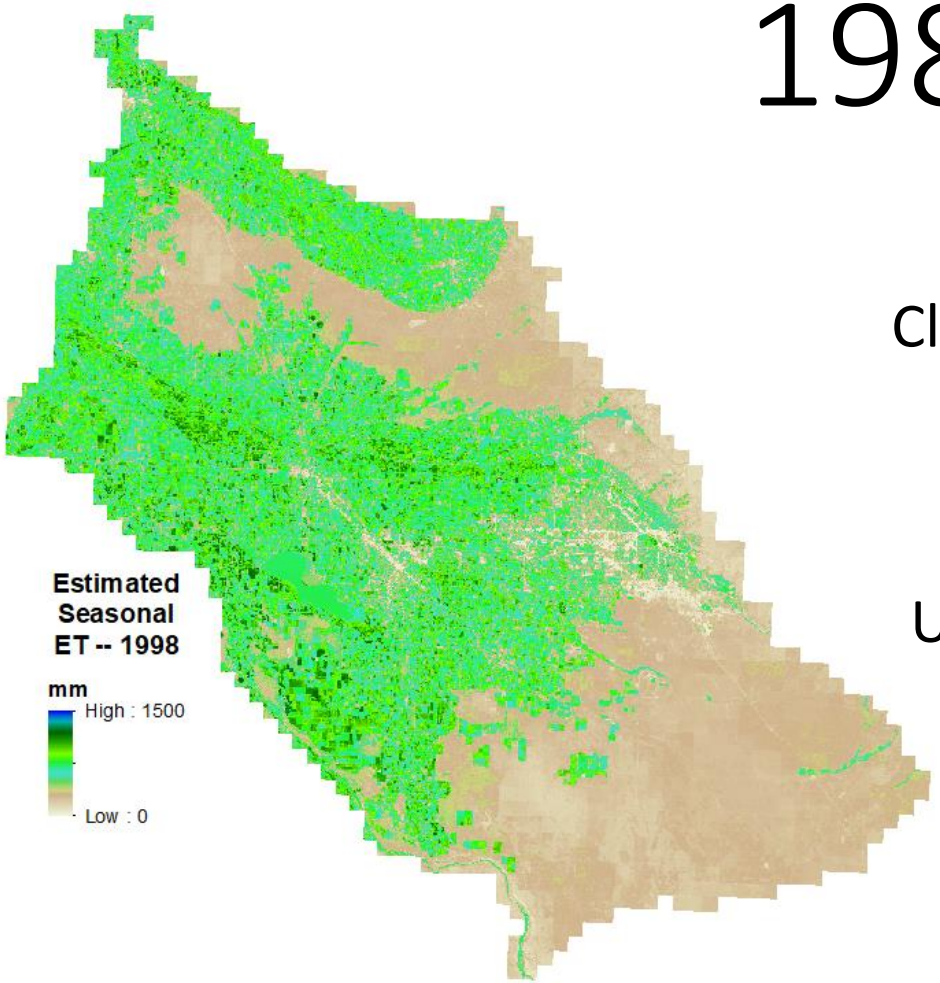
Treasure Valley Evapotranspiration 1986 -- 2015

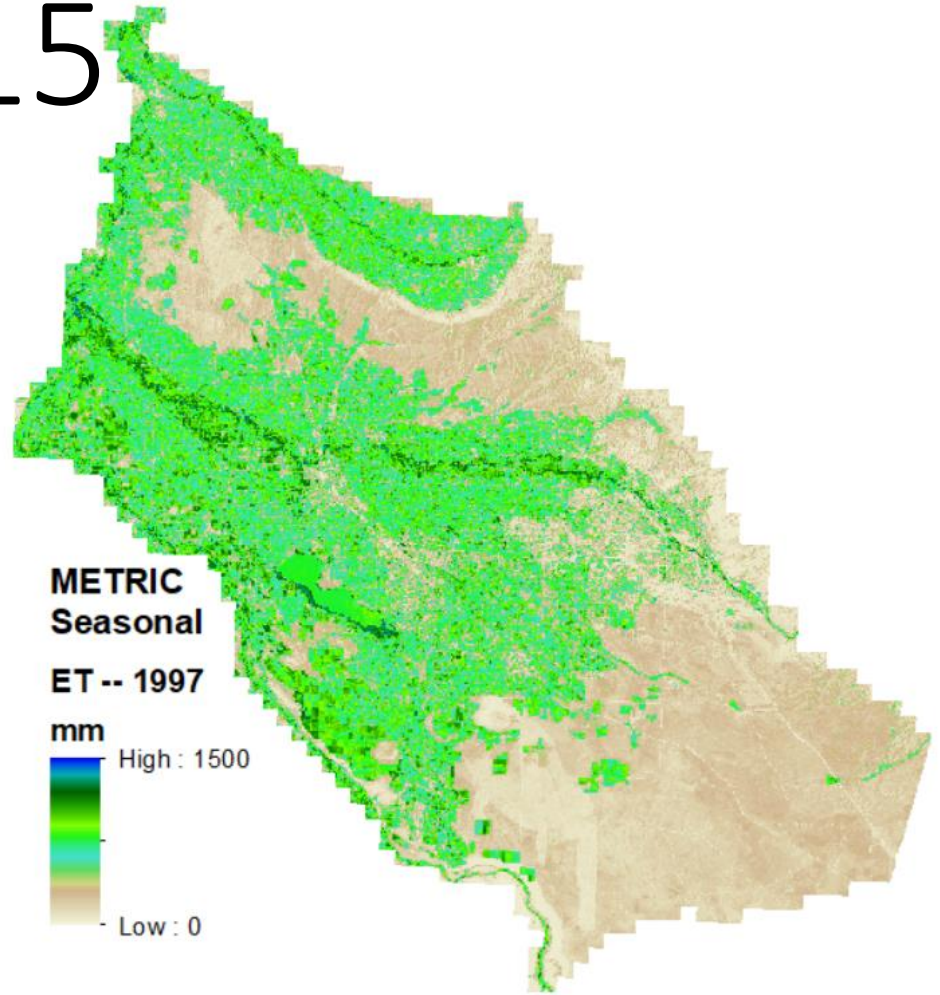
Wenguang Zhao

Clarence W. Robison

Richard G. Allen

University of Idaho
Kimberly, Idaho





Presentation to the Treasure Valley Model Technical Advisory Committee – June 4, 2020.

