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RECLAMATION



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Klamath River Basin Revised Natural Flow Study

August 15, 2024

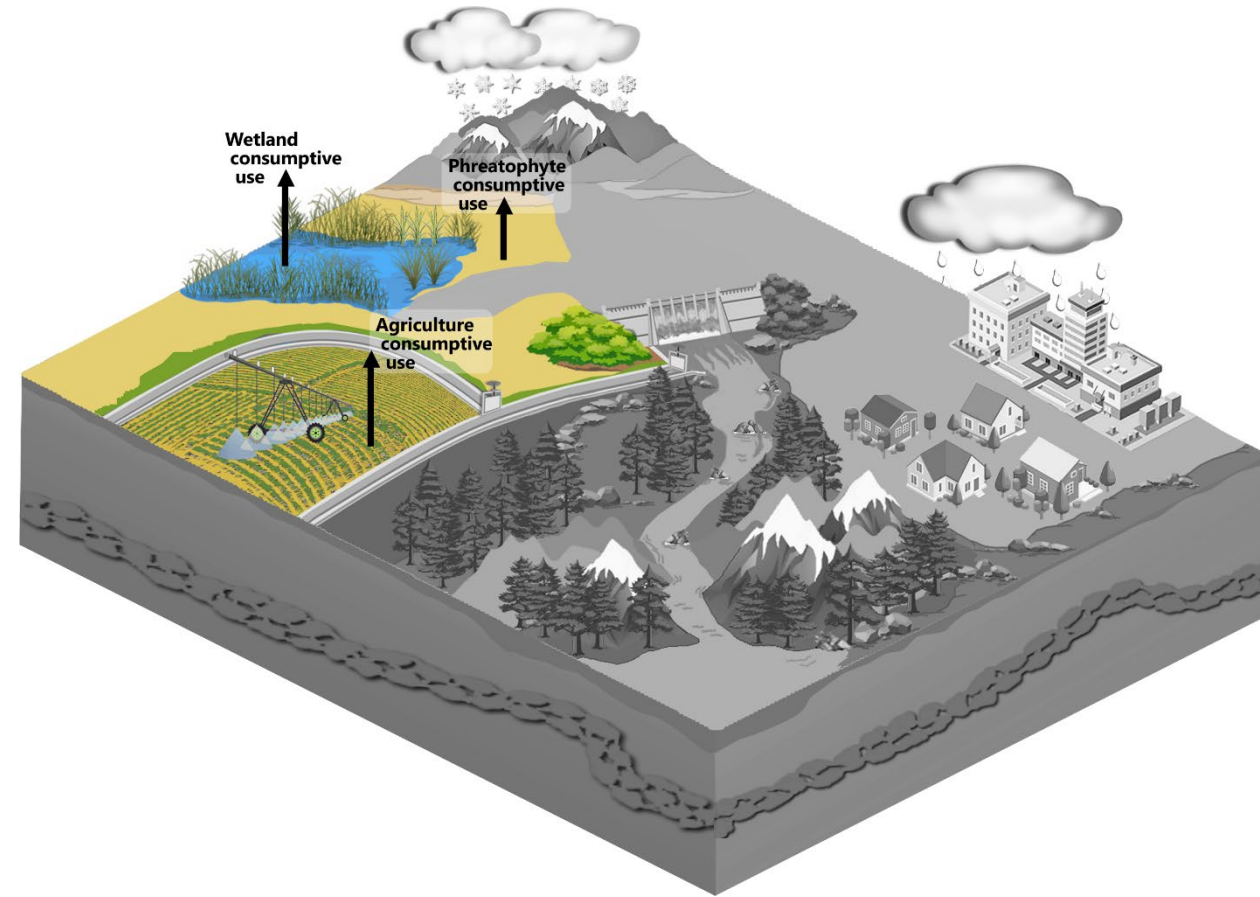
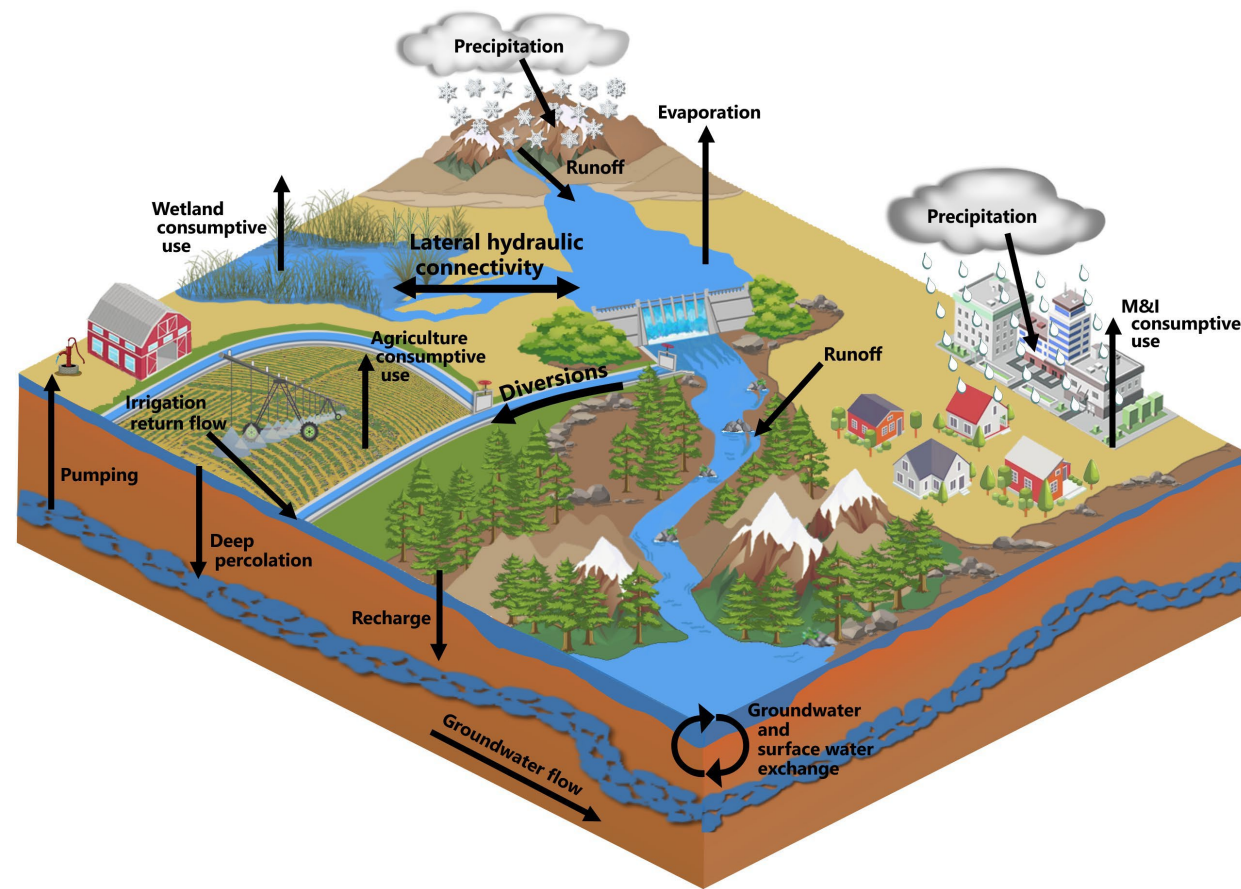
Evapotranspiration & Irrigation Demand
Modeling Results

Presentation Overview

- Analysis Approach
- Methods
 - Field boundary digitizing & attribution
 - eeMETRIC
 - ET Demands
 - Beamer-Minor Model
- Results
- Limitations & Uncertainty

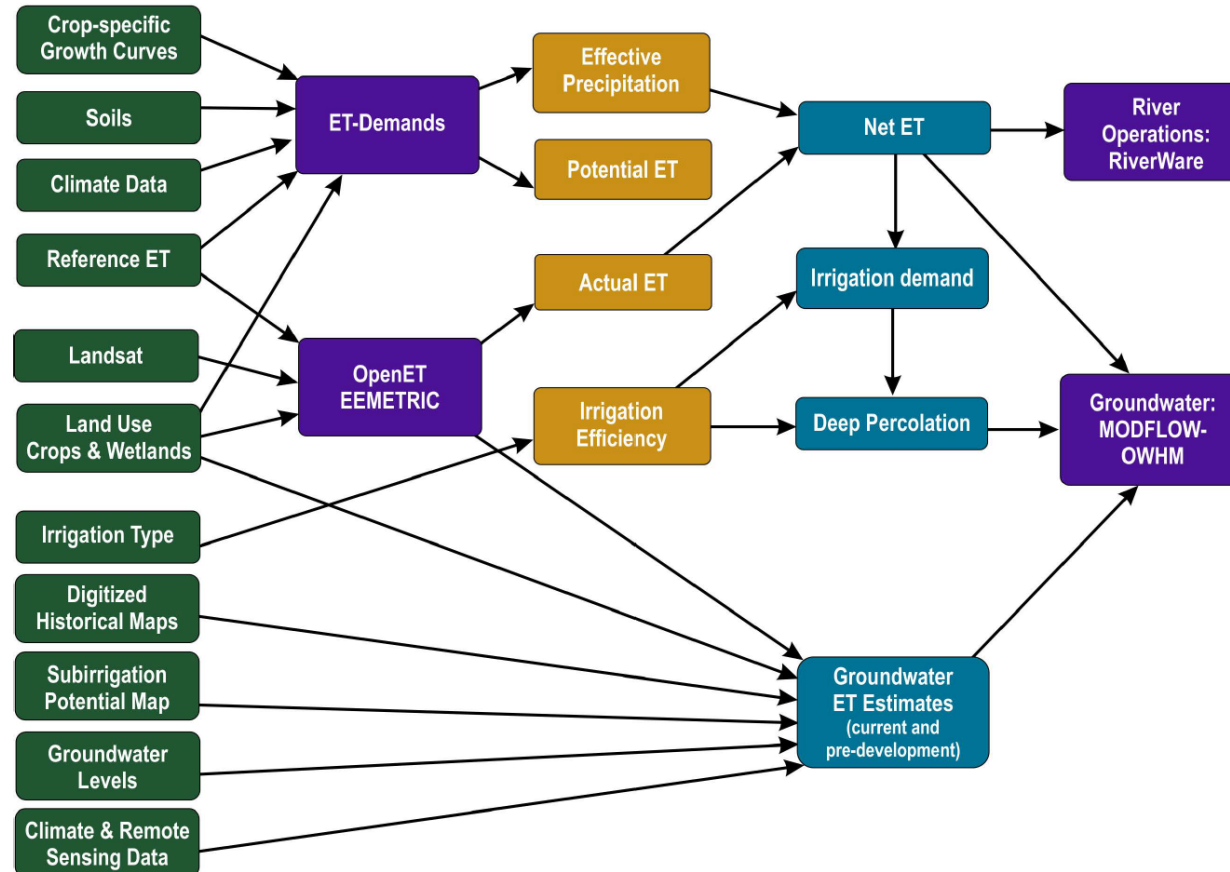
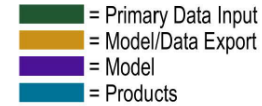


