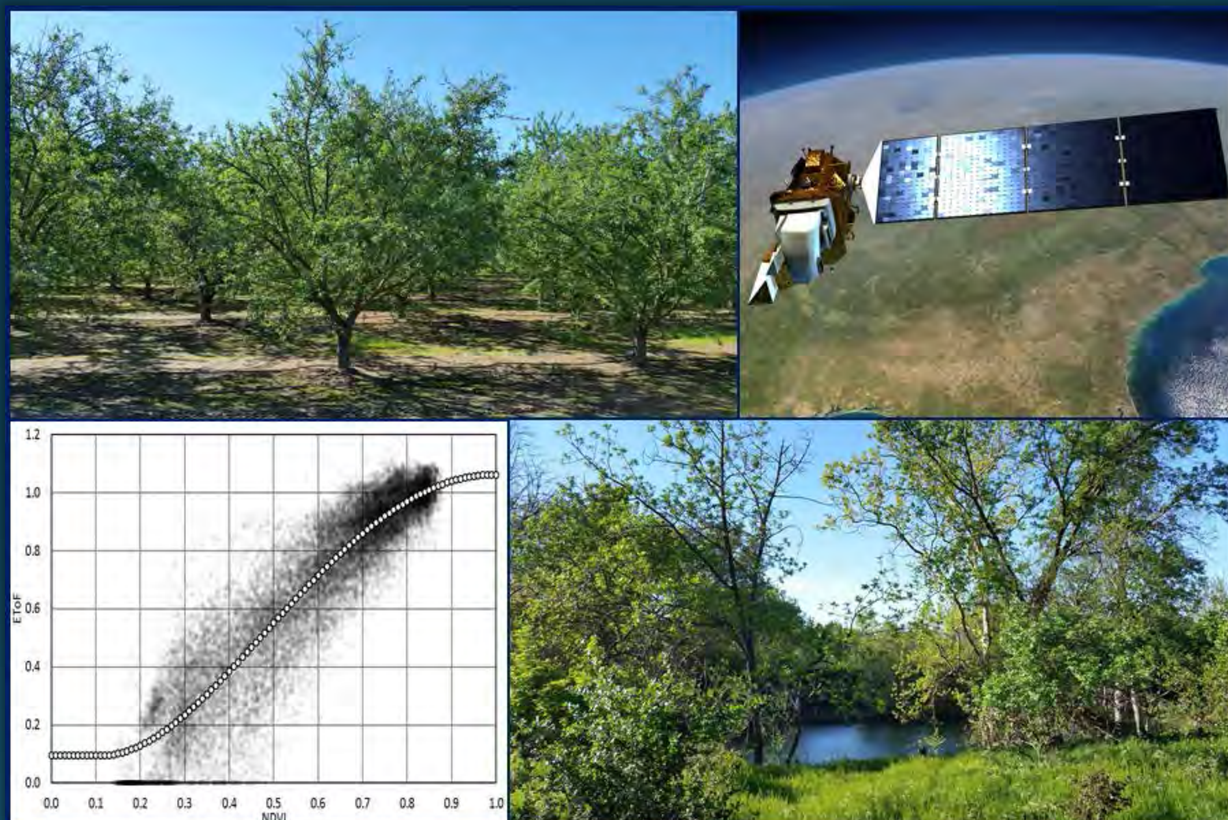
Consumptive Use of Water by Riparian Habitat and Orchards along the Sacramento River Floodplain



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Acknowledgements

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- California Department of Water Resources
- NASA and USGS

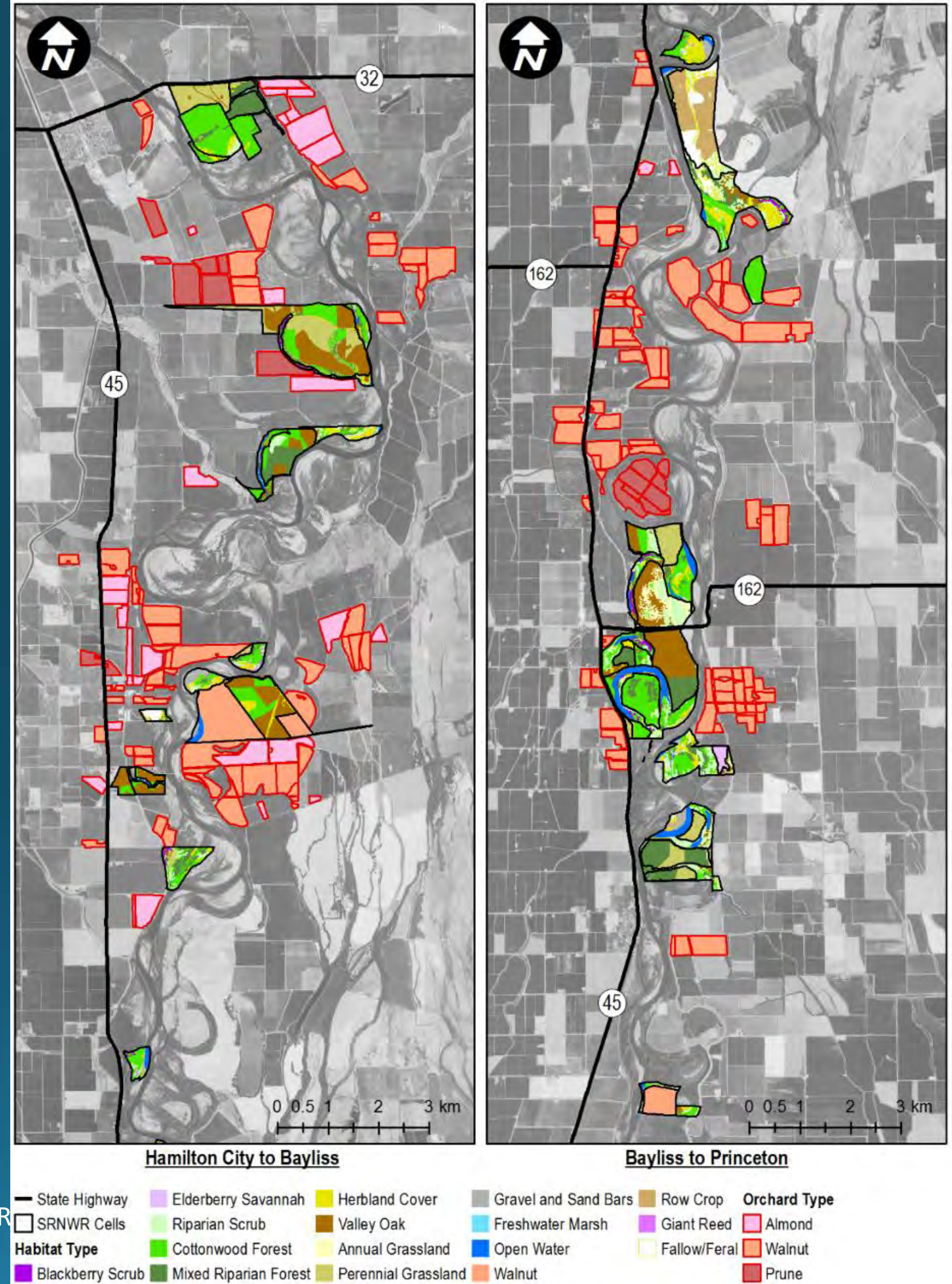
(Use of logos does not represent endorsement of draft results.)

