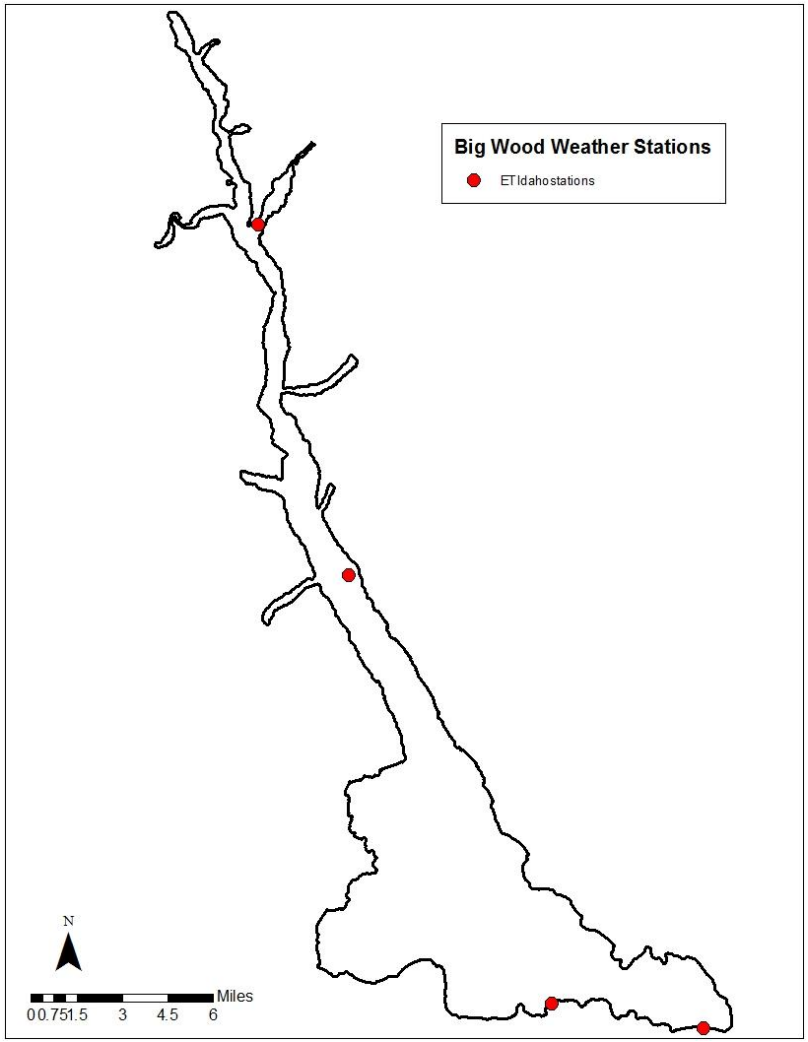
# ETIdaho and Weather Data

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

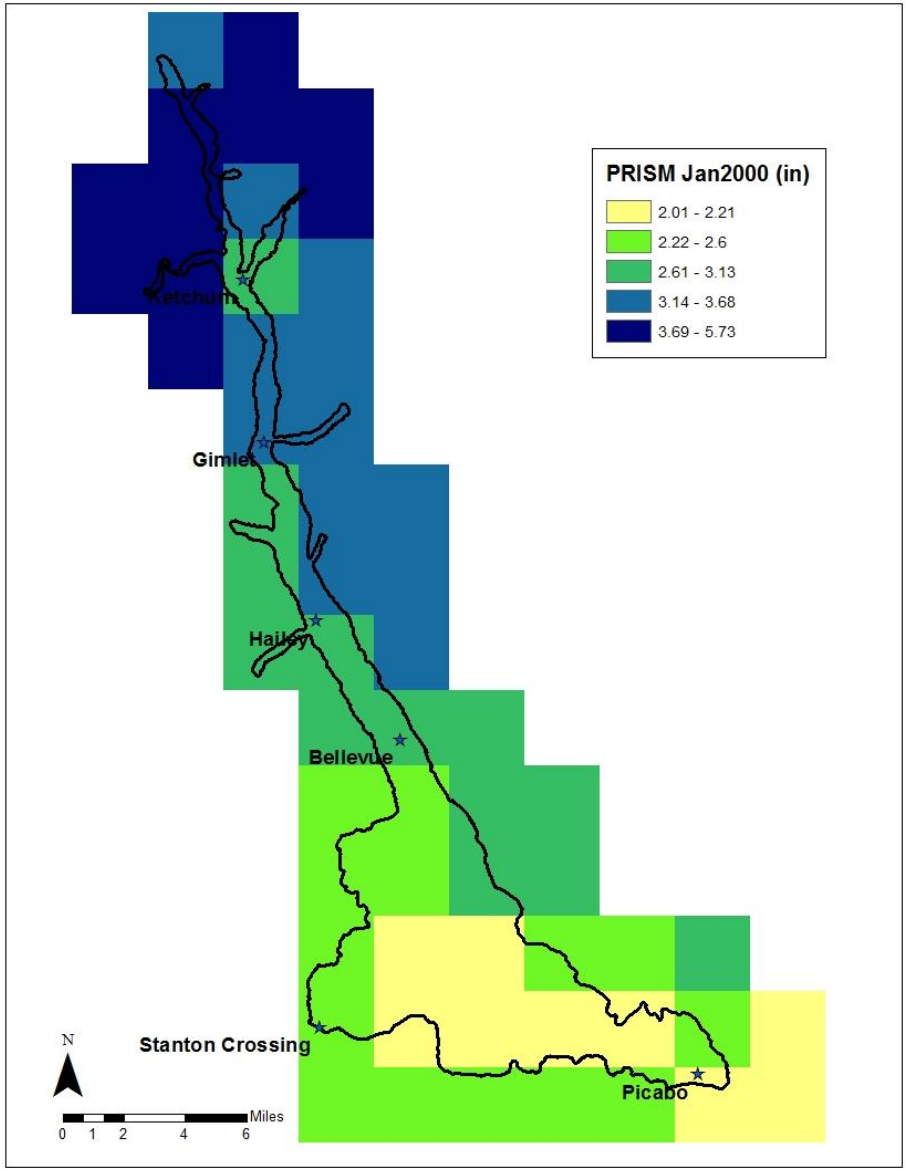
- ETIdaho can estimate ET with +/- 10-15%.  IF DONE WELL.
  - Crop classification is difficult.
- ETIdaho gives actual ET for every day.
  - Not very good spatial resolution.
- METRIC can estimate ET with +/- 10-15%.  IF DONE WELL.
  - We have the very best METRIC processors.
- METRIC gives spatially 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.