Analysis Approach



Input Data

Evapotranspiration



Methods

Field Boundaries

Maximum Irrigated Extent

Field Boundaries

- DRI and USBR TSC reviewed and refined over ~13,000 field boundaries
- Compared boundaries to aerial imagery and Landsat NDVI
- California boundaries required refinements to include maximum irrigated extent
- Oregon boundaries developed by OWRD/DRI for maximum irrigated extent, but needed refinement
- Boundaries edited in GIS at 1:2,500 scale

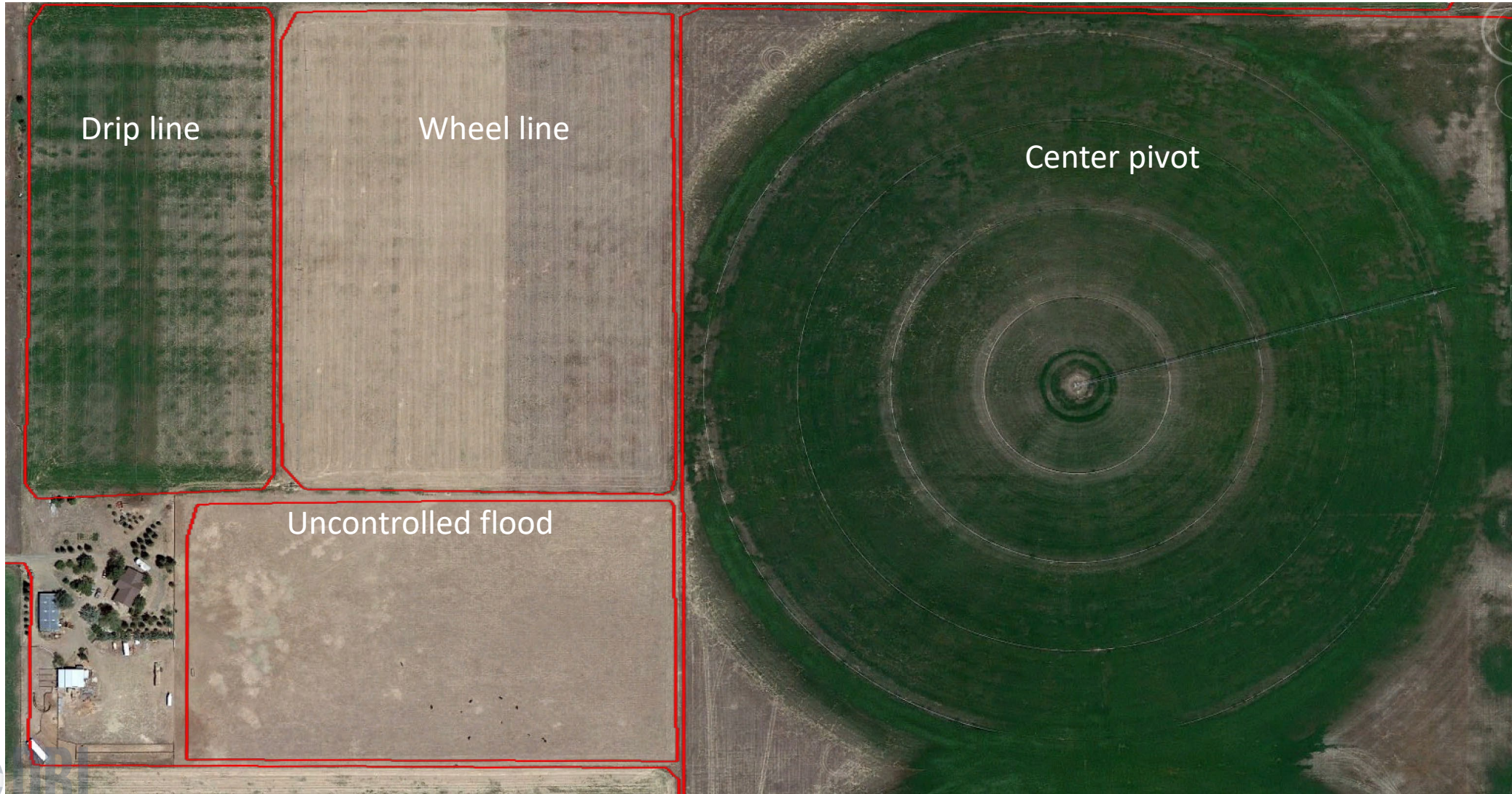


Irrigation System Type and Efficiencies

- Evaluation of one-meter resolution aerial photography from the National Agricultural Imagery Program (NAIP) (2003 – 2020)
- Five irrigation types with varying irrigation efficiency rates
- 1980 – 2002 irrigation types assumed unchanged from 2003
- Attribution by TSC/DRI Team guided by KBAO

<u>Irrigation Type</u>	<u>Efficiency Rate</u>
Sprinkler pivot	85%
Sprinkler other	75%
Flood controlled	65%
Flood uncontrolled	50%
Micro	85%

Irrigation Type Examples

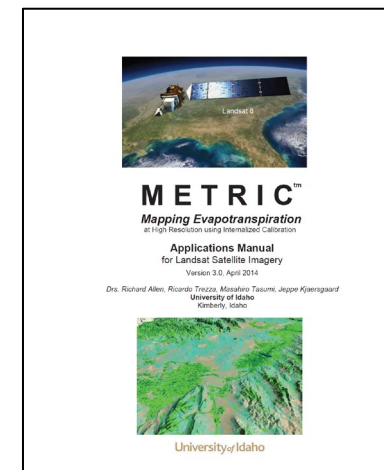
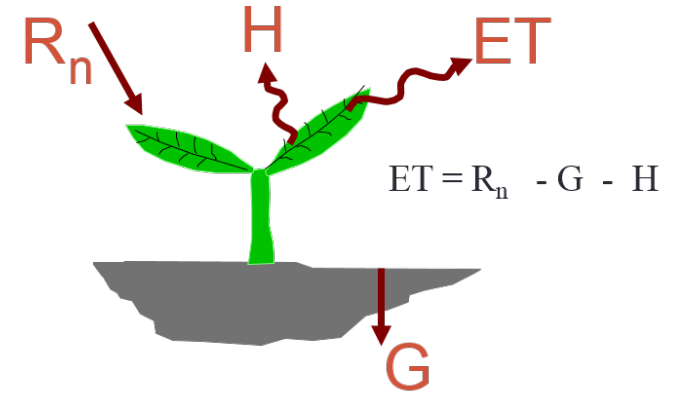


eeMETRIC

Agricultural & Wetland ET

eeMETRIC

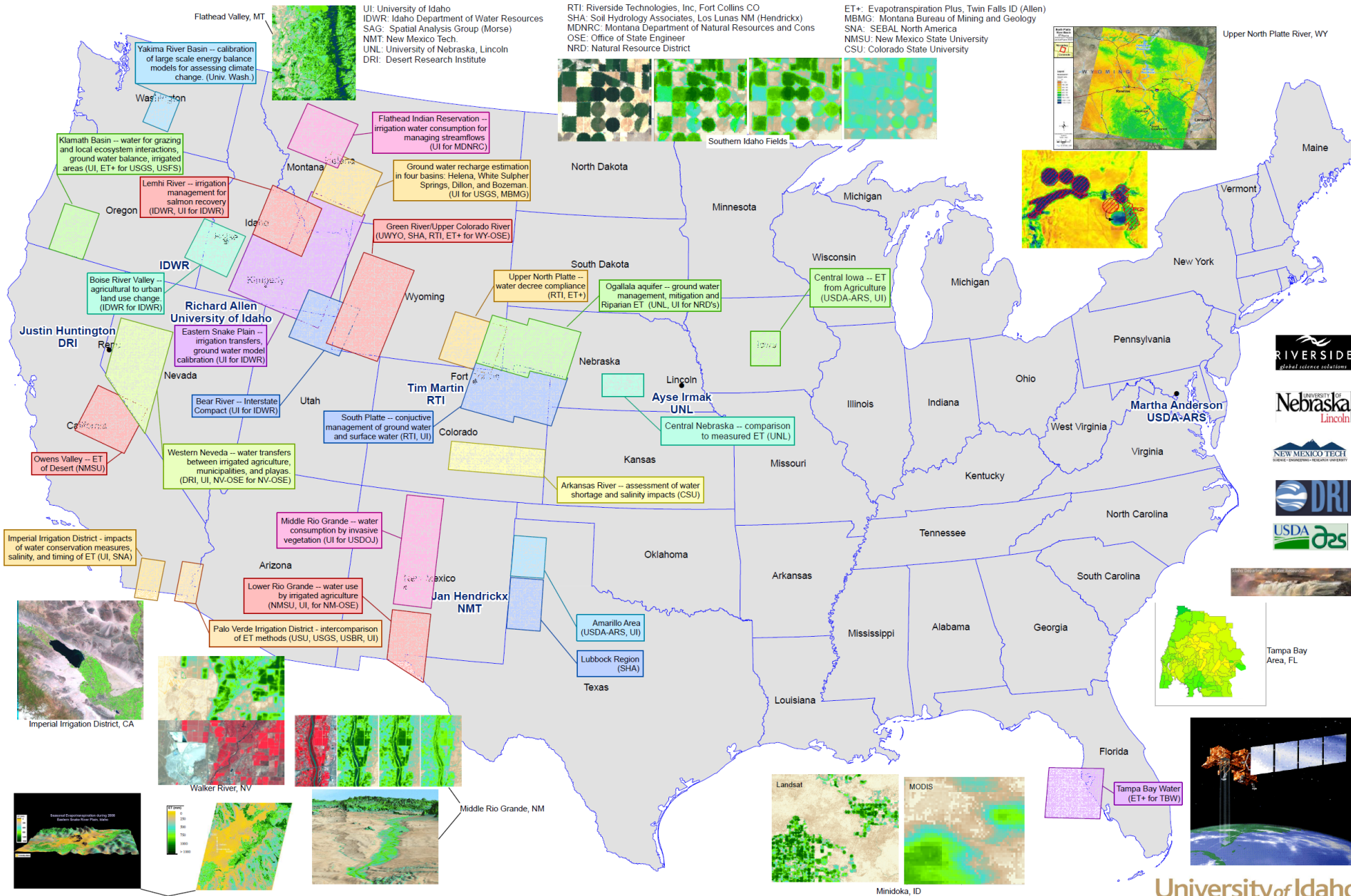
- eeMETRIC was selected for this study to estimate ET for agricultural areas
- Uses energy balance approach to estimate ET
- The METRIC model has been used to estimate actual ET (ET_a) in the Klamath River Basin (2004, 2006, 2010, 2013, and 2014)



ET Investigations involving METRIC/Landsat -- Applications for Water Management

University of Idaho and Associates/Partners

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Input Data

Agricultural Field Boundaries

- Maximum irrigated extent

Remote Sensing

- Landsat Collection 2 Surface Reflectance (optical and thermal)

Climate

- gridMET
 - Tmin, Tmax, RH, Windspeed, Solar Radiation, Precipitation

ASCE Standardized PM Reference ET

- Grass Reference ET, ETo
- Bias corrected to station data using OpenET bias correction layer