Objectives

- Better understand consumptive use of water (actual evapotranspiration or ET_a) for orchards and riparian habitat along the Sacramento River
- Evaluate potential impacts of riparian restoration activities on timing and amount of water use

Study Area

- Sacramento River from Hamilton City (Highway 32) to Princeton
- Riparian Habitat (2,285 ha)
  - Cottonwood Forest
  - Valley Oak
  - Mixed Riparian Forest
  - Riparian Scrub
  - Perennial Grassland
  - Herbland Cover
- Orchards (2,174 ha)
  - Walnuts
  - Almonds
  - Prunes



Estimation of ET_a

- Crop Coefficient Approach (Allen et al. 1998):

$$ET_a = ET_o \times ET_oF$$

where:

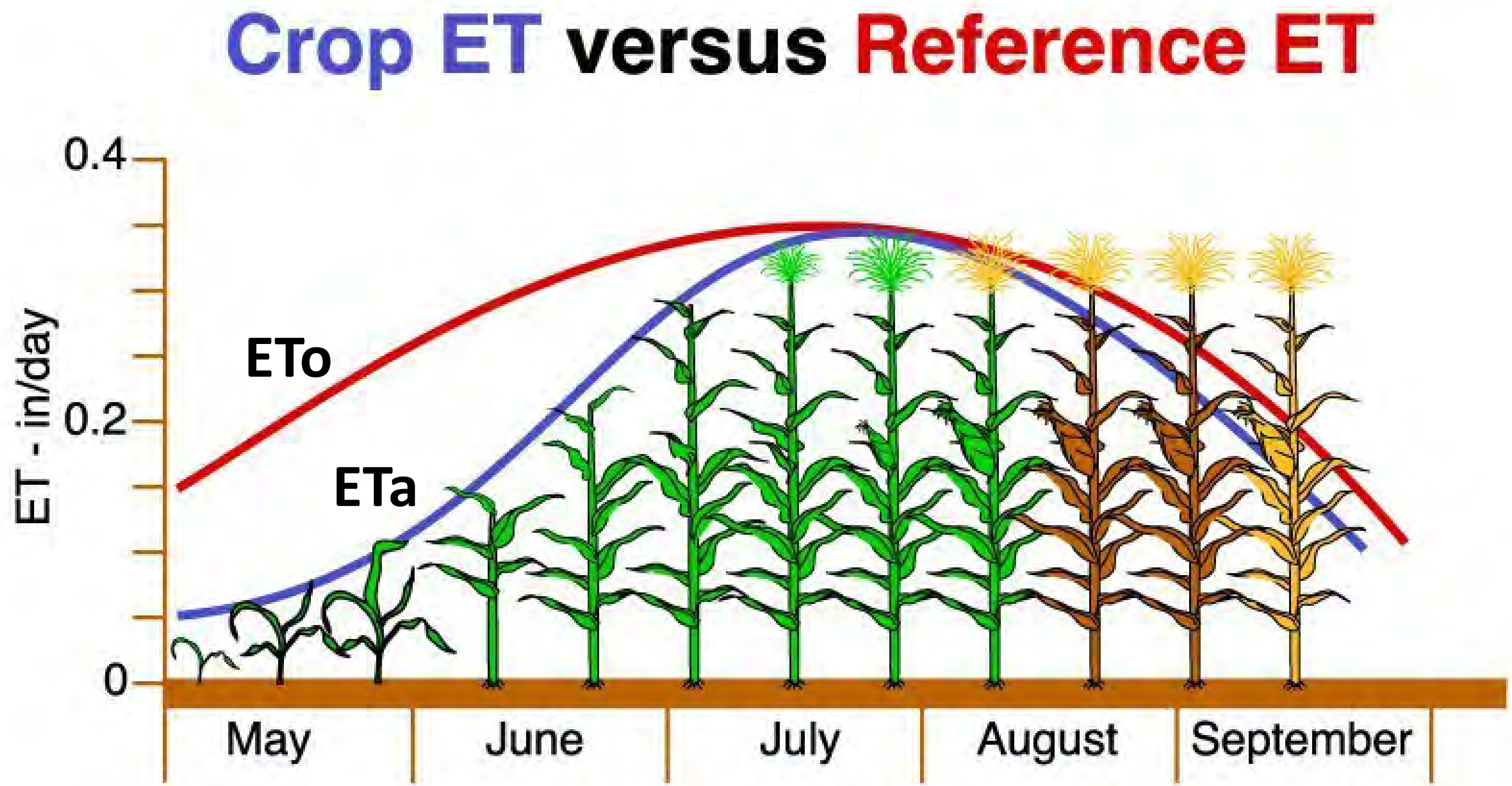
ET_a = actual evapotranspiration (mm/d)

ET_o = reference evapotranspiration (mm/d)

ET_oF = fraction of reference ET (unitless)

- Data Sources:
  - ET_o – California Irrigation Management Information System (CIMIS)
  - ET_oF – Remote Sensing (Landsat/SEBAL)

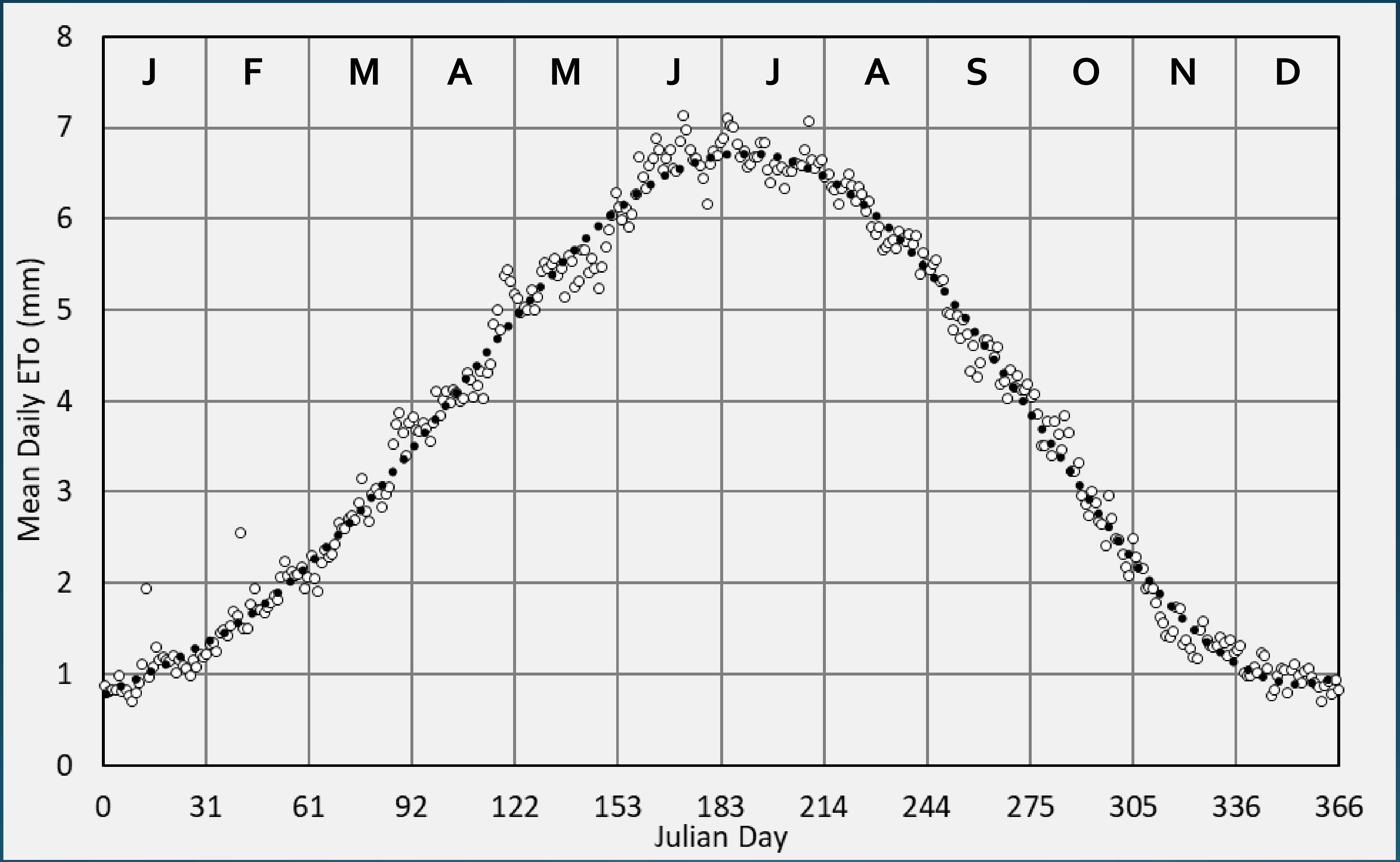
ET_o and ET_a



mesonet.k-state.edu

Reference Evapotranspiration (ET_o)