Evapotranspiration Determination Method

Year	Method	Year	Method	Year	Method
1986	non-METRIC	1996	non-METRIC	2006	non-METRIC
1987	METRIC	1997	METRIC	2007	METRIC
1988	non-METRIC	1998	non-METRIC	2008	non-METRIC
1989	non-METRIC	1999	non-METRIC	2009	non-METRIC
1990	non-METRIC	2000	METRIC	2010	METRIC
1991	non-METRIC	2001	non-METRIC	2011	non-METRIC
1992	non-METRIC	2002	non-METRIC	2012	non-METRIC
1993	non-METRIC	2003	non-METRIC	2013	non-METRIC
1994	METRIC	2004	METRIC	2014	non-METRIC
1995	non-METRIC	2005	non-METRIC	2015	METRIC

8 METRIC years (over 100 images); 22 nonMETRIC years

METRIC -- Eight Years

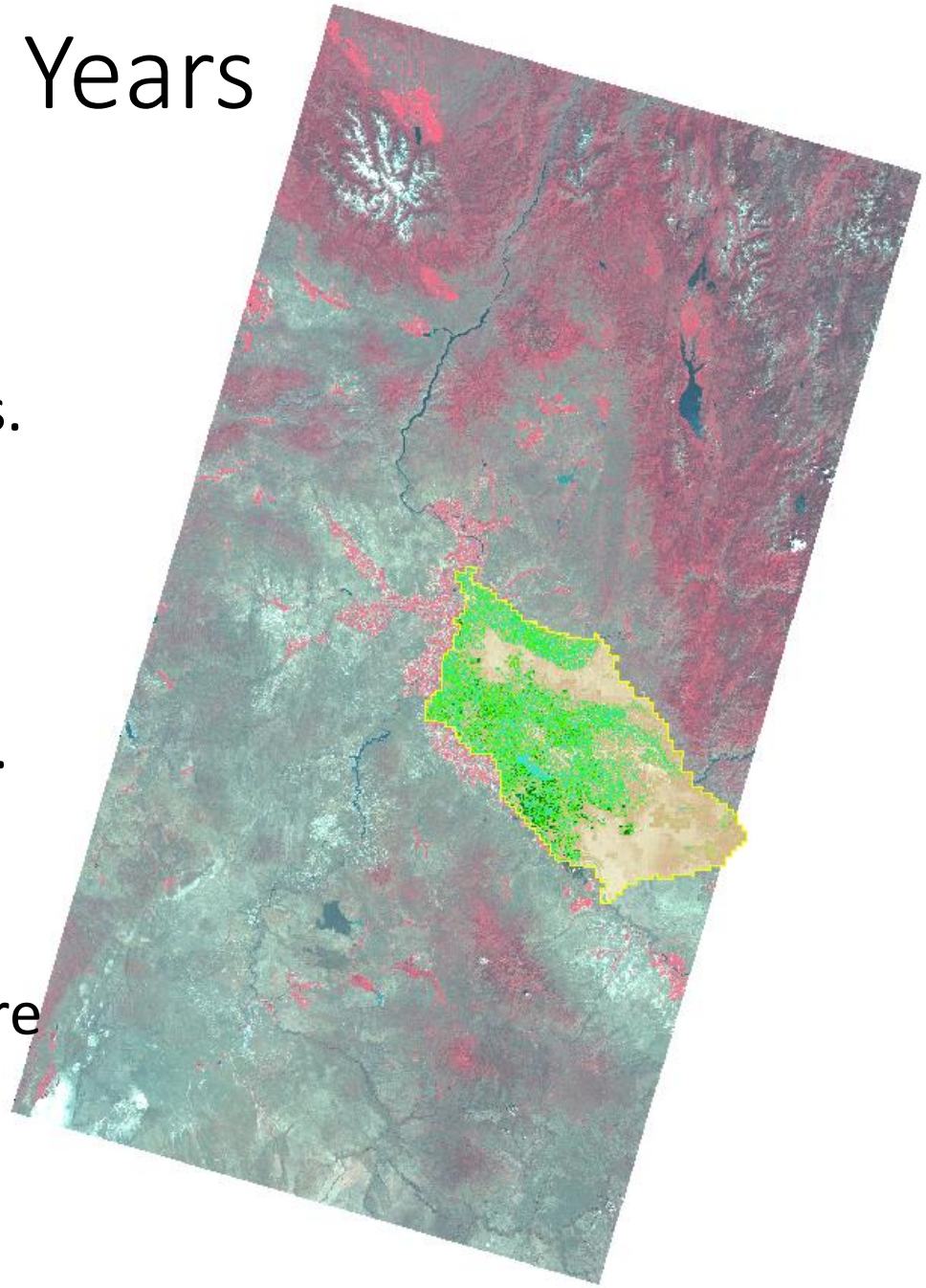
The METRIC procedure utilizes visible, near-infrared and thermal infrared energy spectrum bands from Landsat satellite images and weather data to calculate ET on a 30 m pixel-by-pixel basis. ET is estimated from a surface energy balance.

Selection of years was influenced by cloudiness.

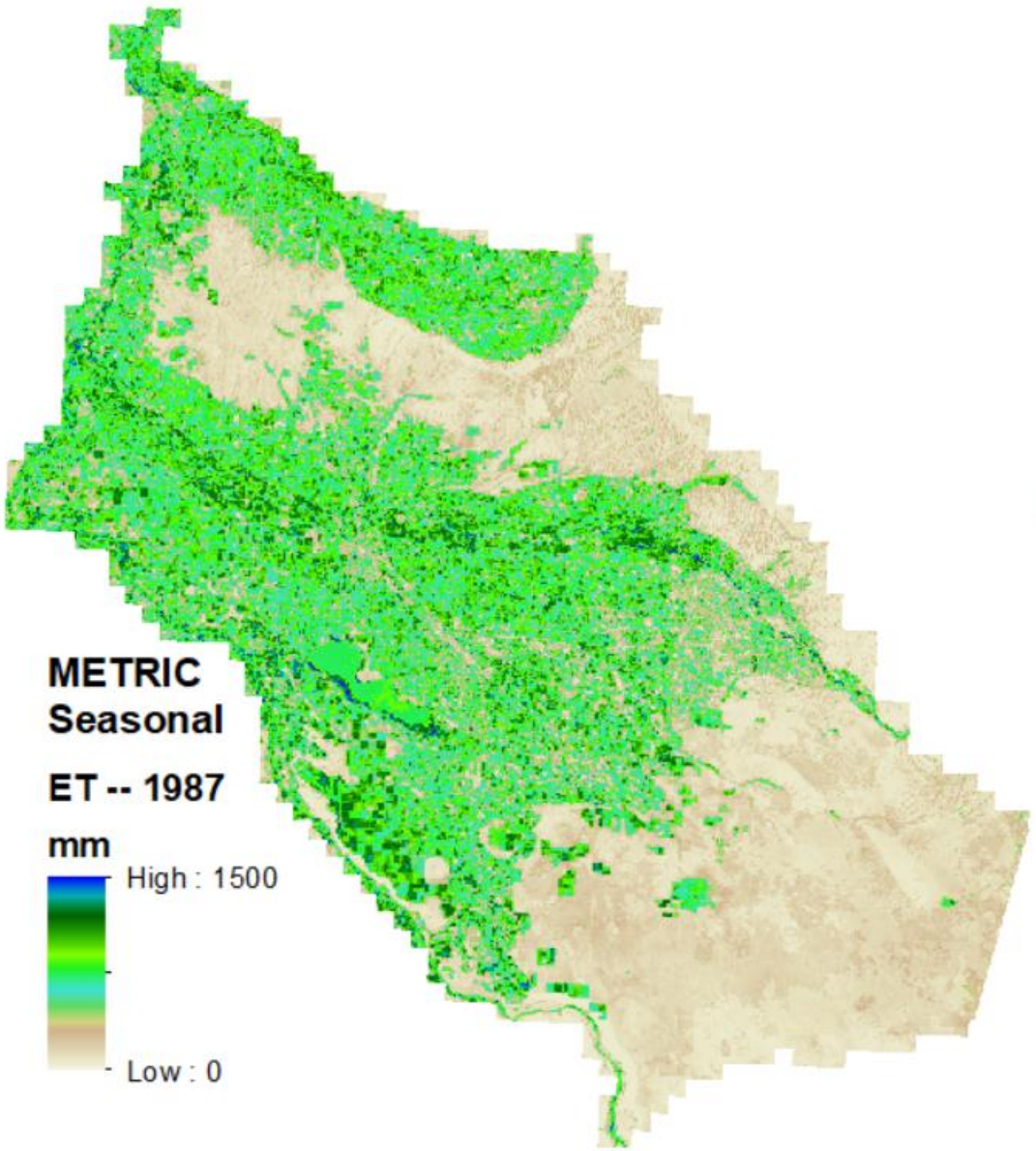
Expected METRIC ET accuracy is 5 to 10% when processed by knowledge and qualified personnel.