Crop Type

- USDA Cropland Data Layer (2008-2020)

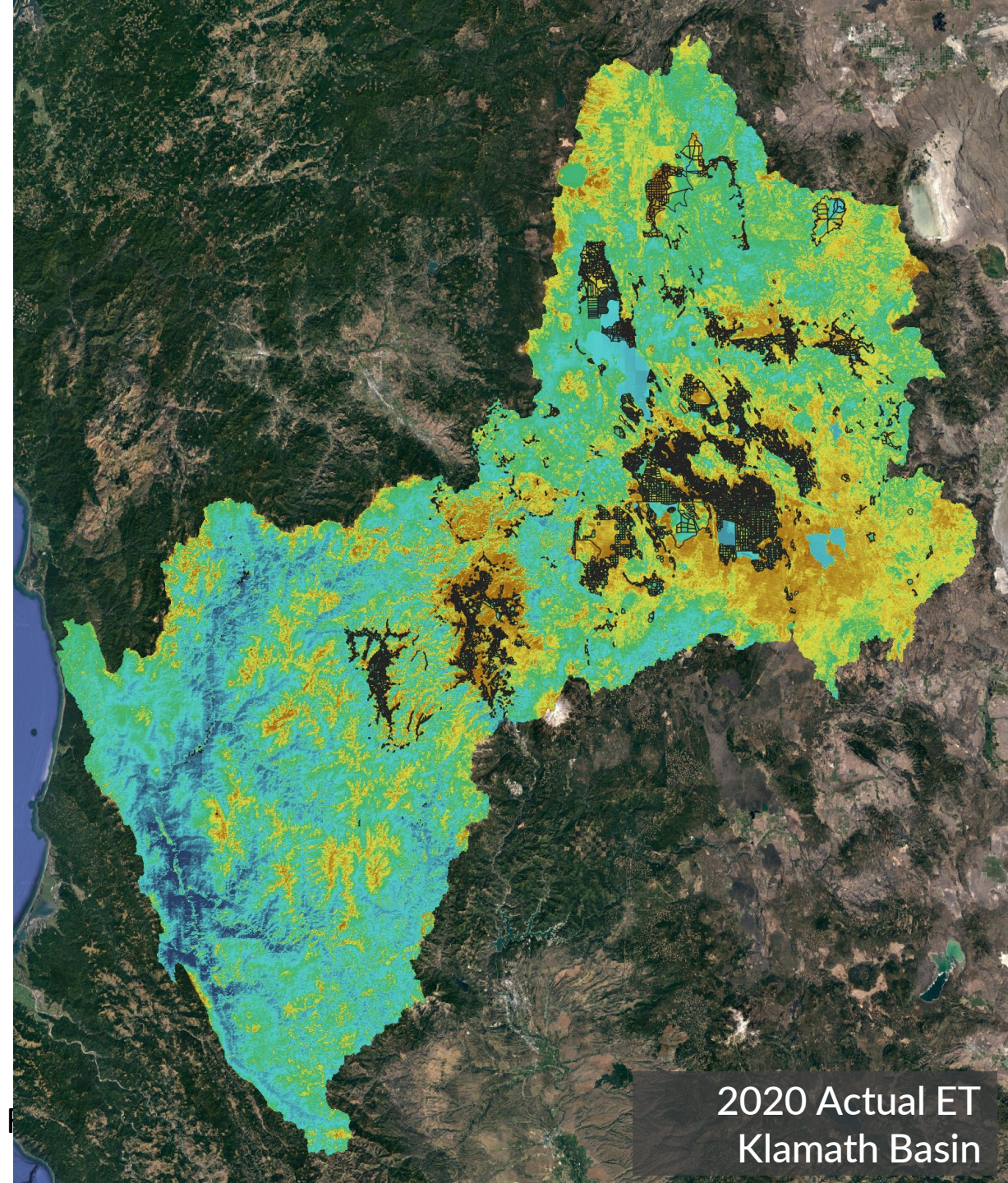


Google Earth Engine

OPENET

Model Extent

- Data Processed through OpenET using Google Earth Engine
- Monthly ETa for 1985-2020 at 30-meter resolution
- Model domain covers the entire Klamath River Basin
- Spatial summaries extracted for all fields



2020 Actual ET
Klamath Basin

ET Demands

Effective Precipitation

Methods - ET Demands

The eeMETRIC model provides estimates of total ET (ET_a)

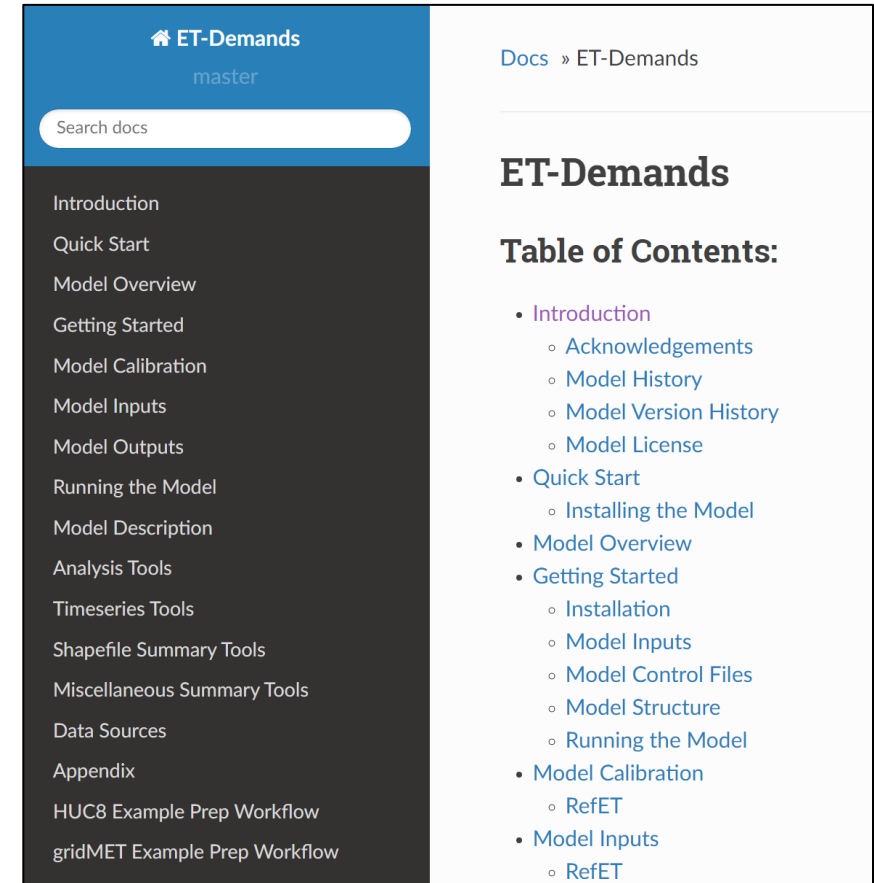
- $\text{Total ET} = \text{ET}_{\text{precipitation}} + \text{ET}_{\text{irrigation}}$

To calculate ET_{irrigation} effective precipitation must be subtracted

Effective precipitation is defined as the amount of precipitation that is available for ET (Bos et al., 2009).

ET Demands provides estimates of daily Crop ET and Pe using a daily soil water balance approach

- Previous Applications:
 - Upper Colorado River Basin
 - Nevada
 - Idaho
 - Oregon
 - West-wide Climate Risk Assessments



The screenshot shows the documentation page for ET-Demands. The page has a blue header with the title 'ET-Demands' and 'master' below it. A search bar is present. The left sidebar contains a navigation menu with the following items: Introduction, Quick Start, Model Overview, Getting Started, Model Calibration, Model Inputs, Model Outputs, Running the Model, Model Description, Analysis Tools, Timeseries Tools, Shapefile Summary Tools, Miscellaneous Summary Tools, Data Sources, Appendix, HUC8 Example Prep Workflow, and gridMET Example Prep Workflow. The main content area shows the title 'ET-Demands' and a 'Table of Contents' section. The Table of Contents lists the following items: Introduction (with sub-items: Acknowledgements, Model History, Model Version History, Model License), Quick Start (with sub-item: Installing the Model), Model Overview, Getting Started (with sub-items: Installation, Model Inputs, Model Control Files, Model Structure, Running the Model), Model Calibration (with sub-item: RefET), and Model Inputs (with sub-item: RefET).

Model code and documentation:

<https://github.com/WSWUP/et-demands>

Model Extent

Model Set-up

- Spatially varying climate and crop information
- Simulated Crop ET and Effective Precipitation for 1980-2020
 - 1979 initialization year
- Model domain covers all areas with irrigated agricultural
- Based on agricultural field boundary dataset

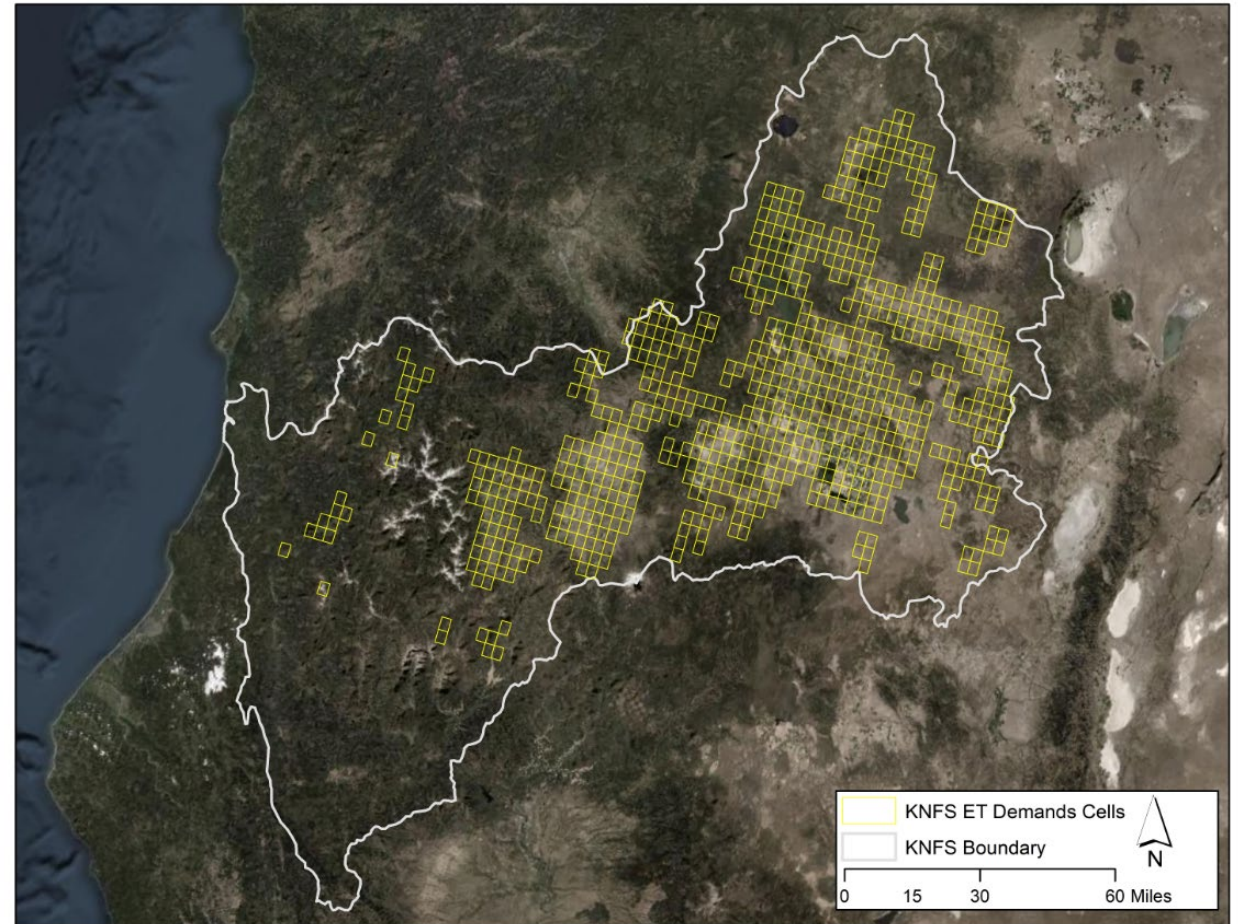


Figure: Map of Klamath NFS ET Demands Model domain. Crop ET simulations are made for each for each unique crop, grid cell combination.