- Mean Daily ET_o at Colusa, 1984 – 2016



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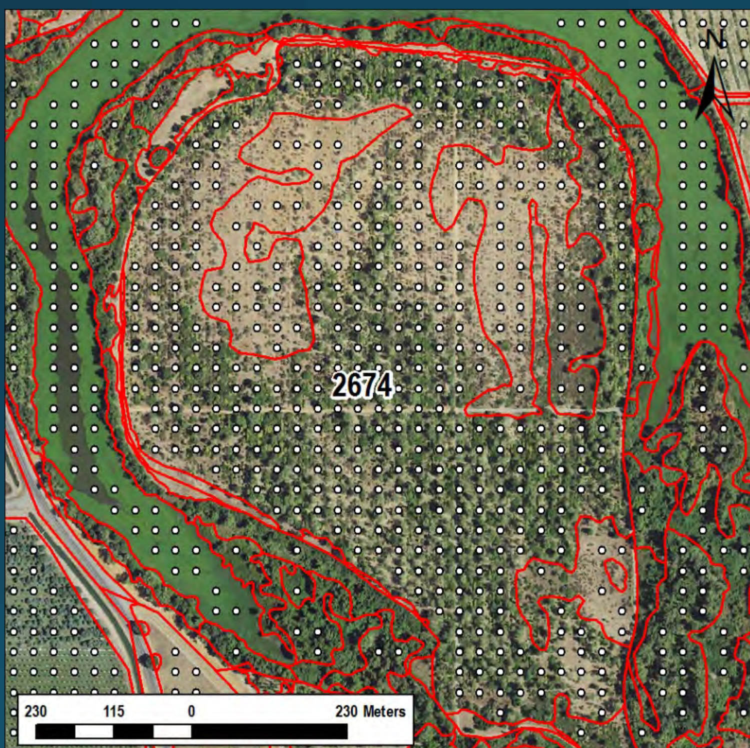
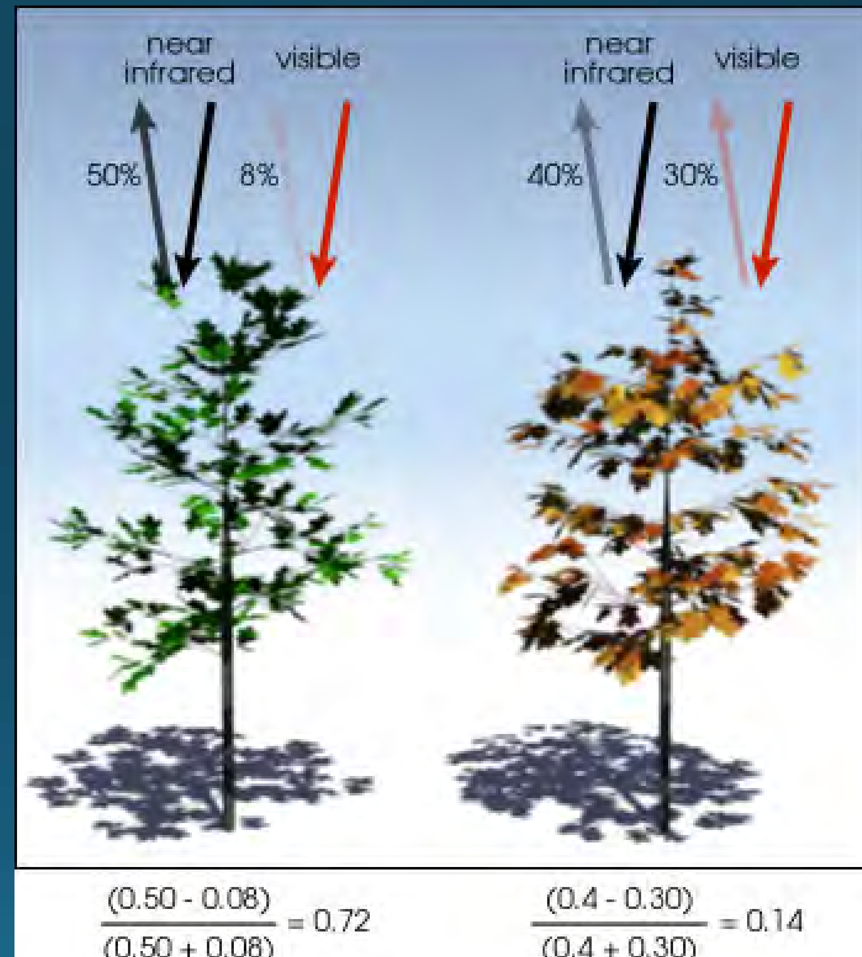
Fraction of Reference Evapotranspiration (ET_oF)

- Calculated for individual 30m Landsat pixels based on Normalized Difference Vegetation Index (NDVI)





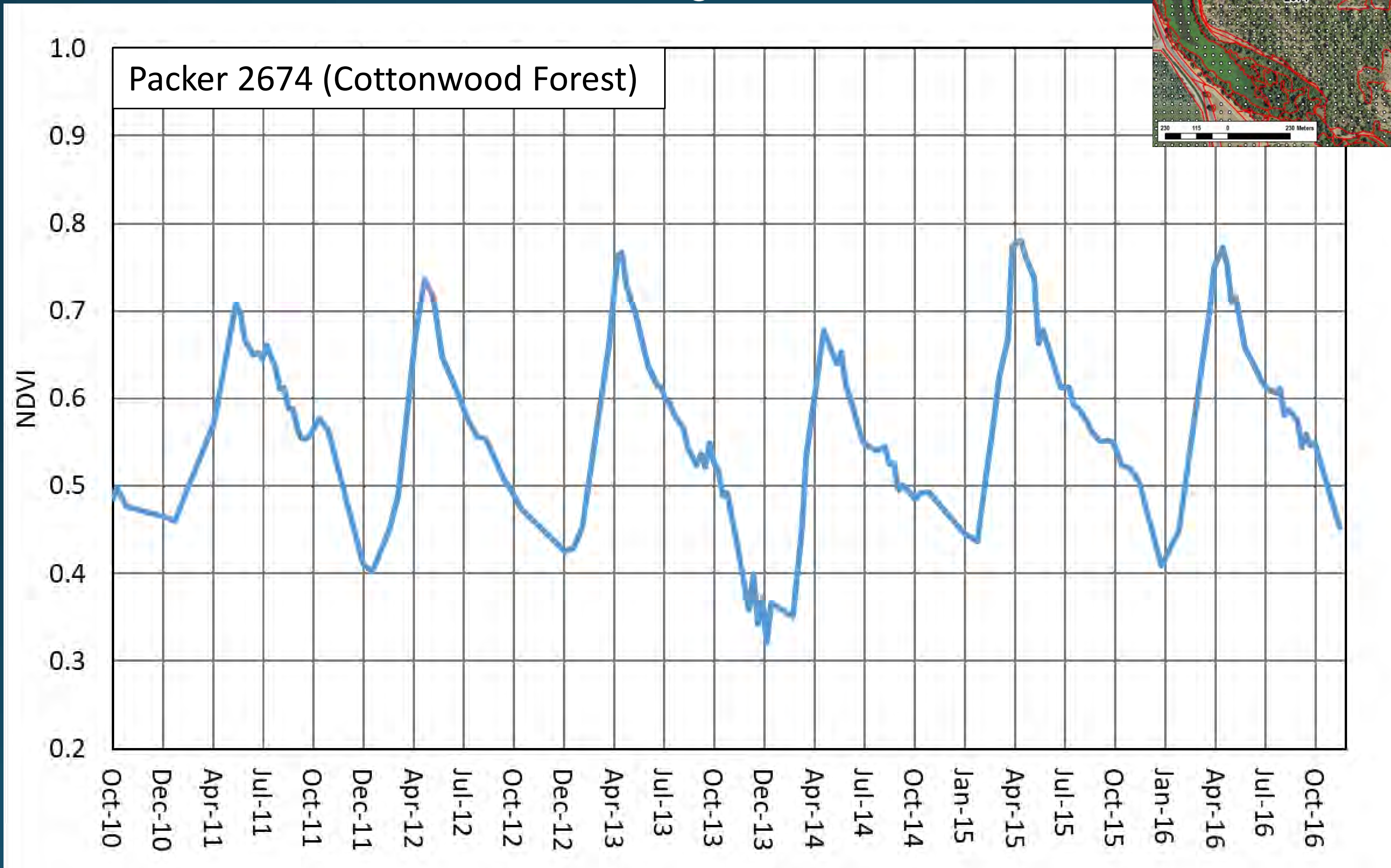
(earthobservatory.nasa.gov)