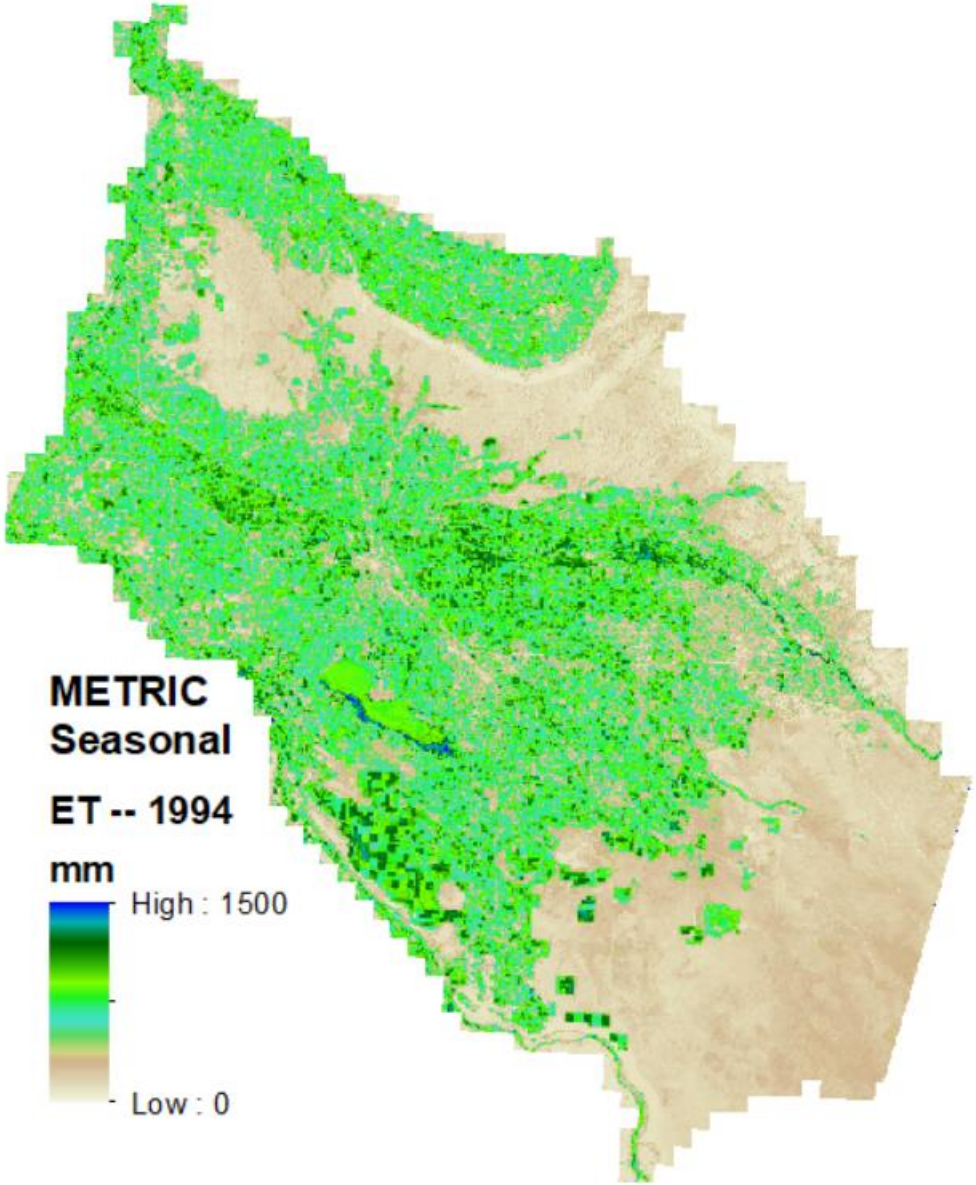
METRIC ET represents actual ET_a which includes impacts of wetness, density and stress.

METRIC ET products were developed for the entire Landsat Path 42 Rows 29 and 30 footprint. The Treasure Valley Groundwater model area lies in both rows.