Overview

Daily Data Produced by ET Demands:

- Crop ET
 - ASCE Standardized PM Reference ET
 - FAO-56 Dual Crop Coefficient Method
- Daily Soil Water Balance
 - Effective Precipitation
 - P_{rz} = Amount of PPT available for both E and T
 - $P_{rz} = PPT - \text{Runoff} - \text{Deep Percolation}$
 - Deep Percolation
 - Drainage below the crop root zone
 - Soil Water Content > Field Capacity
 - Runoff
 - USDA NRCS CN Approach
 - Net Irrigation Water Requirement (NIWR)
 - $ET_c - P_{rz}$

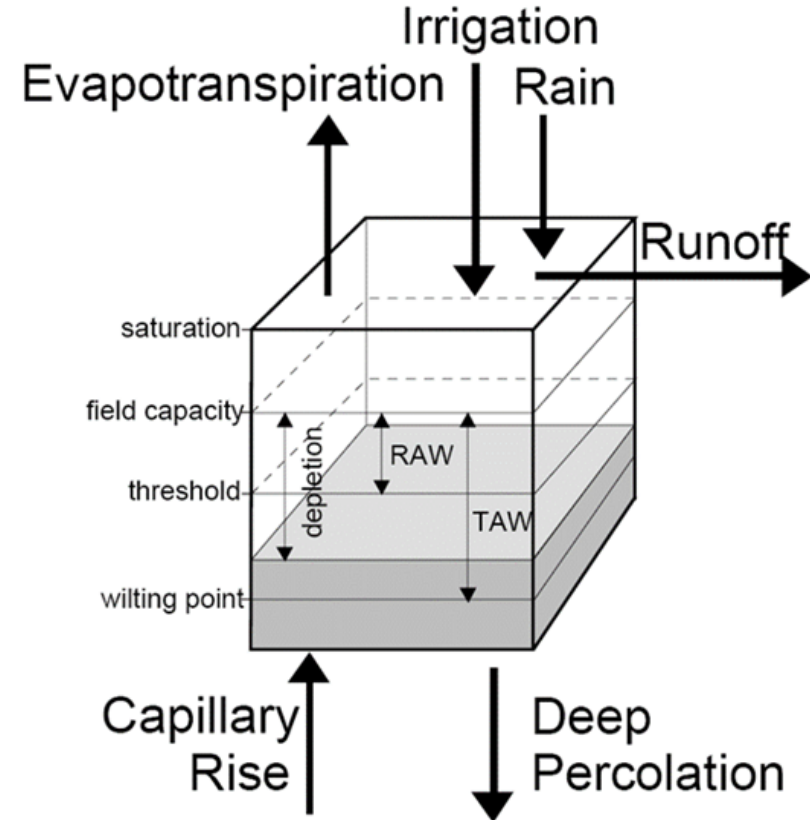


Figure: Conceptual diagram of the FAO-56 daily soil water balance utilized within ET Demands (modified from Allen et al., 2006).

Input Data

Climate

- gridMET
 - Daily estimates at 4 km resolution
 - Tmin, Tmax, RH, Windspeed, Solar Radiation, Precipitation

ASCE Standardized PM Reference ET

- Grass Reference ET (ET_o)
- Bias corrected to station data using OpenET bias correction layer

Soil

- NRCS SSURGO/STATSGO2 Database
- Average 0-150cm available water capacity
- Hydrologic Group – A, B, C
- Sand, Silt, Clay Fraction

Crop Type

- USDA Cropland Data Layer (2008-2020)

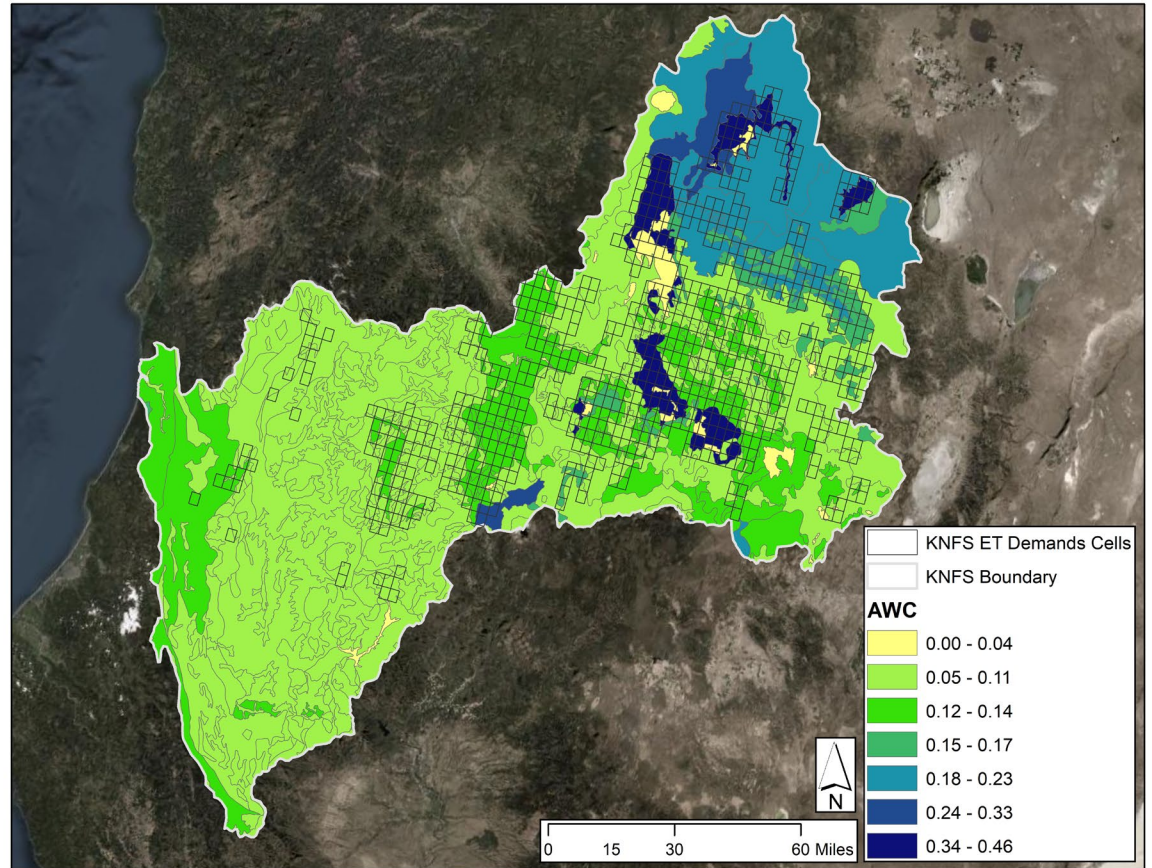


Figure: Map of Klamath Natural Flow study area soil available water capacity from SSURGO/STATSGO dataset.

Modeling Methodology

Crop Growth and ET Simulation

- Temperature based model
- Green Up
 - T30 or CGDD
- Effective Full Cover
 - CGDD or Time
- Harvest/Killing Frost
 - CGDD, Time, KF

Irrigation Scheduling

- Maximum allowable depletion thresholds
- Irrigation occurs when $MAD < \text{Threshold}$
- For example, 50%

Each crop, grid cell combination is simulated separately. Daily time series output is aggregated to monthly for pairing with RSM ET.

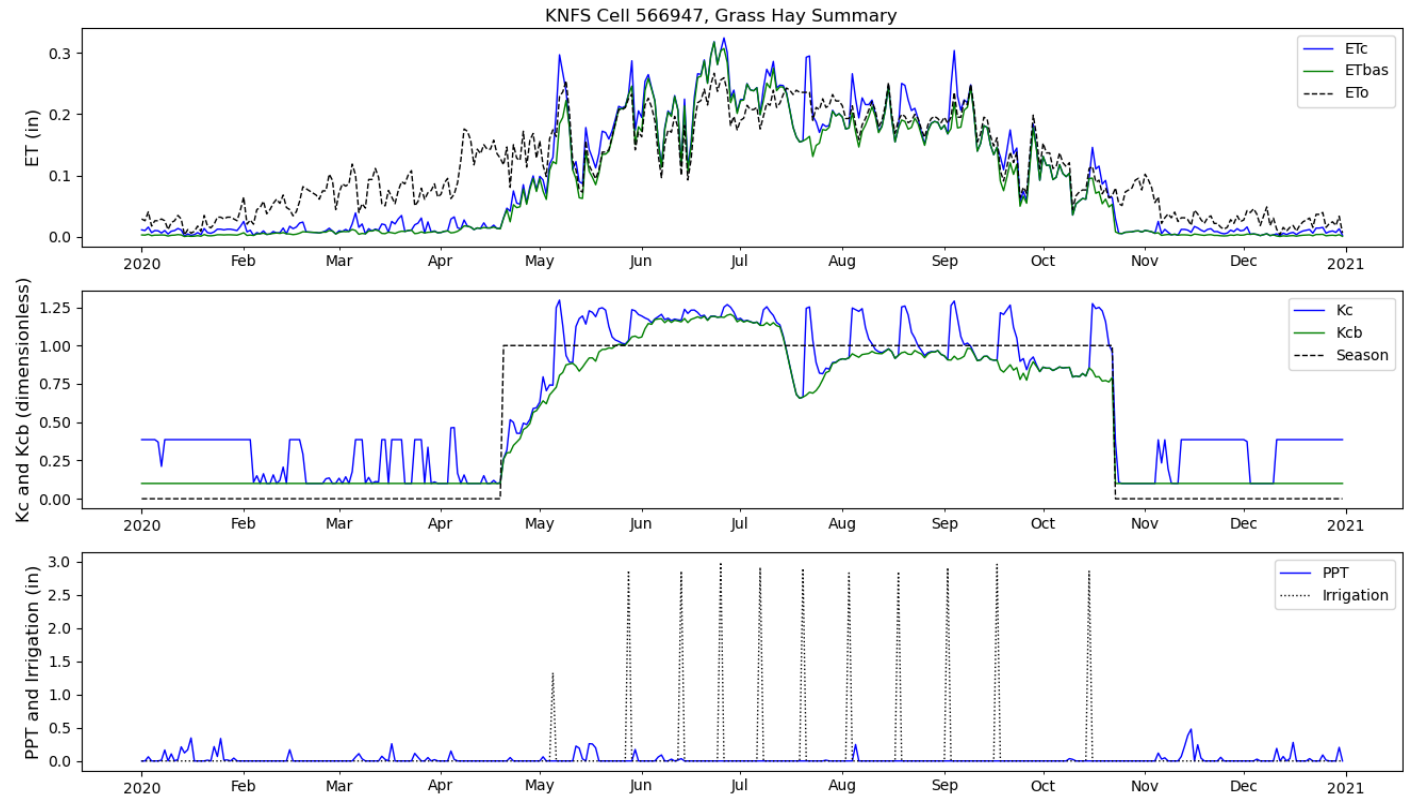


Figure: Example ET Demands output for Grass Hay Crop ET simulation.