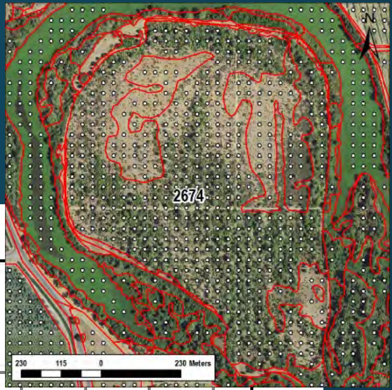
Fraction of Reference Evapotranspiration (ET_oF) (Continued)

- NDVI estimated for each cloud-free pixel for each image date
- NDVI values interpolated over time
- Greater image availability between April and September due to less clouds
- Greater image availability following 1998 due to additional satellites

Year	Cloud-Free Images by Month												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
1985	0	0	0	2	2	2	1	2	1	2	0	0	12
1986	0	0	1	1	2	2	2	2	1	2	1	1	15
1987	1	2	0	2	2	2	2	2	1	1	0	0	15
1988	0	0	1	1	1	1	1	1	1	1	0	1	9
1989	1	0	0	1	1	2	2	2	2	1	0	1	13
1990	1	2	0	1	1	2	0	1	1	2	0	0	11
1991	0	0	0	0	2	1	2	2	1	1	2	0	11
1992	0	0	0	0	2	1	0	1	1	0	0	1	6
1993	1	0	0	1	0	2	2	1	0	2	2	0	11
1994	1	0	2	2	0	0	2	1	1	1	1	0	11
1995	0	0	0	0	1	0	2	2	1	1	0	0	7
1996	0	0	1	0	1	2	1	2	0	2	1	1	11
1997	1	0	1	1	1	2	2	0	2	1	0	0	11
1998	0	0	1	0	0	1	2	2	1	1	0	0	8
1999	0	1	0	0	1	2	3	3	2	3	2	2	19
2000	0	0	1	3	2	3	3	4	3	3	0	2	24
2001	0	1	1	1	1	3	2	4	4	2	1	0	20
2002	0	0	0	0	3	4	3	3	3	4	3	1	24
2003	1	1	2	1	2	2	3	4	2	2	1	0	21
2004	0	2	2	2	3	4	4	4	4	3	2	1	31
2005	1	1	2	3	1	4	4	2	3	2	1	0	24
2006	2	2	0	1	2	2	4	4	3	3	2	2	27
2007	2	2	2	2	2	3	4	3	2	0	1	0	23
2008	0	1	3	3	3	2	3	2	4	2	1	0	24
2009	2	0	3	4	3	2	4	4	2	2	3	1	30
2010	0	0	3	2	1	2	4	4	2	3	0	0	21
2011	2	0	0	2	3	3	2	4	4	2	0	1	23
2012	1	1	1	2	2	2	2	2	2	1	0	0	16
2013	2	1	1	3	2	3	4	4	3	4	1	4	32
2014	2	1	2	1	3	3	1	3	2	3	0	1	22
2015	1	1	3	2	3	1	3	2	3	2	1	1	23
2016	1	0	2	2	3	1	4	3	3	1	0	0	20
Average	0.7	0.6	1.1	1.4	1.8	2.1	2.4	2.5	2.0	1.9	0.8	0.7	18.0
Total	24	21	38	50	61	72	85	88	74	70	37	33	575

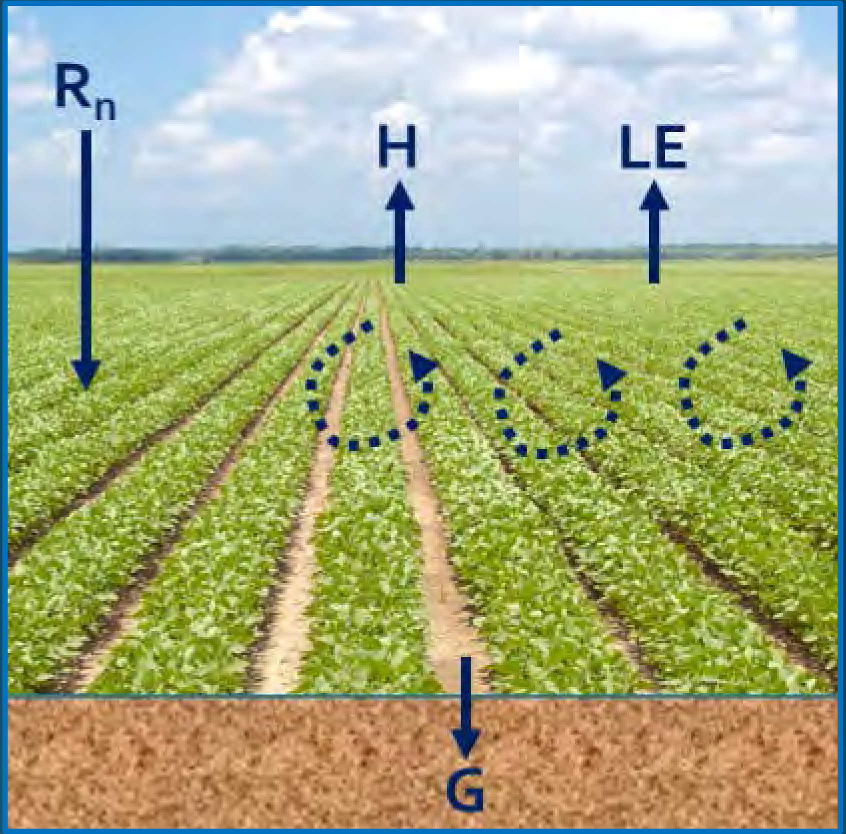
Fraction of Reference Evapotranspiration (ET_oF) (Continued)





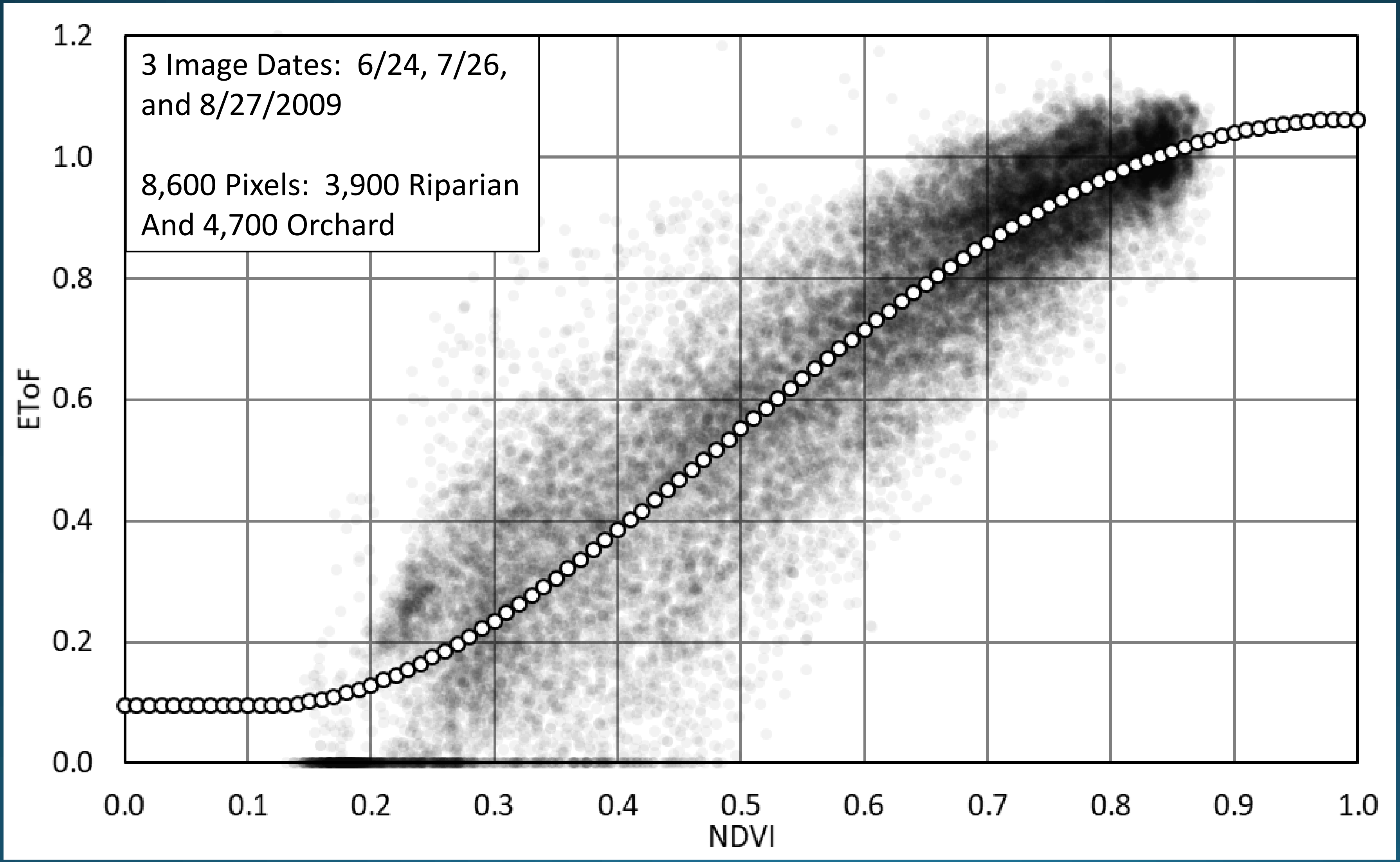
Fraction of Reference Evapotranspiration (ET_oF) (Continued)