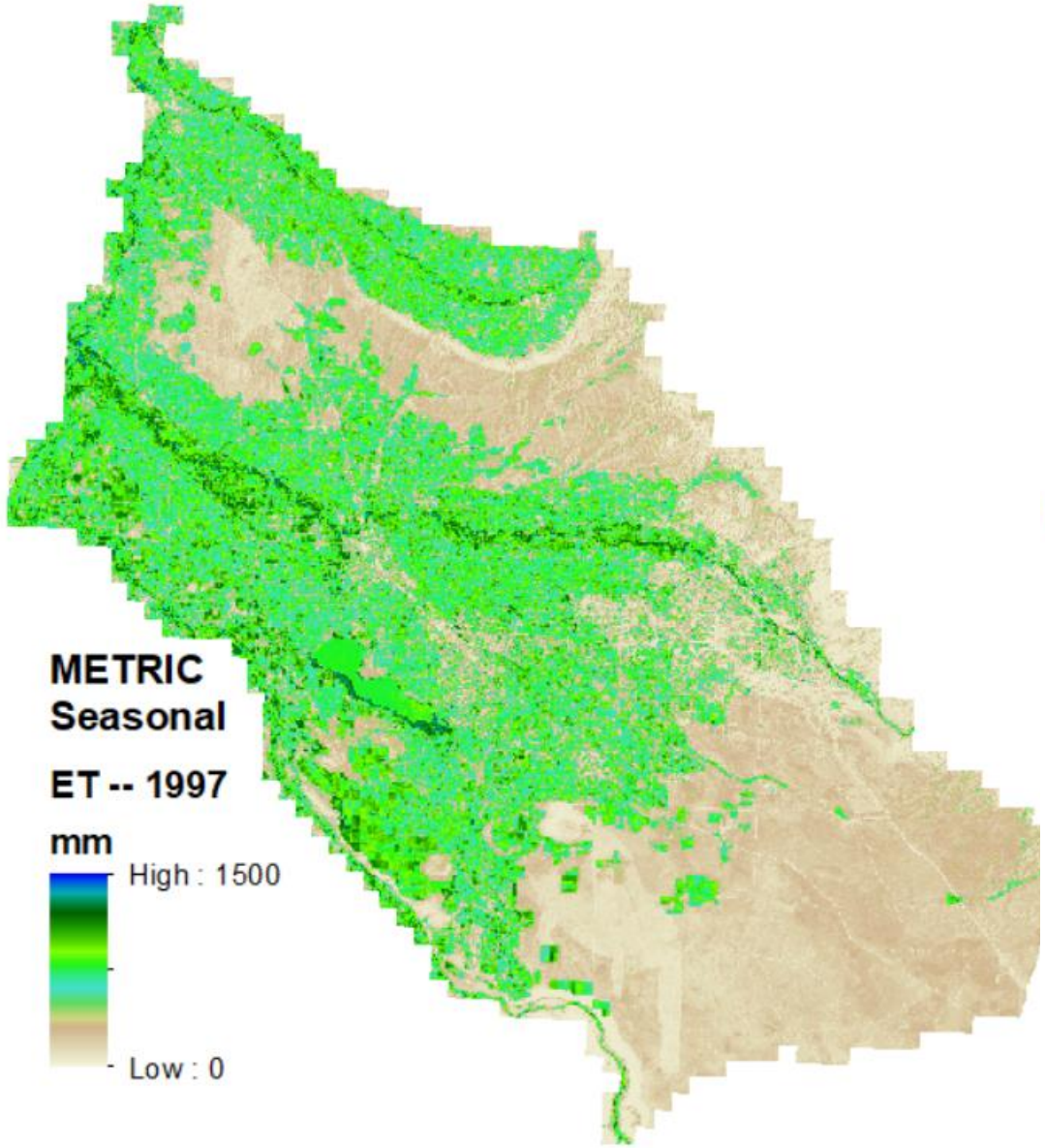


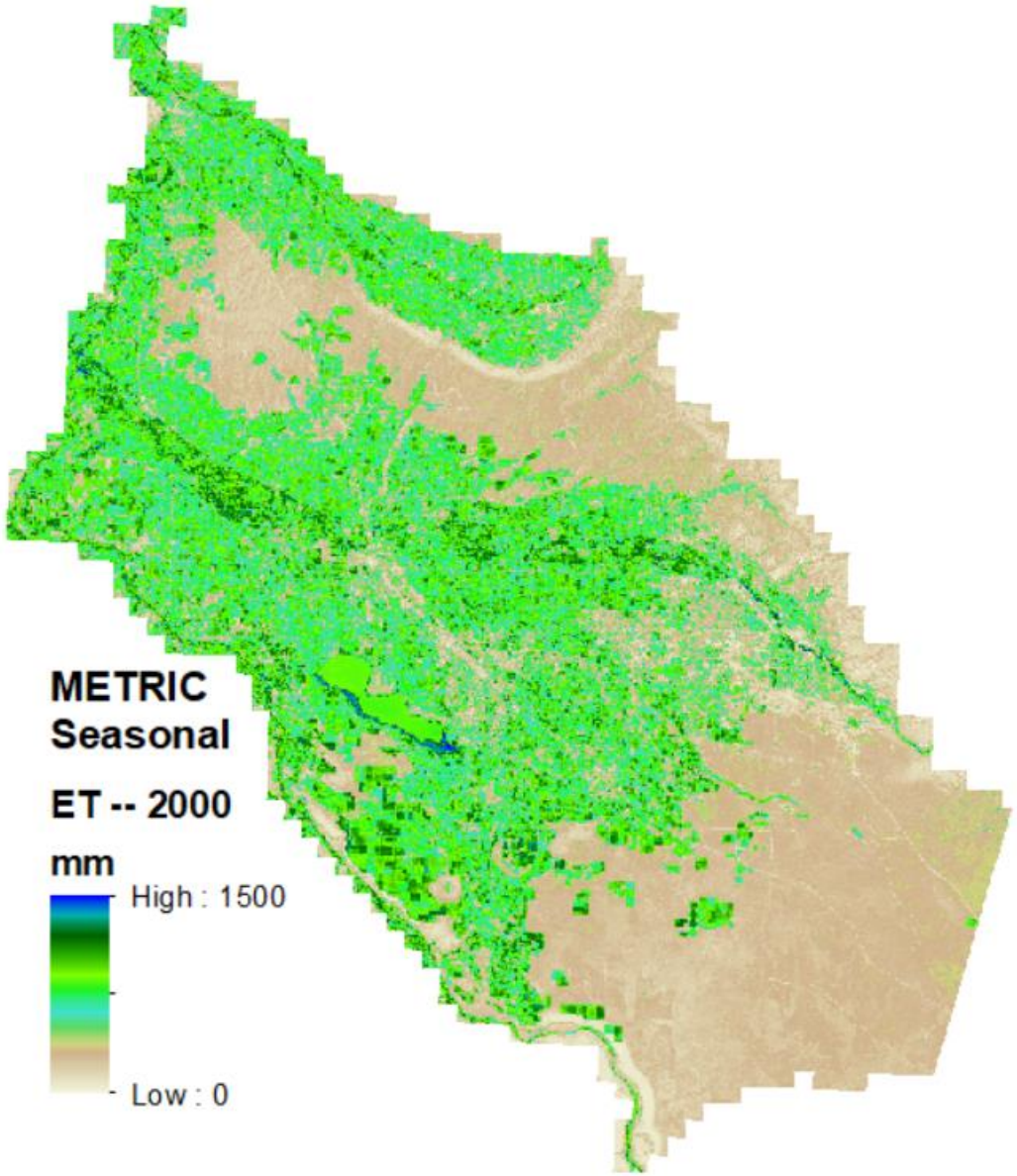
METRIC ET over the Treasure Valley: 1987 and 1994