Model Calibration

Calibration Sites

- Crop specific calibrations
- NDVI Comparisons
- Adjust Kc curve based on NDVI phenology
- Leverage typical growing season start and end dates

Goal is to capture average signal and interpolate throughout the entire study area.

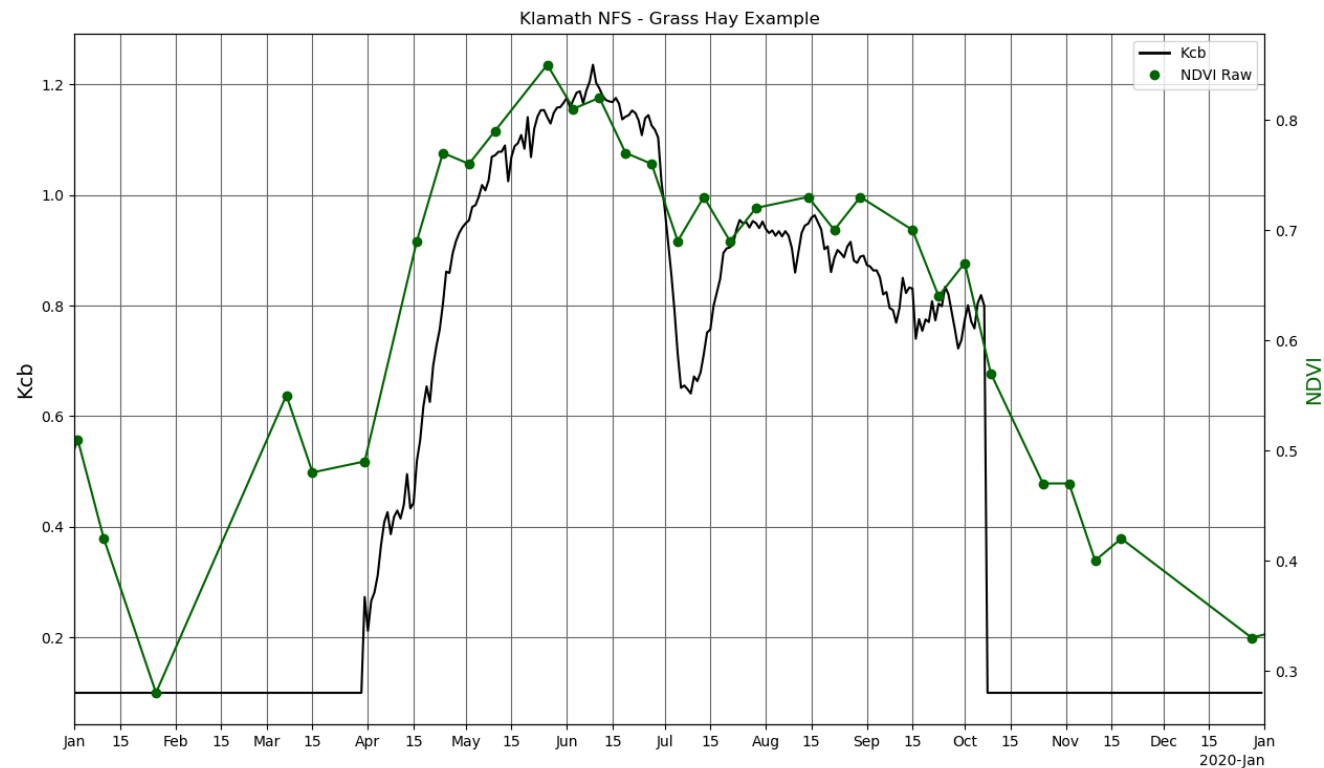


Figure: Time series comparison of Landsat derived NDVI and ET Demands simulated Kcb for grass hay crop in grid cell 564161 near Copoco Lake, CA.

Beamer-Minor Model

Groundwater Discharge from Phreatophyte Shrublands

Overview

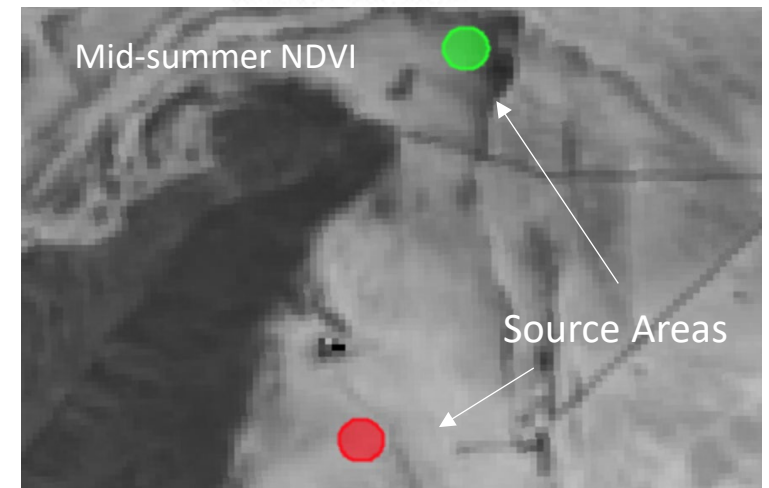
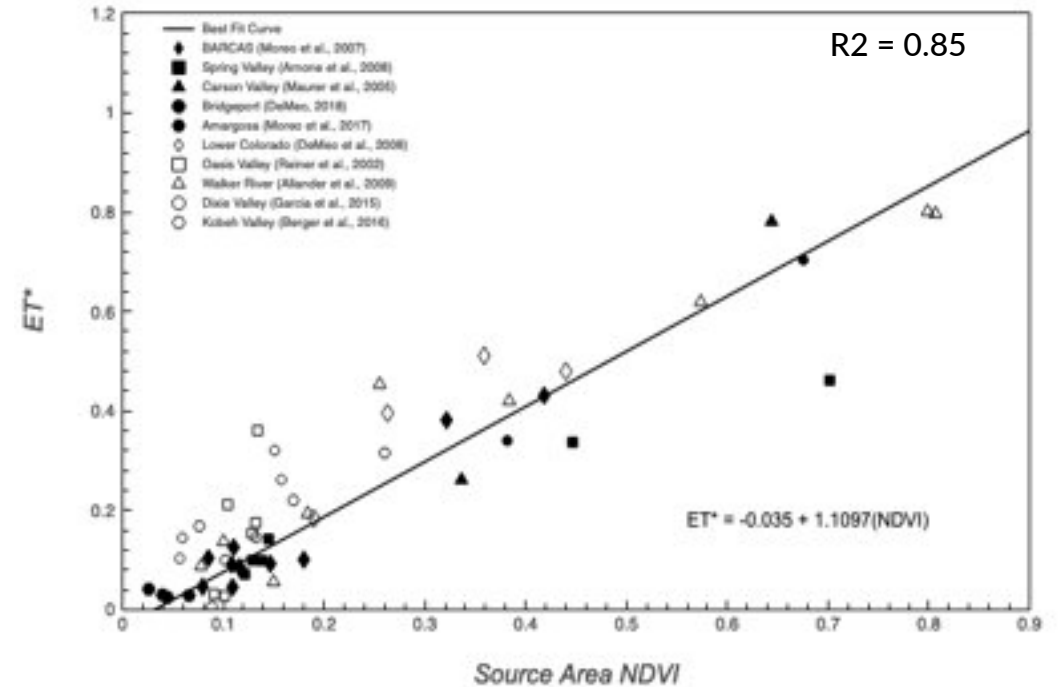
Annual Groundwater ET

- Model relates in-situ estimates of annual actual ET from phreatophytes to mid-summer Landsat source-area average NDVI
 - Energy balance corrected ET
 - Normalization to account for variations in climate, enabling transferability

$$ET^* = (ET_a - PPT) / (ET_o - PPT)$$

- Mid-summer NDVI images (1984-2020) used to predict ET^* from groundwater discharge areas
- Reference ET (ET_o) and precipitation (PPT) used to then estimate actual ET (ET_a) and groundwater ET (ET_g)

$$ET_g = (ET_o - PPT)ET^*$$



Model Inputs

Phreatophyte shrubland boundary

- Shapefile/polygons delineating contemporary extents

Remote Sensing

- Landsat Collection 2 Surface Reflectance
 - 30m resolution NDVI

Climate

- GridMET
 - Daily estimates at ~4km resolution Tmin, Tmax, RH, Windspeed, Solar Radiation, Precipitation