- ET_oF correlated to NDVI based on 2009 Surface Energy Balance Algorithm for Land (SEBAL) ET_a analysis prepared for DWR
- SEBAL is a robust, energy balance technique to estimate ET_a using remote sensing
- Correlation of ET_oF to NDVI leverages available SEBAL data

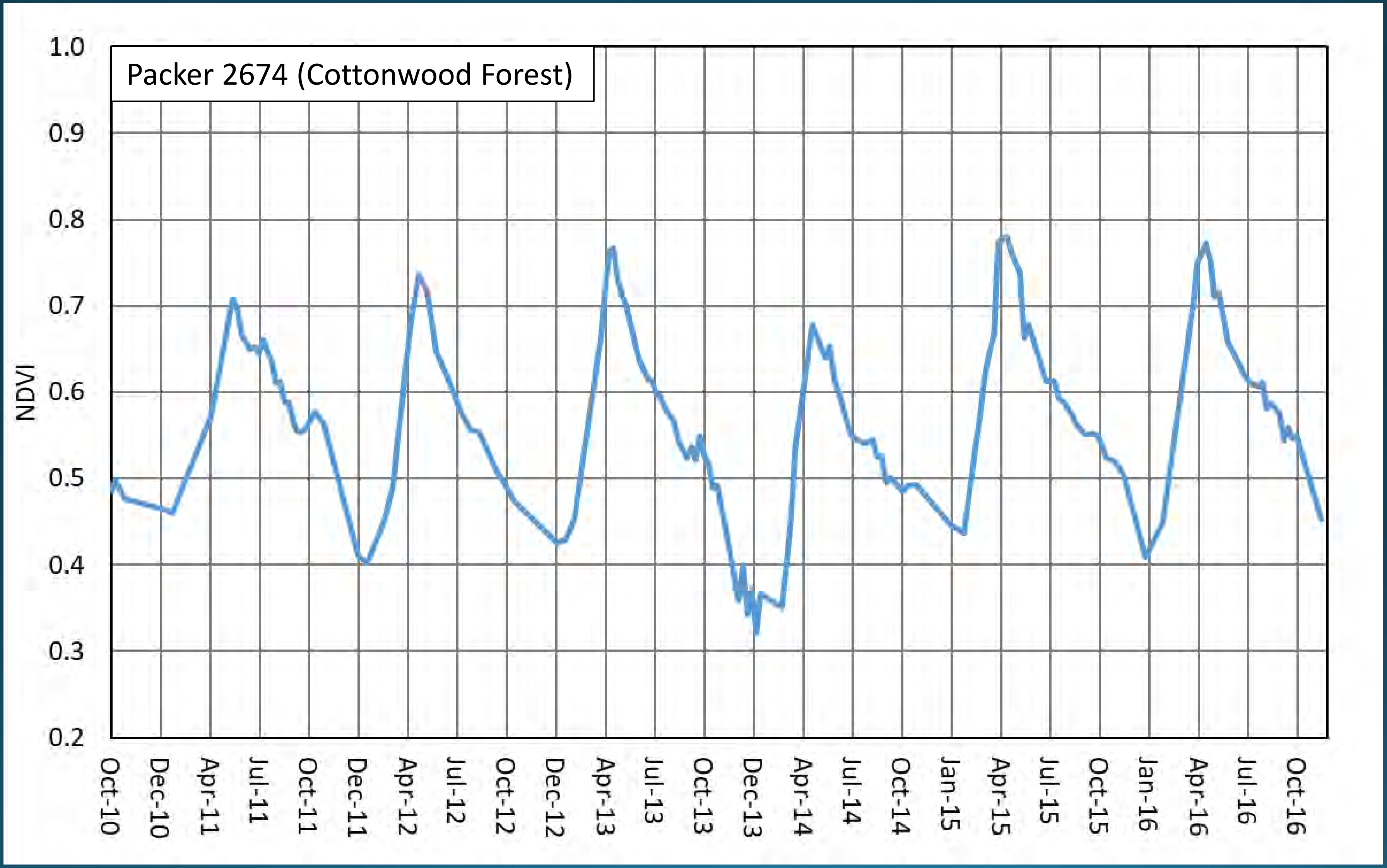


ET (LE) = latent heat flux
LE = R_n – H – G, where
R_n = net incoming radiation
H = sensible heat flux
G = ground heat flux

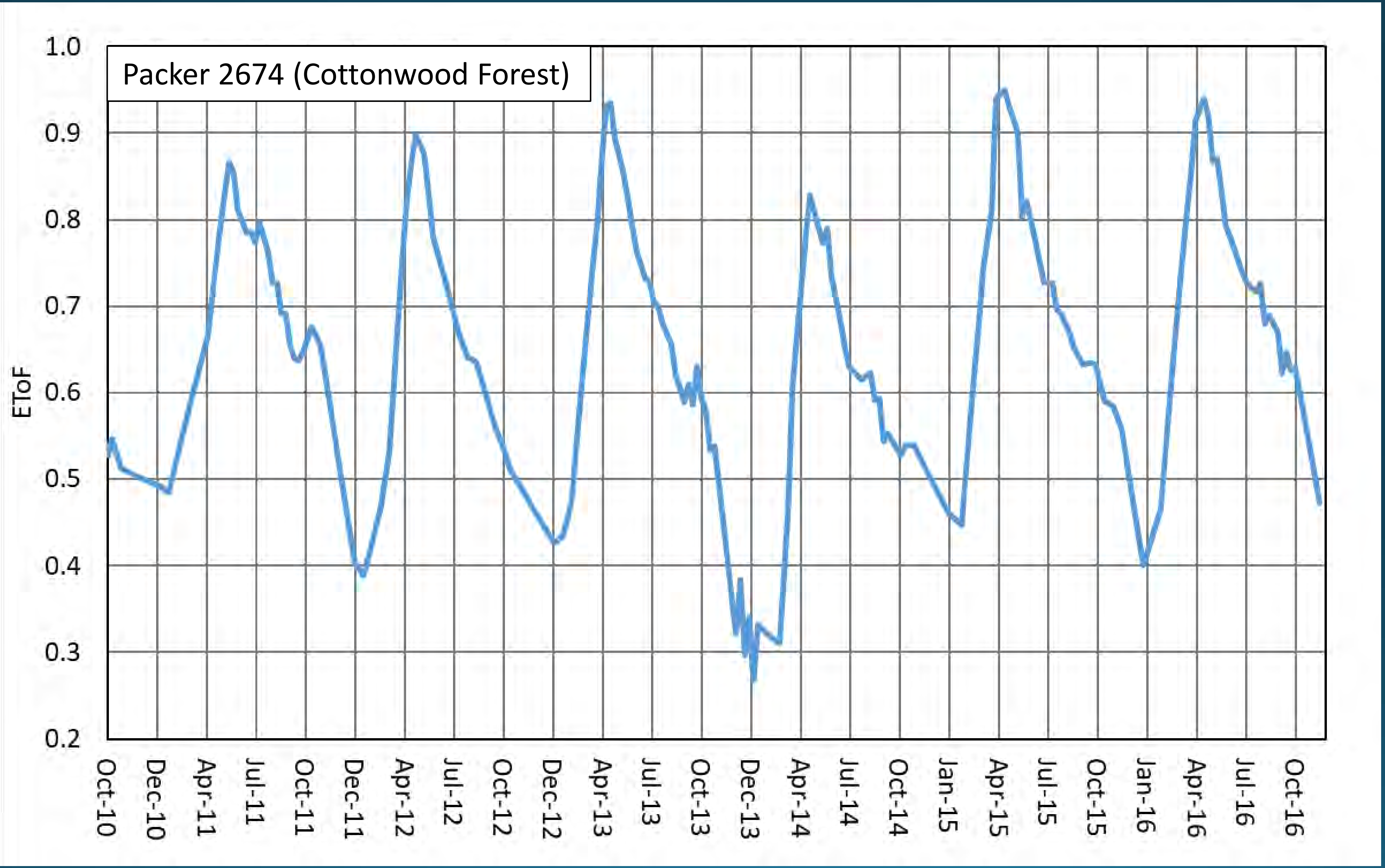
Fraction of Reference Evapotranspiration (ET_oF) (Continued)