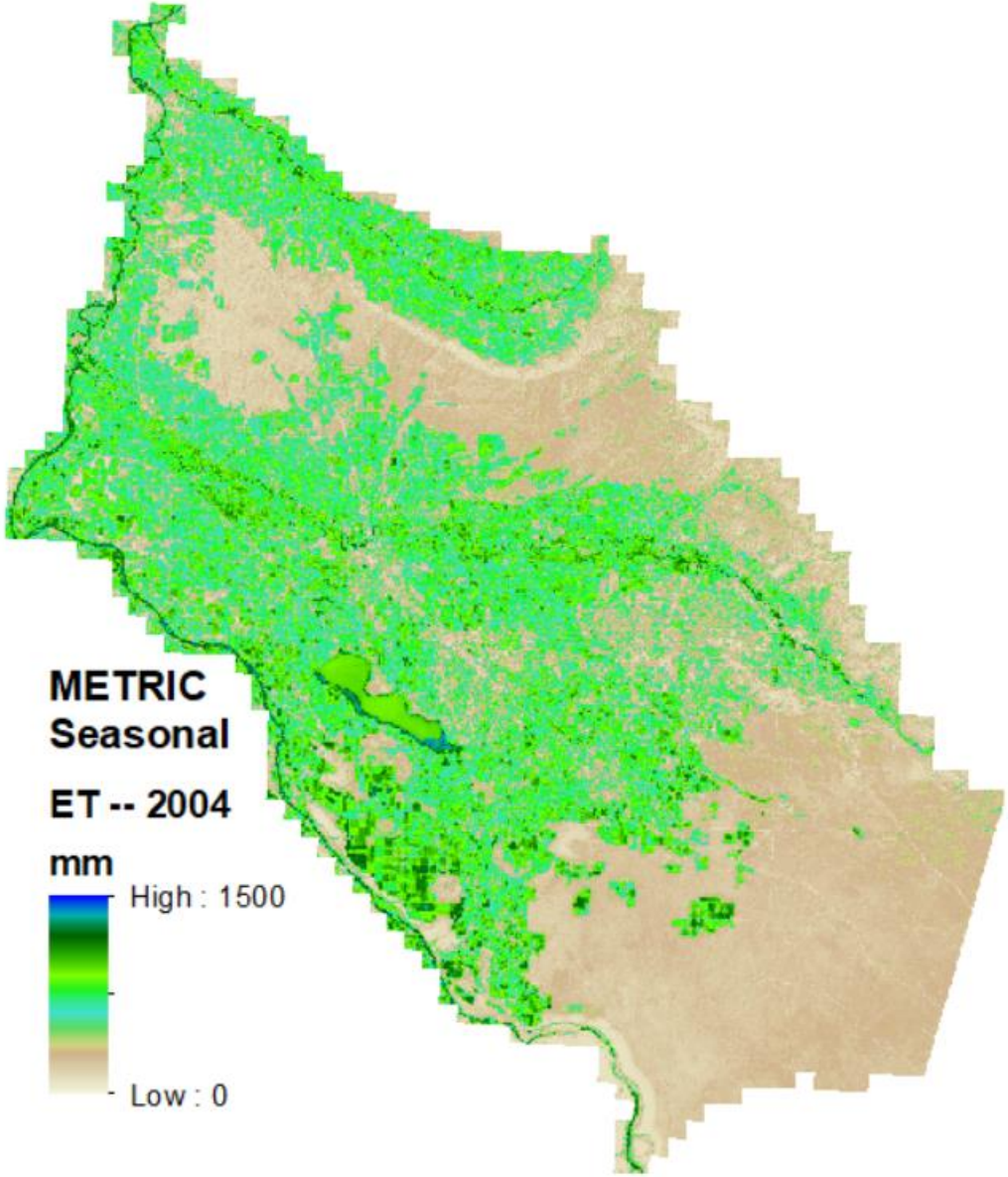


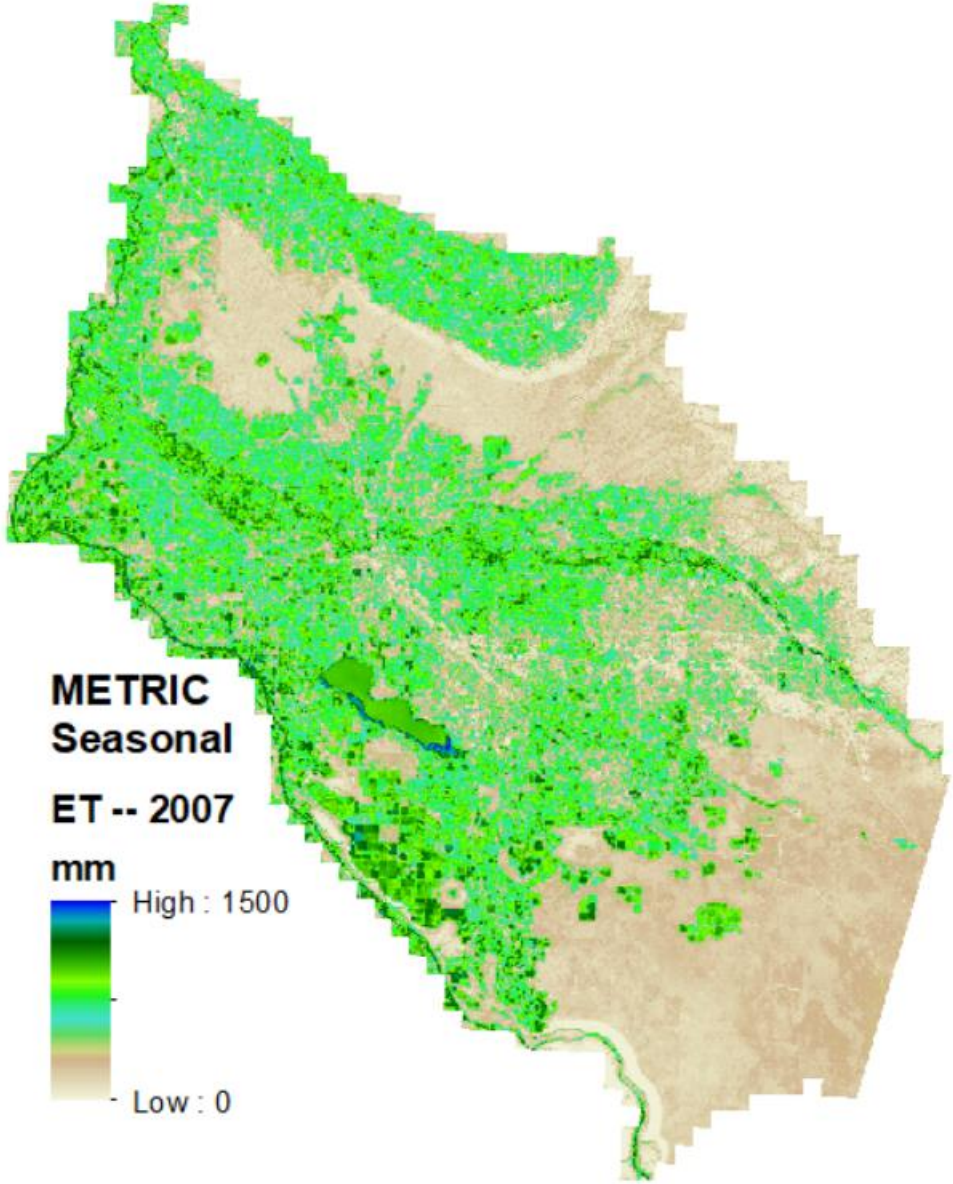
METRIC ET over the Treasure Valley: 1997 and 2000