ASCE Standardized PM Reference ET

- Grass Reference ET, ETo

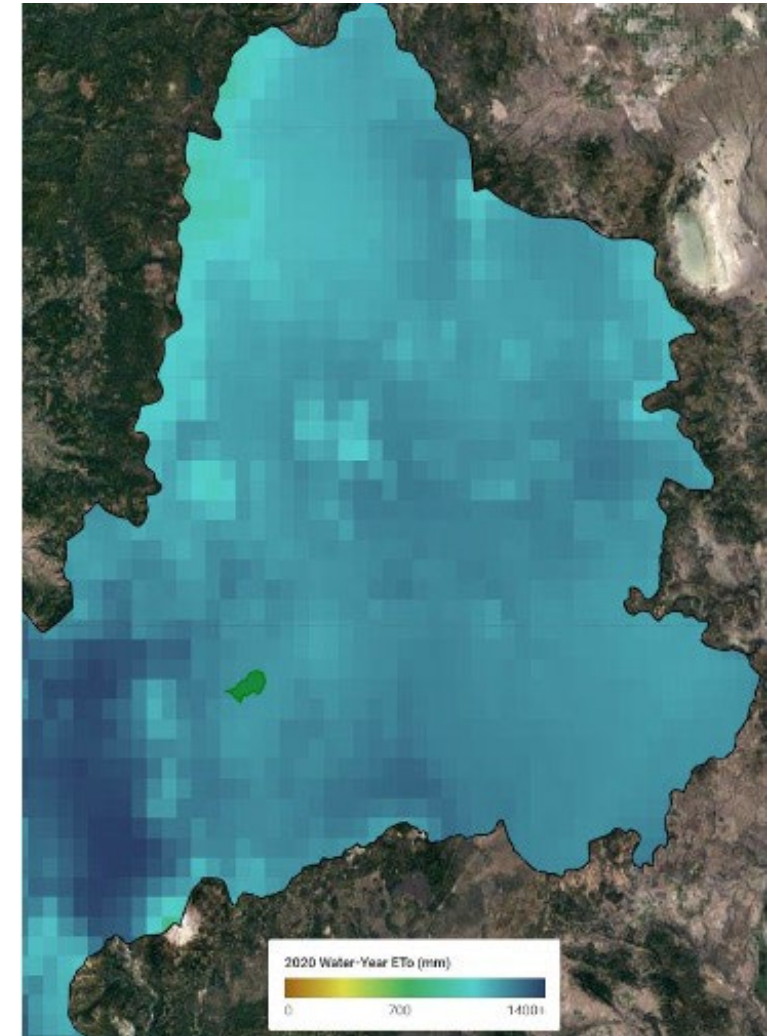
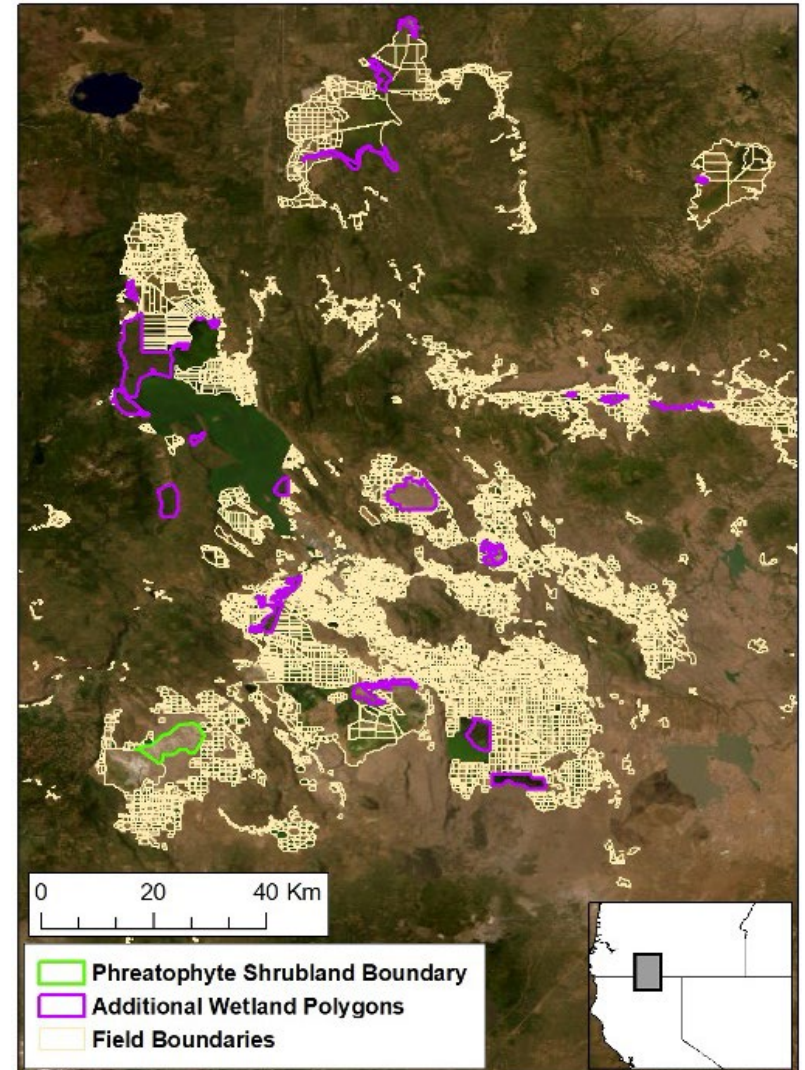


Figure: Map showing 2020 bias-corrected annual grass reference ET (ETo)

Beamer-Minor Model

- Groundwater ET from 1984-2020 at 30m resolution
- Model originally used for wetlands in the basin, but based on model performance eeMETRIC was deemed more appropriate for wetlands
- Model domain covers phreatophyte shrubland areas only (Butte Valley)
- Extent based on contemporary and pre-project phreatophyte mapping effort in the upper Klamath Basin



Results

eeMETRIC

Monthly ET rasters (1985-2020)

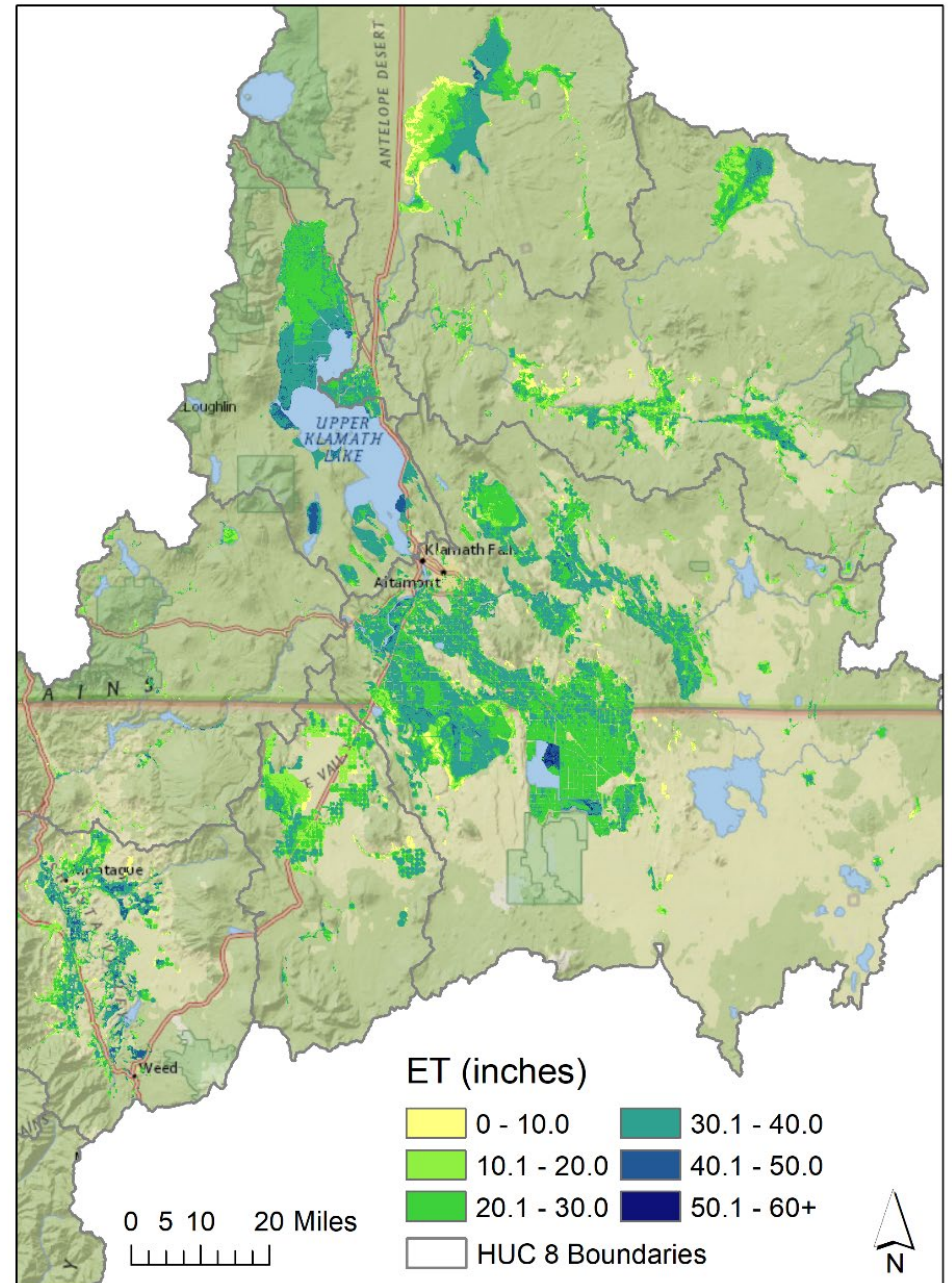
- Actual ET at 30-meter resolution

Spatial summaries

- Monthly time series for ~ 13,000 fields
- Analogous years used to populate 1980-1984 ET

eeMETRIC summaries paired with ET Demands
effective precipitation to estimate monthly Net ET

- Majority crop type 2008-2020 used for pre-2008 classifications



ET Demands

- Effective Precipitation
 - Monthly output (1980-2020)
 - Crop specific pairing with field-level ET data from remote sensing
- Net ET:
 - $eeMETRIC\ ET_a - ET\ Demands\ Eff.\ Precip$
- All precipitation in wetlands is assumed effective

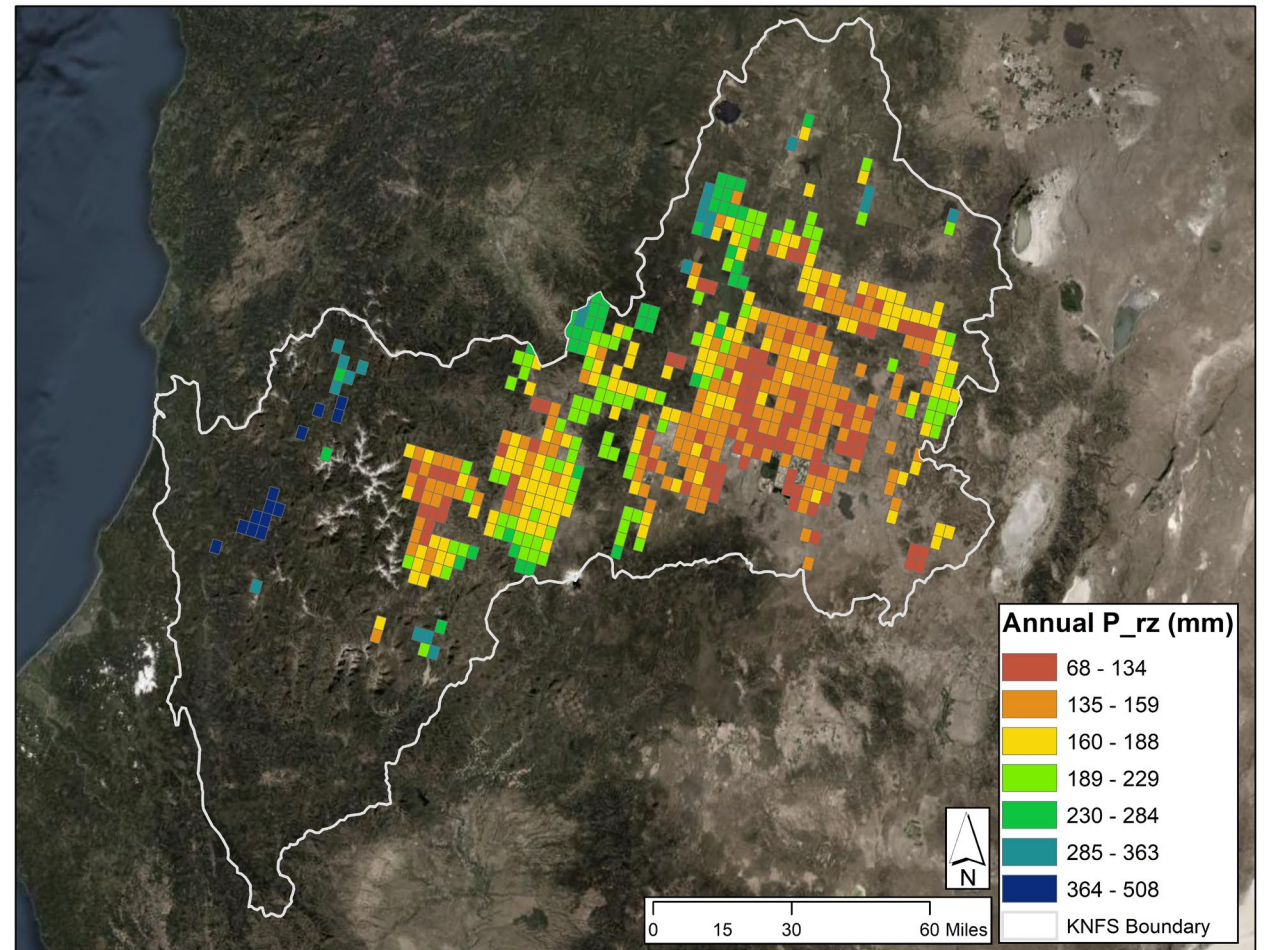


Figure: Map of ET Demands estimated effective precipitation for grass hay fields in 2020.