Fraction of Reference Evapotranspiration (ET_oF) (Continued)

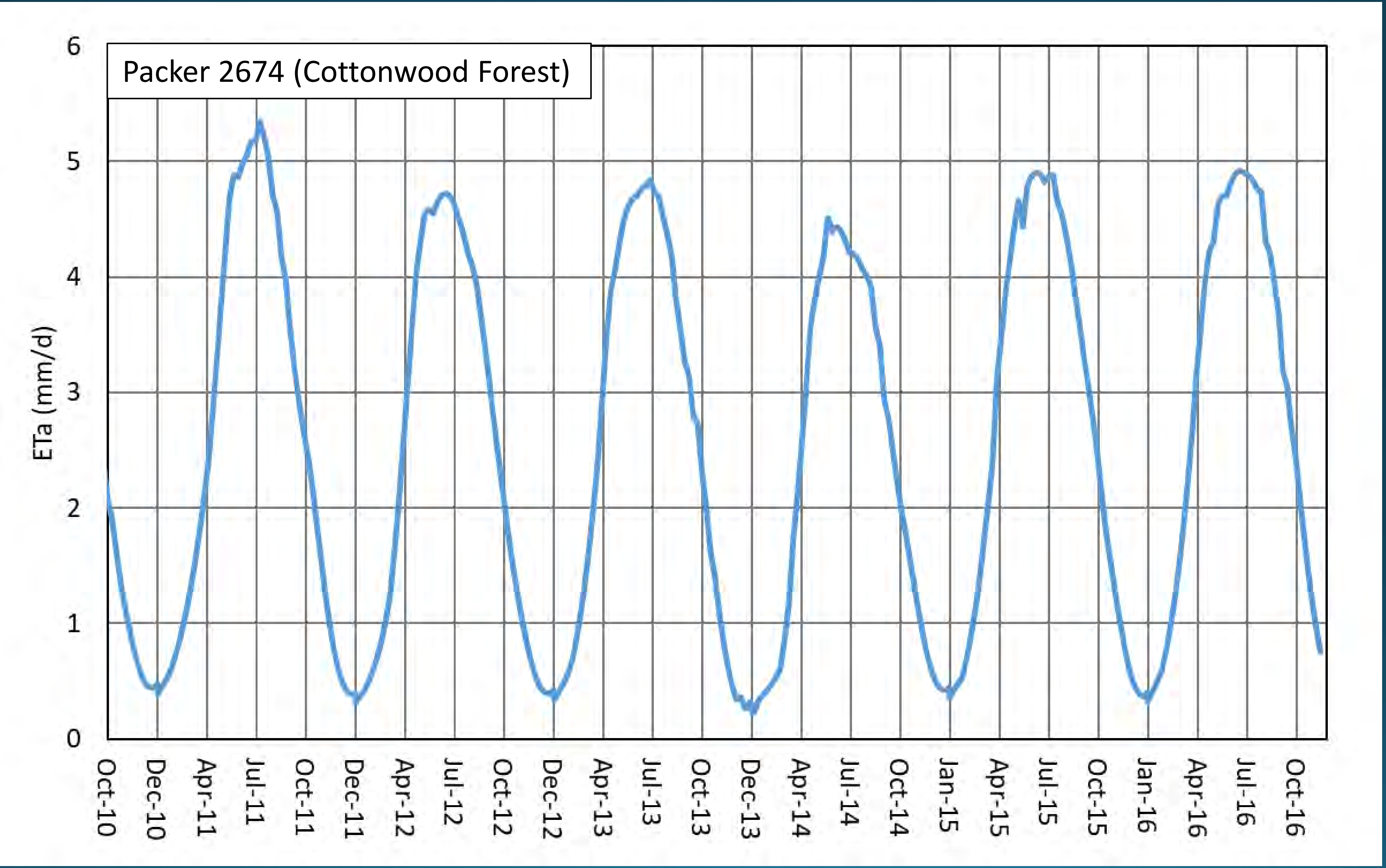


$ET_oF = f(NDVI)$

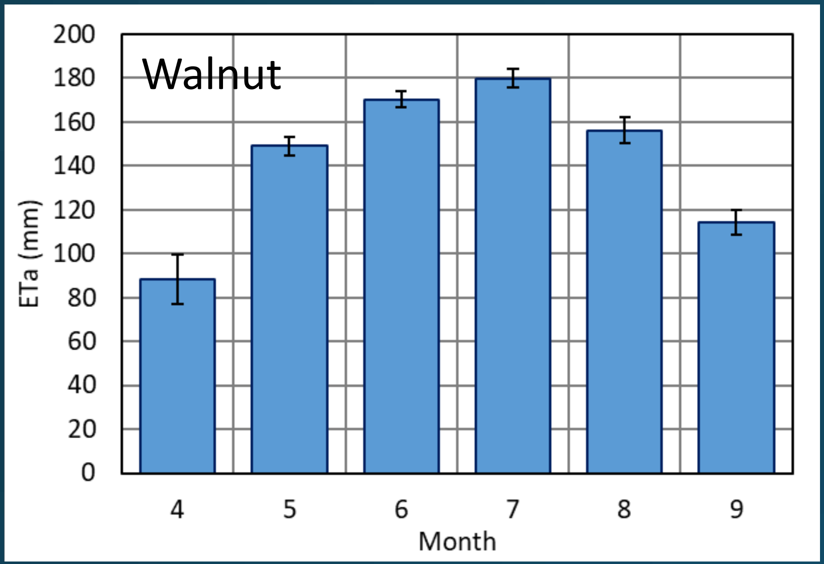


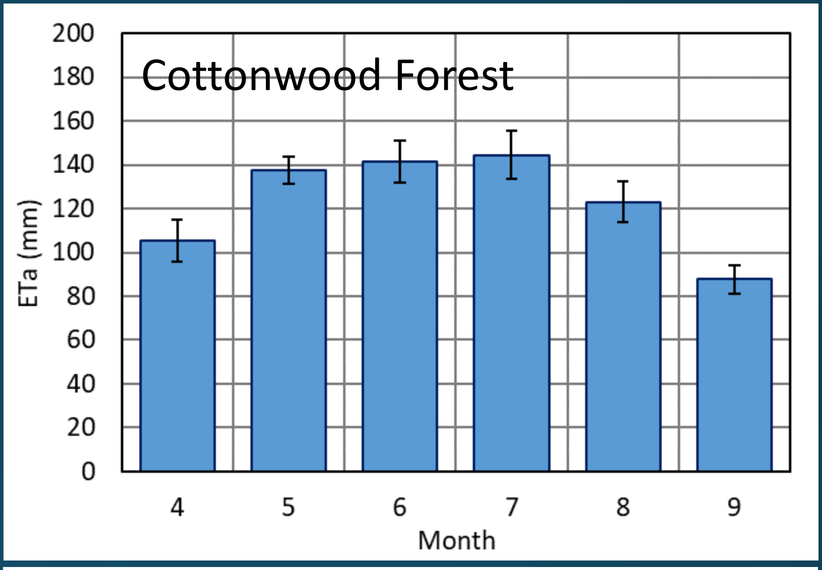
Packer 2674 (Cottonwood Forest)
EToF
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Oct-10
Dec-10
Apr-11
Jul-11
Oct-11
Dec-11
Apr-12
Jul-12
Oct-12
Dec-12
Apr-13
Jul-13
Oct-13
Dec-13
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16