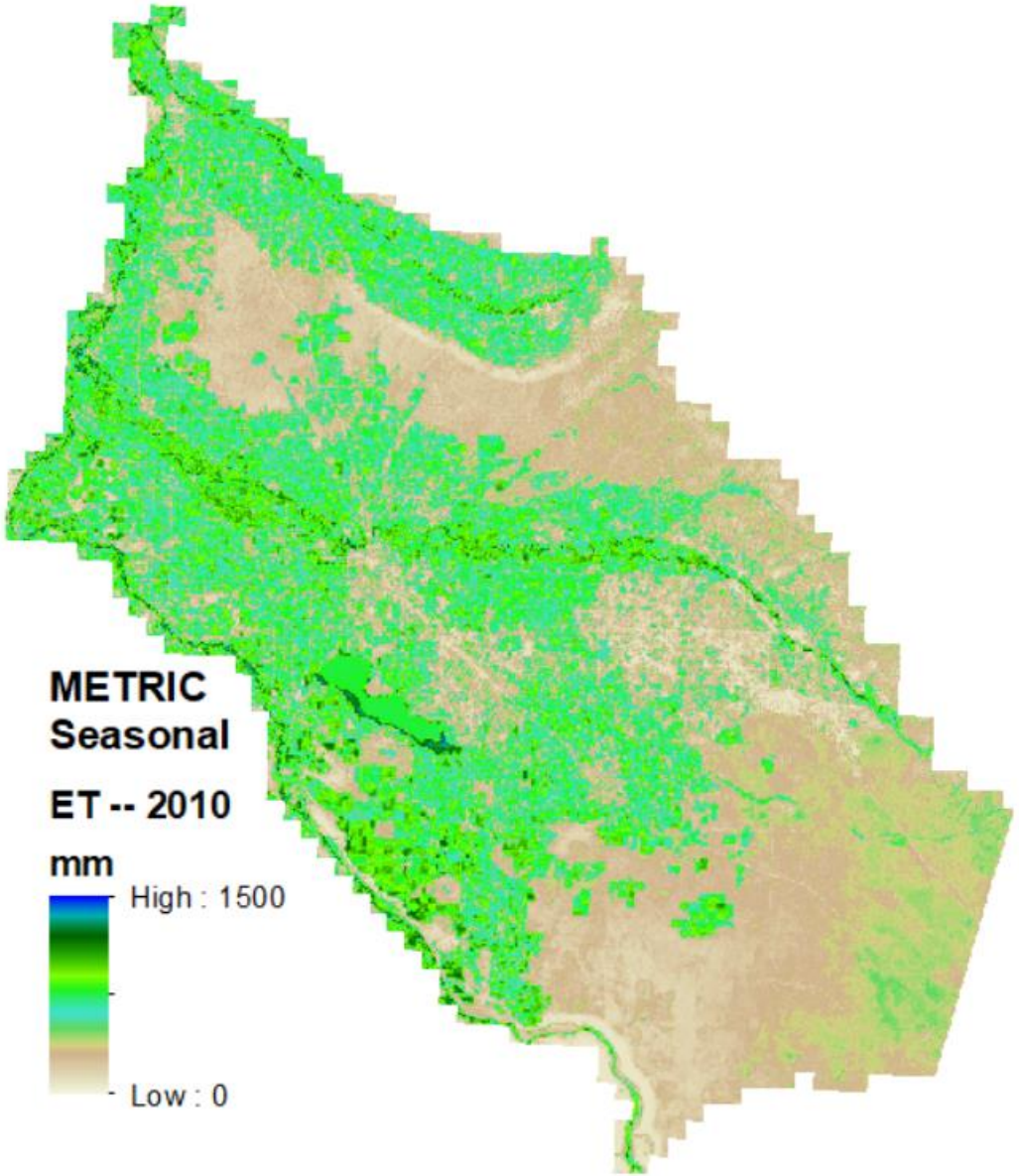


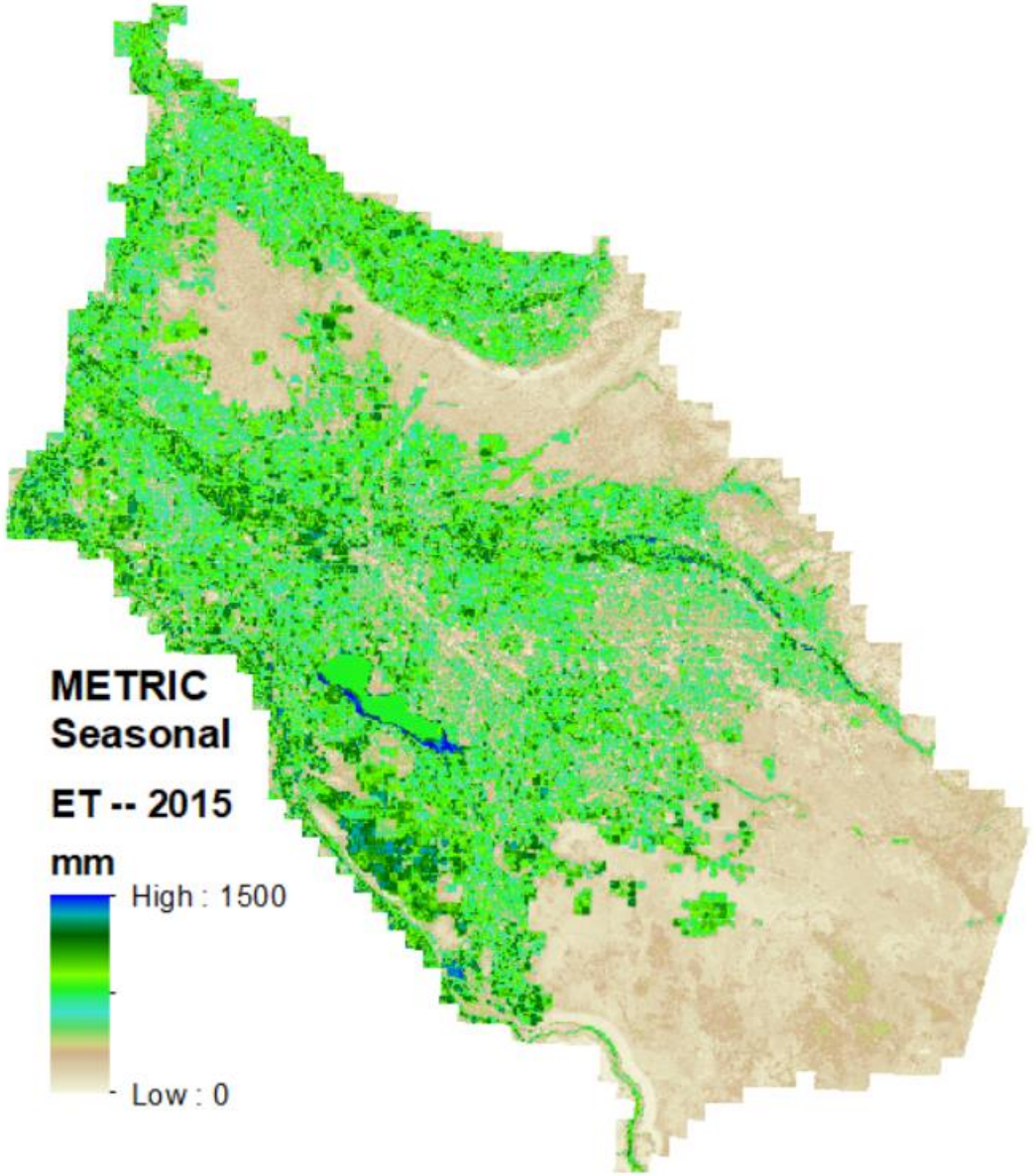
METRIC ET over the Treasure Valley: 2004 and 2007

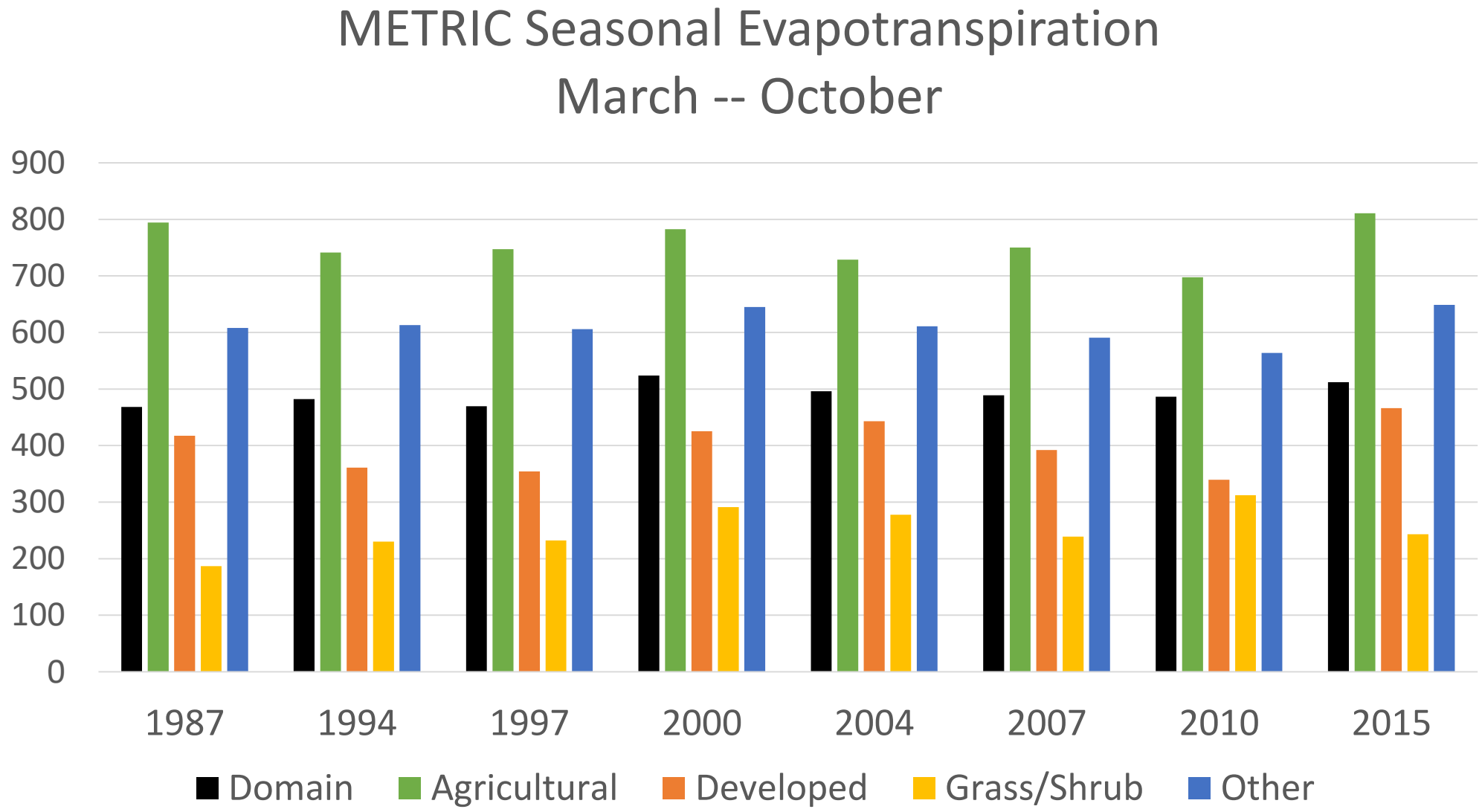




METRIC ET over the Treasure Valley: 2010 and 2015







Same classification over the eight METRIC years. Other classification includes pixels that changed overtime.

Evapotranspiration for non-METRIC years

Limited to the Treasure Valley groundwater model domain.

Original concept:

- Use ETIdaho vegetation evapotranspiration
- Use USDA crop statistical and census data (by county).
- Adjust estimated ET based on METRIC monthly ET from METRIC years.