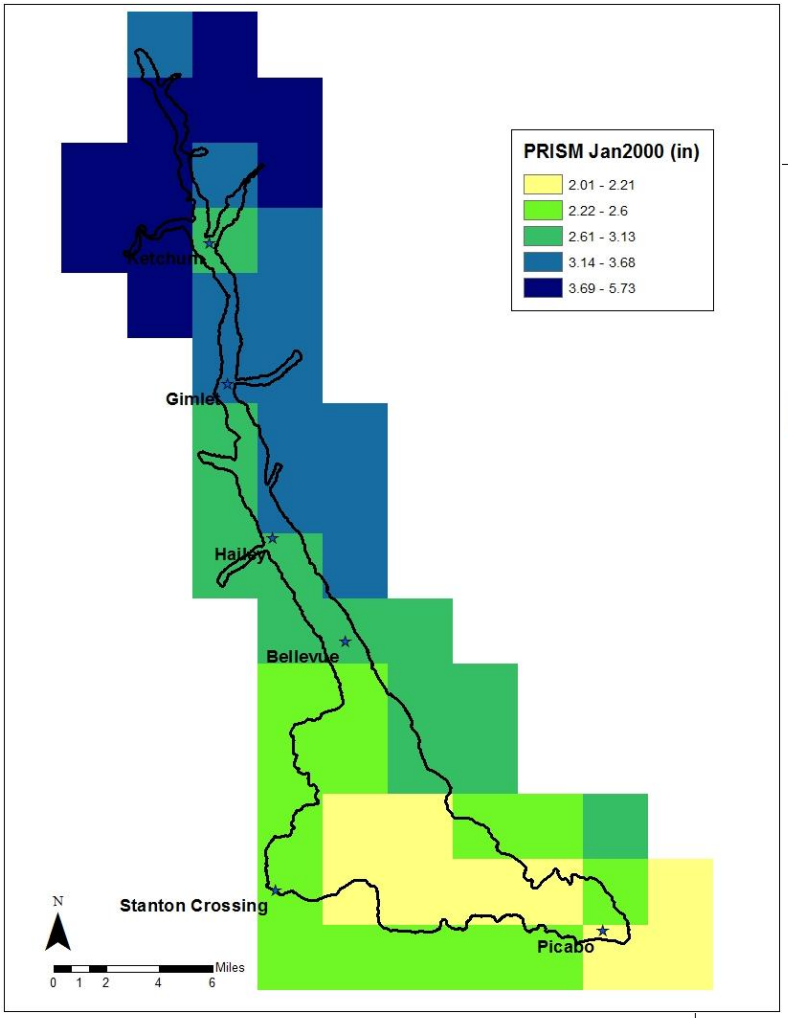
We have Monthly PRISM data; however, spatial resolution (4 km) is problematic in the Big Wood River valley.