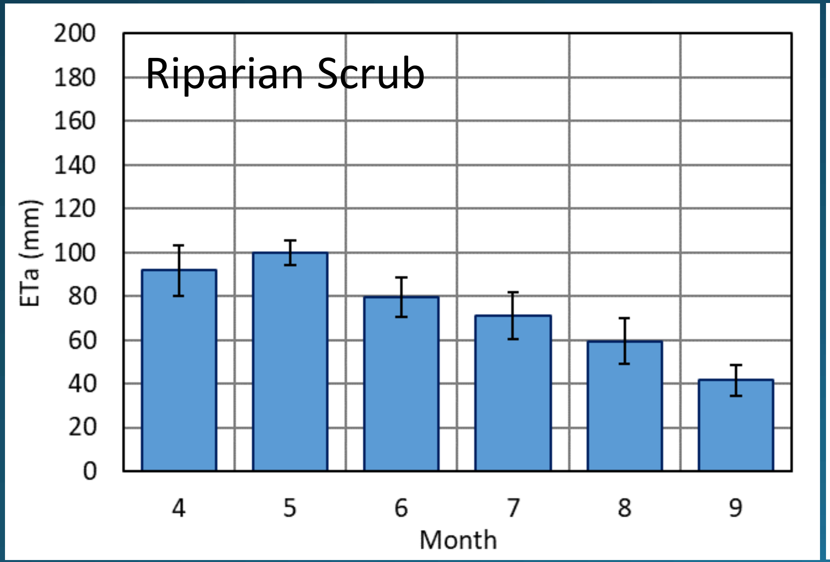
$ET_a = ET_o \times ET_oF$

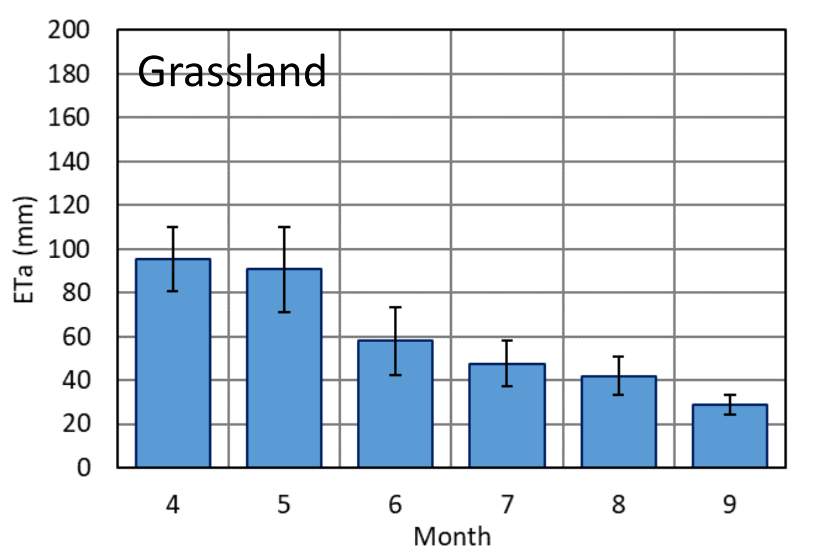


Estimated April - September ET_a by Selected Orchard/Restored Habitat Type, 2005 - 2016









Summary of Estimated April - September ET_a by Orchard/Restored Habitat Type, 2005 - 2016

Orchard/Habitat Type	Number of Years	April-September ETa (mm)	
		Mean	Std. Dev.
Almonds	12	719	48
Prunes	12	658	69
Walnuts	12	858	35
Grassland	12	362	74
Cottonwood Forest	12	740	52
Herbland Cover	12	351	78
Mixed Riparian Forest	12	721	54
Riparian Scrub	12	444	69
Valley Oak	12	666	83

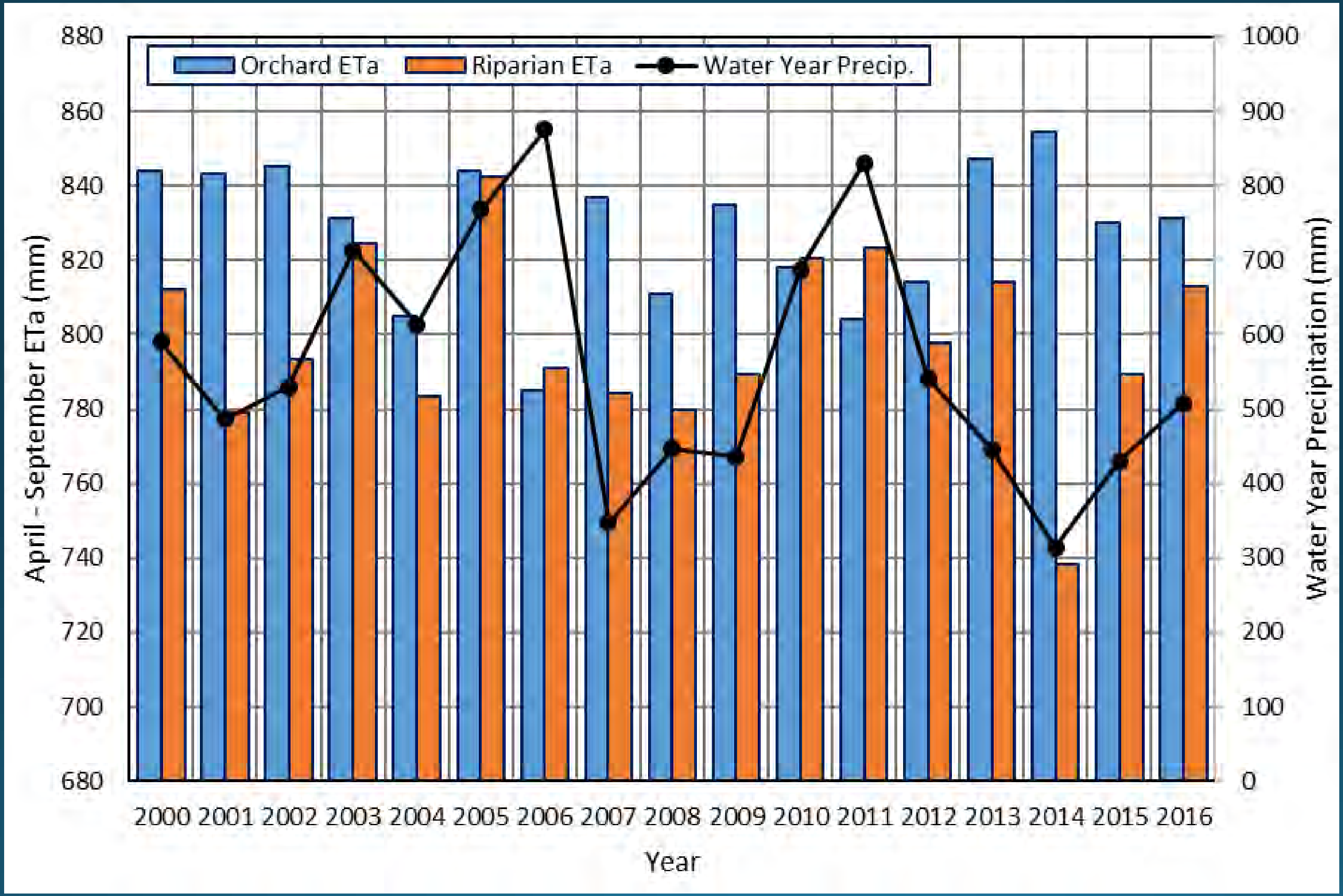
Comparison of ET_a for Orchards and Riparian Habitat

- Continuously Planted Areas
- 2000 to 2016
- April – September ET_a
- Correlate to Water Year Precipitation