Beamer-Minor Model

Groundwater ET

- Annual output (1984-2020)
- Raster (30 m) and spatial summary table formats
- 90% confidence and prediction interval rasters

Disaggregation to seasonal

- Water-year ET_g/ET_o ratios applied to seasonal summaries of ET_o
 - Quarterly ET_g rasters for each water-year
 - Oct-Dec, Jan-Mar, Apr-Jun, Jul-Sep

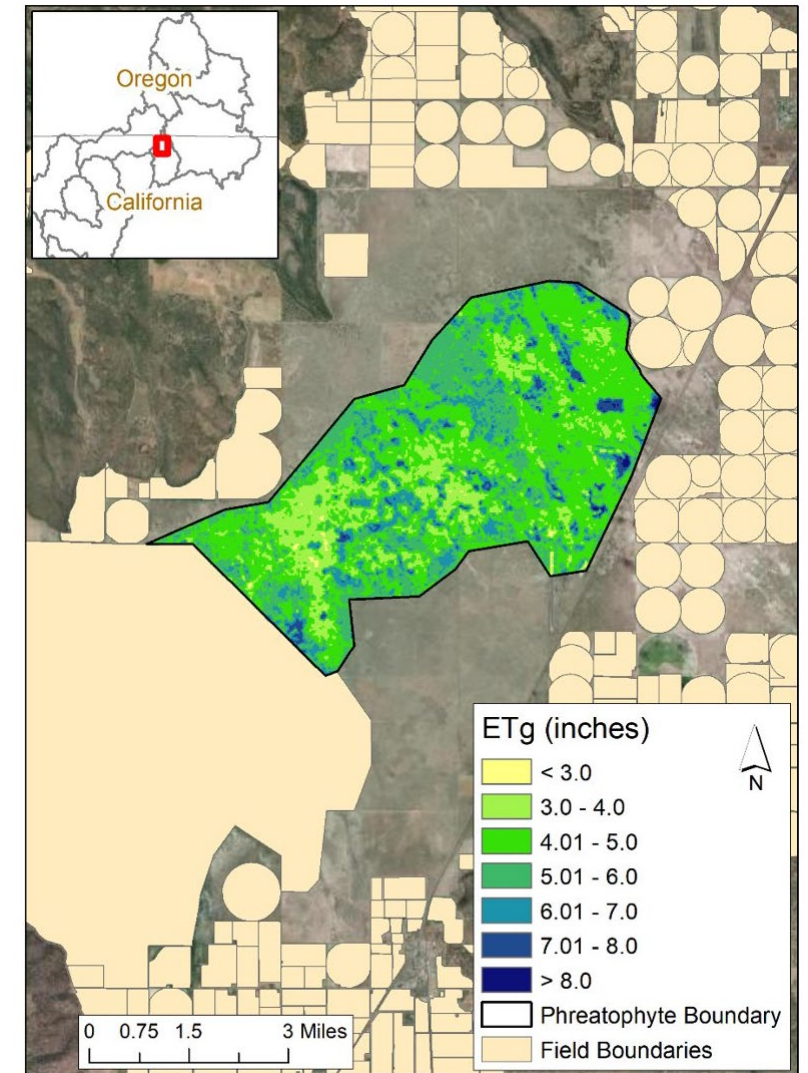
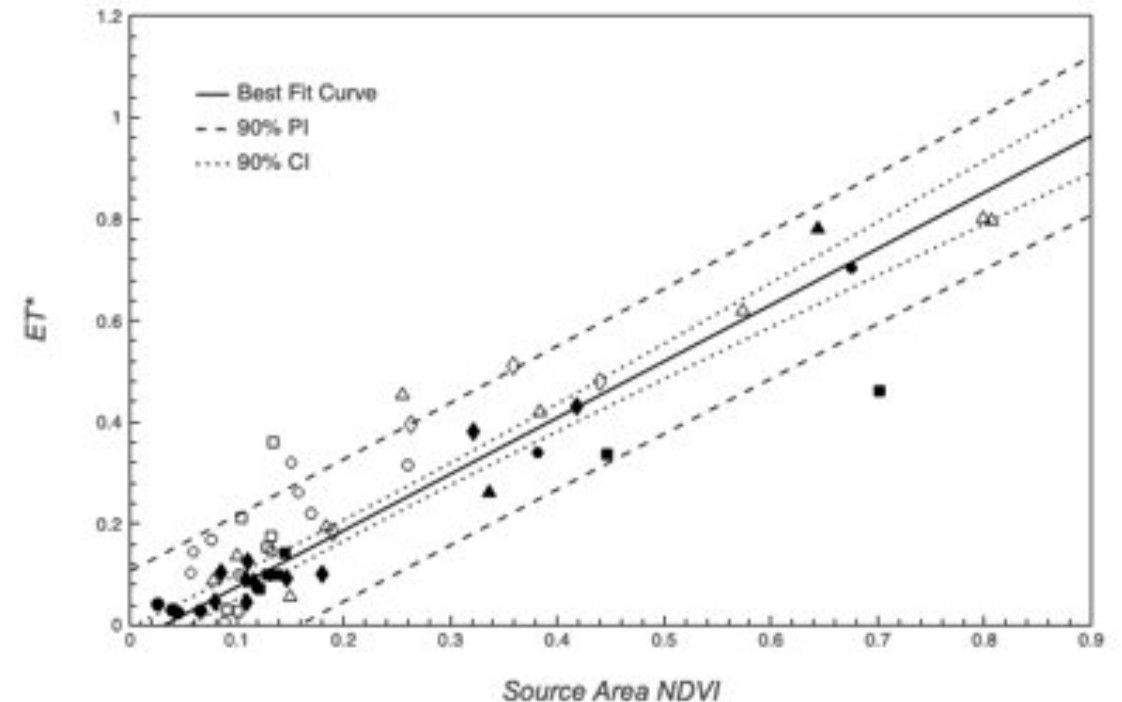


Figure: Map showing median annual groundwater ET rates for Butte Valley phreatophyte shrublands.

Limitations & Uncertainty

Beamer-Minor Method

- Model produces upper and lower 90% confidence and prediction interval estimates
 - CI shows range of values associated with some statistical parameter of the data, such as the population mean ET^*
 - PI shows the range in which a future individual observation will fall
 - Must account for both the uncertainty in estimating the population mean, plus the random variation of the individual values
- Assumes all precipitation discharges through ET



ET Demands

Advantages

- ET Demands captures spatial variability related to soil type, precipitation, and crop water demand
- Daily soil water balance is considered most accurate method for estimating effective precipitation
- Includes non-growing season carry forward soil moisture

Disadvantages

- Crop ET and growing season calibration relies on manual calibration that may not capture management everywhere
- Snow is currently not considered
- Soil type is based on average of agricultural conditions across each 4km grid cells