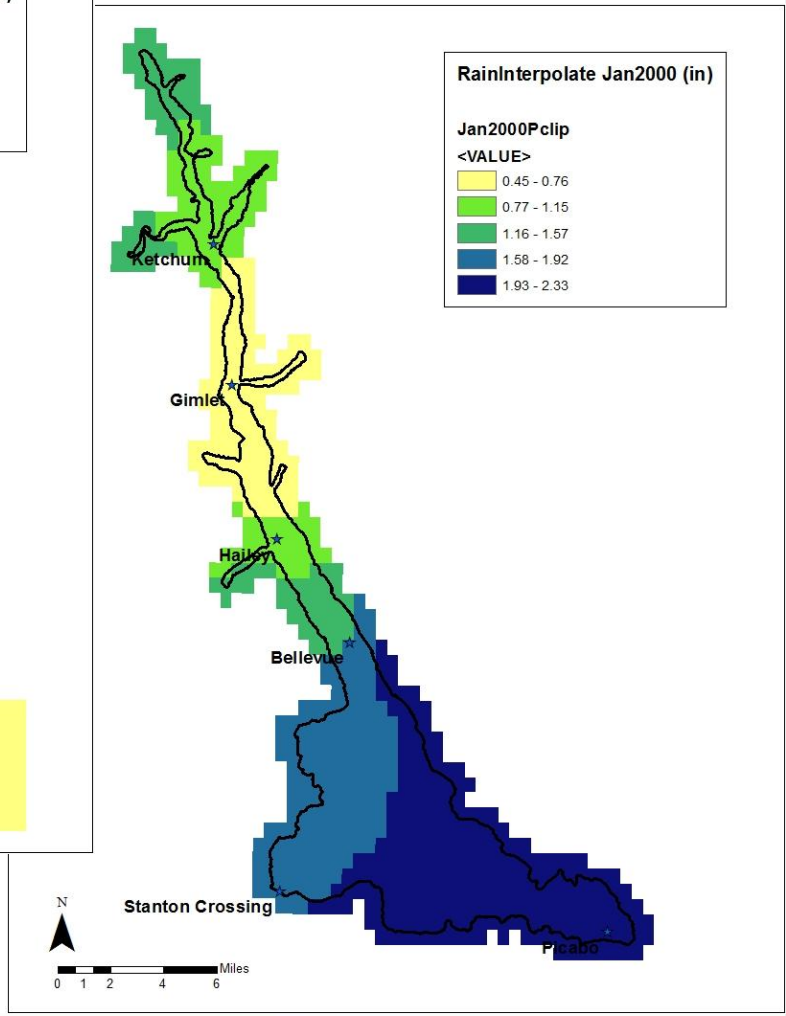
The PRISM Climate Group is located at Oregon State University

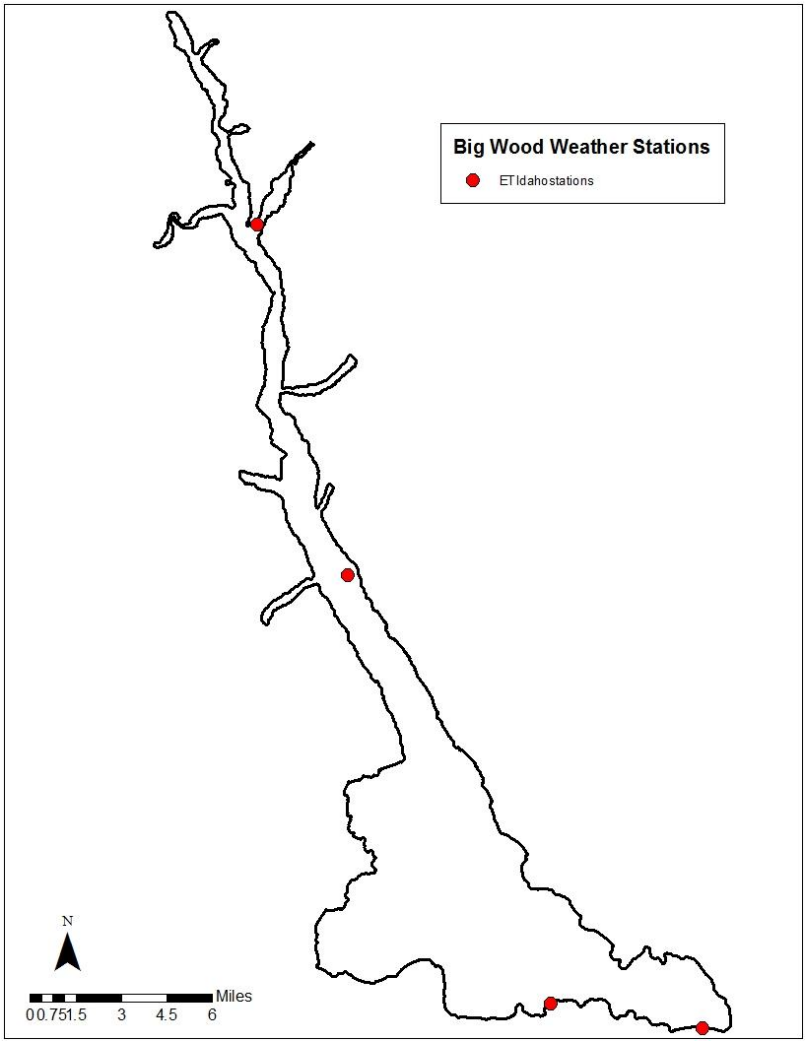
# Precipitation

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.