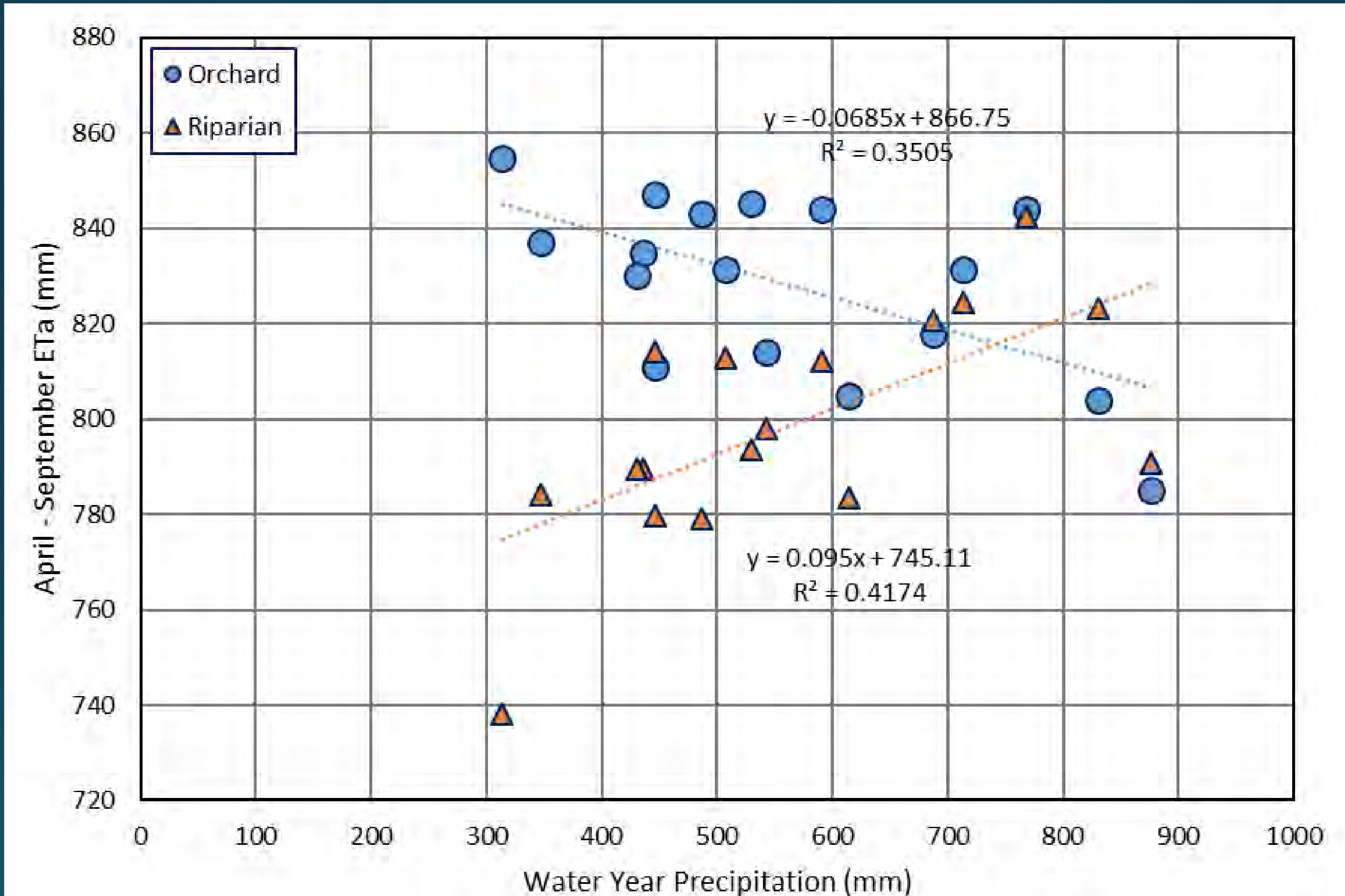
Habitat Type	Hectares	n Polygons	n Pixels
Annual Grassland	2.0	2	4
Cottonwood Forest	171.6	41	873
Herbland Cover	85.9	24	372
Mixed Riparian Forest	65.9	30	242
Perennial Grassland	3.7	1	6
Riparian Scrub	121.3	47	382
Valley Oak	39.2	19	118
Totals	**489.5**	**164**	**1,997**

Orchard Type	Hectares	n Polygons	n Pixels
Almonds	72.9	10	591
Prunes	52.7	8	441
Walnuts	471.1	63	3,963
Totals	**596.7**	**81**	**4,995**

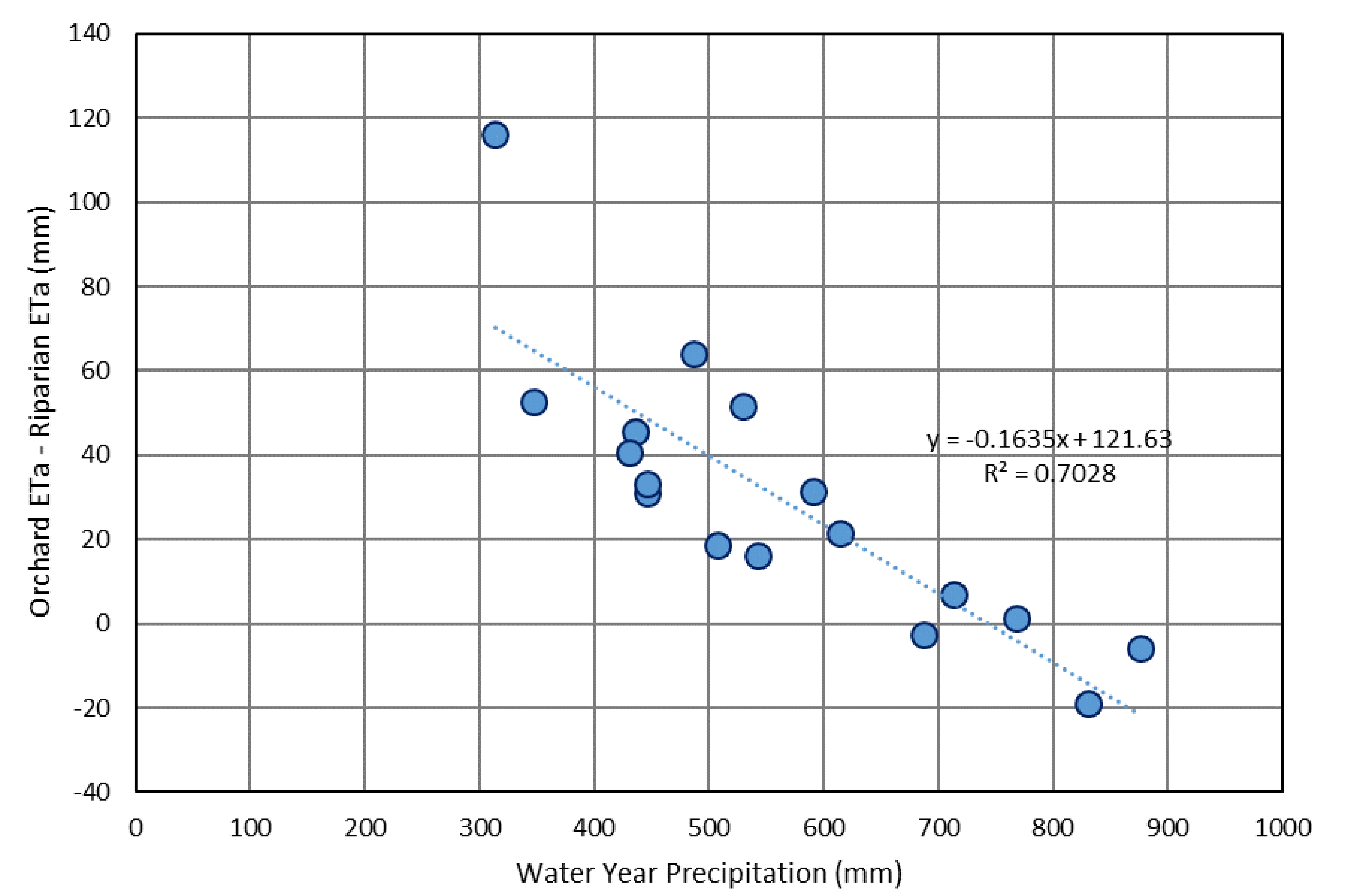
Comparison of ET_a for Orchards and Riparian Habitat (continued)



Comparison of ET_a for Orchards and Riparian Habitat (continued)



Comparison of ET_a for Orchards and Riparian Habitat (continued)



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Observations

- For continuously planted areas, orchard April to September ET_a (830 mm) may be marginally greater than riparian ET_a (800 mm)
- Orchard and riparian ET_a are greater than available precipitation
- Response to hydrology differs:
  - Orchard ET_a tends to decrease in wetter years and increase in drier years
  - Riparian ET_a tends to increase in wetter years and decrease in drier years
- During drought periods, riparian areas are more conservative of water

Thank you!

Discussion