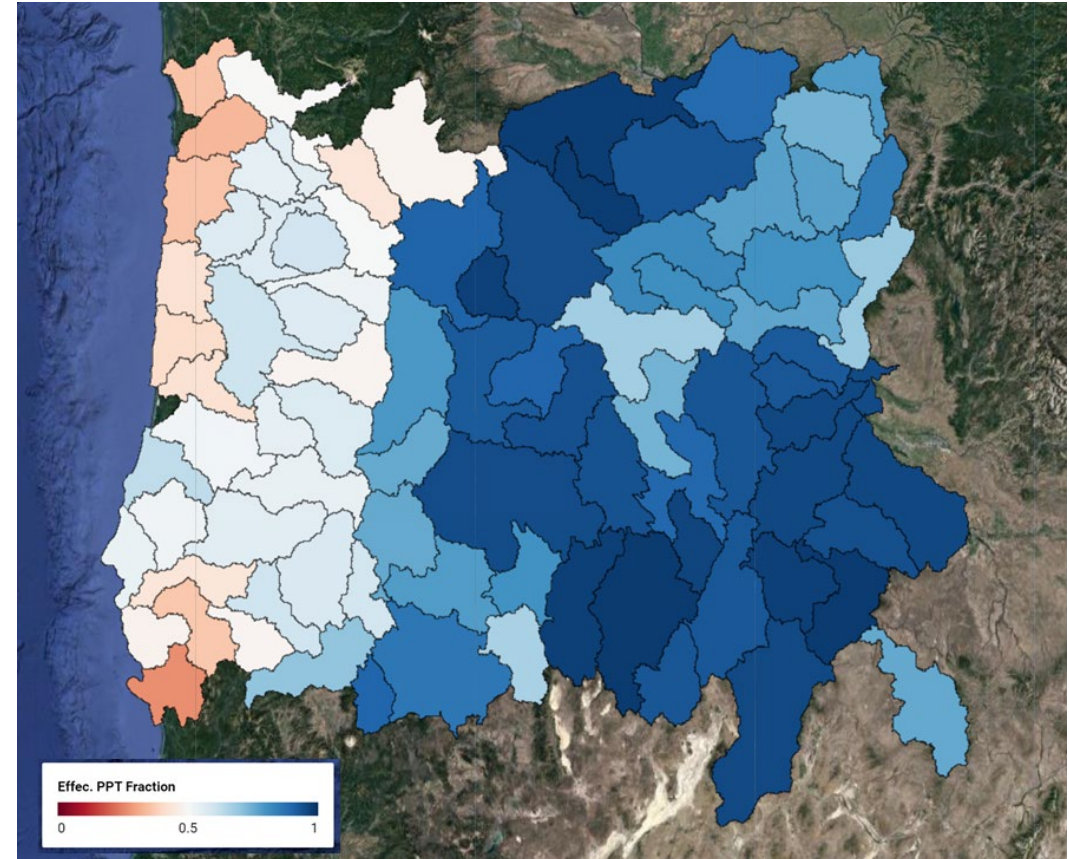
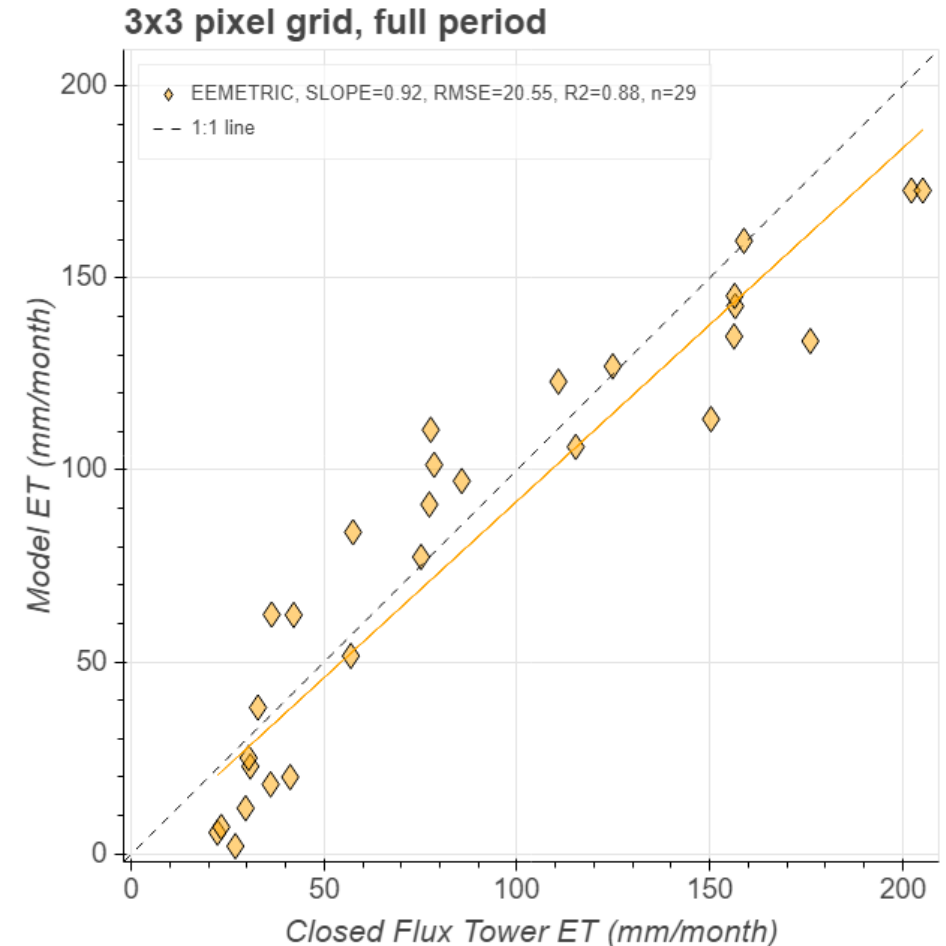


Figure: Map of ET Demands estimated effective precipitation for the Oregon Hydrographic Area.

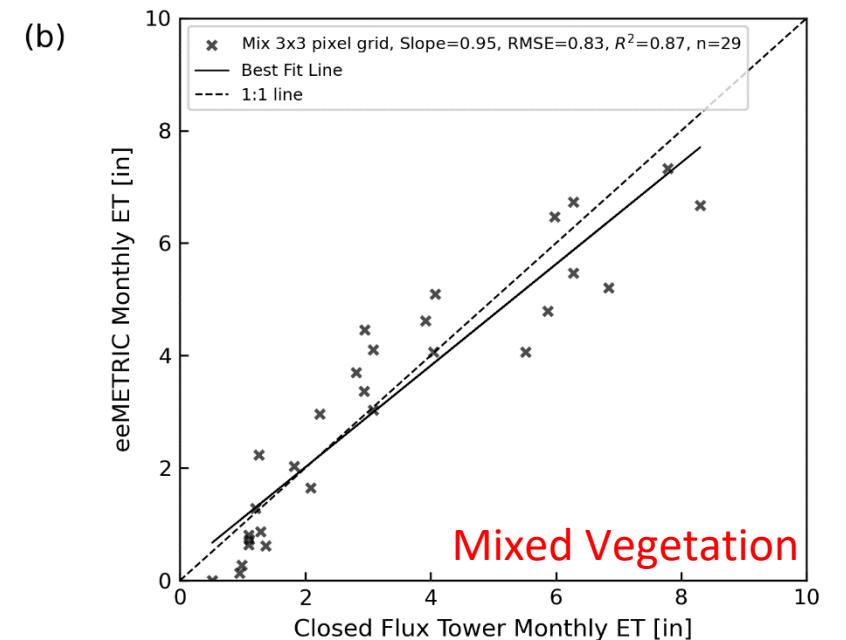
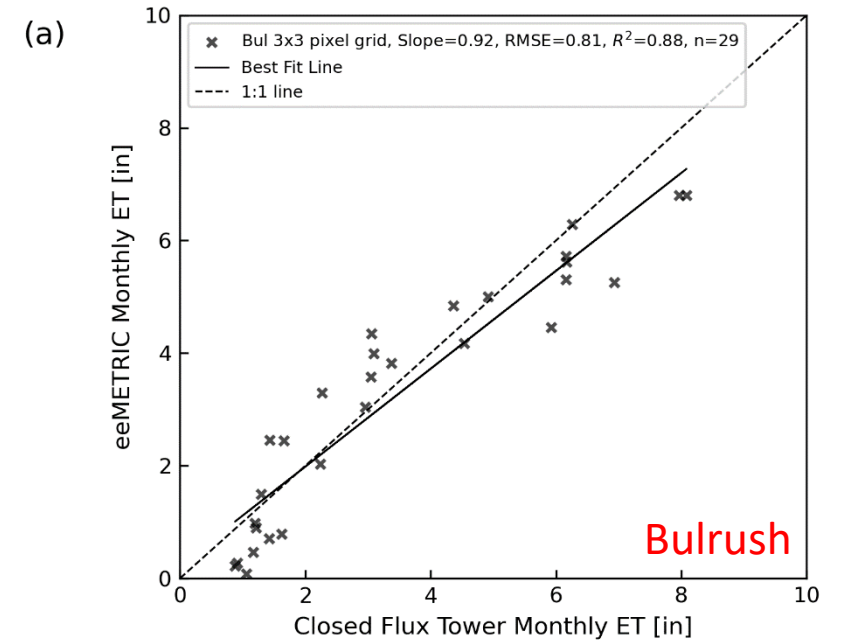
eeMETRIC (Agriculture)

- eeMETRIC is not calibrated/tuned to station data
- eeMETRIC uses automated calibration which relies on normalized vegetation index, surface temperature, and albedo
- OpenET compared eeMETRIC to EC data collected in the Harney Basin
- Supports OpenET stated monthly accuracy of $\pm \sim 17\%$



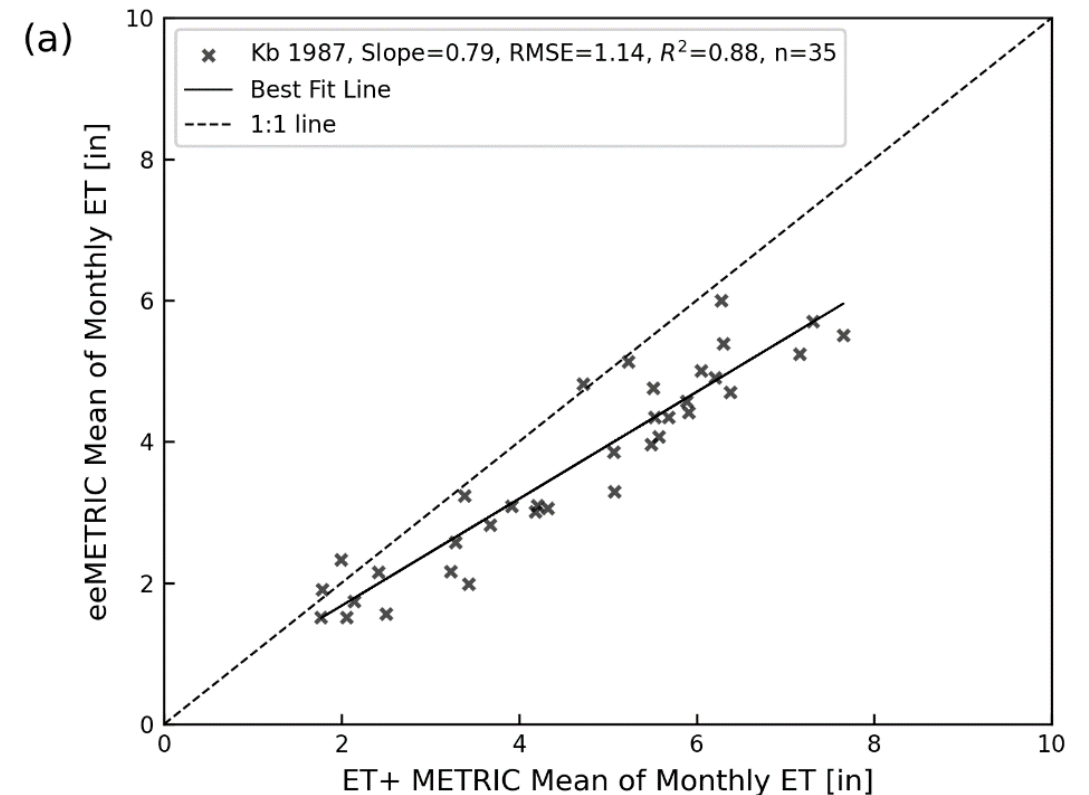
eeMETRIC (Wetlands)

- Comparisons with EC data collected by Stannard et al. (2013)
- Derived monthly ET from 2008-05-01 through 2010-09-01
- Sites located north of Upper Klamath NWR
- QA/QC and energy balance closure corrections performed using flux-data-qaqc github repo (<https://github.com/Open-ET/flux-data-qaqc>)



eeMETRIC (previous METRIC studies)

- METRIC was previously used within the Klamath Basin
 - (2004, 2006, 2010, 2013, and 2014)
- Good agreement on low-end
- Previous METRIC studies produced higher rates of ET
- Sources of difference
 - Calibration
 - Refined data from Landsat



Calculations of Net ET

- Net ET = ET_a - Effective Precipitation
- Uncertainty in Net ET is very difficult to quantify
- Uncertainties in individual components used in calculation (Allen, et al., 2011 & Daly, et al, 2008)
 - ET from Remote Sensing (energy balance) \pm ~10-20%
 - Precipitation from PRISM for Western U.S. \pm 10%
 - Soil water balance \pm 10-30%
- We typically use Eddy Covariance to assess accuracy of remote sensing methods
 - Eddy Covariance \pm 15-30%

Questions & Additional Discussion

Contact Information

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THANK YOU



Researching the human impact on the environment
and the environment's impact on humans.