Adjusted concept:

- Use monthly normalized difference vegetation index (NDVI) from Landsat to estimate ET using ET/NDVI ratios from closest METRIC year
  - This preserves spatial structure at 30 m scale similar to METRIC
- Adjust the ET for each year using ETIdaho for that year to indicate differences in “background” ET caused by differences in precipitation

ETIdaho -- Evapotranspiration In Idaho

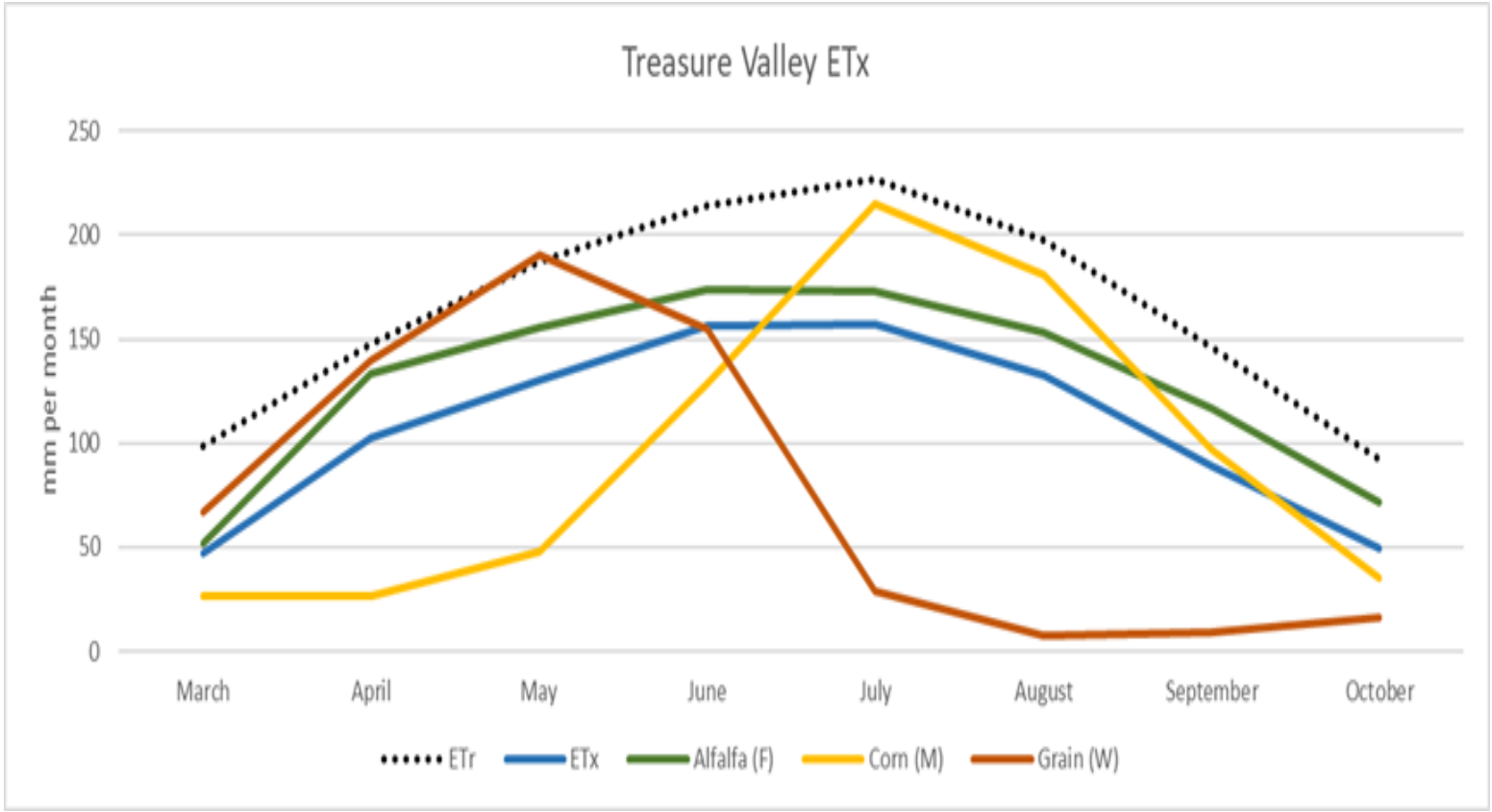
- Daily, monthly, annual time series and statistical summaries
- Monthly Reference Evapotranspiration
  - The ASCE Penman-Monteith alfalfa reference is based on meteorological data. ET_r does not account for precipitation or irrigation or crop. The monthly values used here are daily averages over a month and are only computed for months with less than 5 days missing.
- Monthly Crop/Vegetation Evapotranspiration (ET_a)
  - Evaporation (E) and Transpiration (T) for a surface condition. It includes bare soil and plant surface E due to precipitation and irrigation. Plant transpiration, T, is based on basal crop coefficients which assume ideal management. ETIdaho estimates planting, green-up and harvesting dates from temperature which may not correspond to actual practice. For irrigated areas, ET_a represents potential ET with no stress. For rainfed areas, ET_a represents monthly actual ET_a determined from the daily potential ET and soil water balance accounting for precipitation, rooting depth and soil conditions. ET_a is similar to METRIC ET.

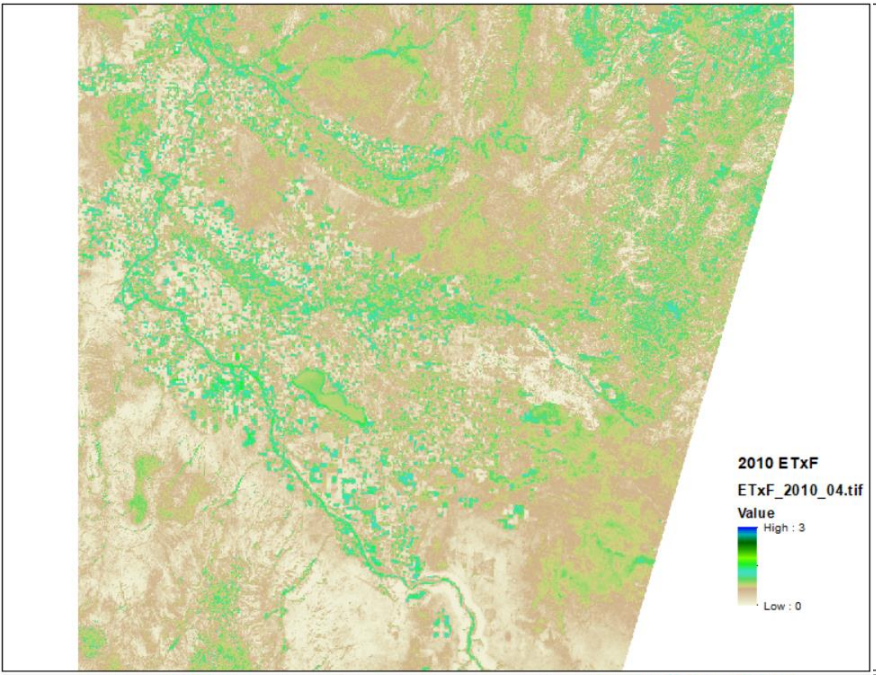
$$ET = E_s + T$$

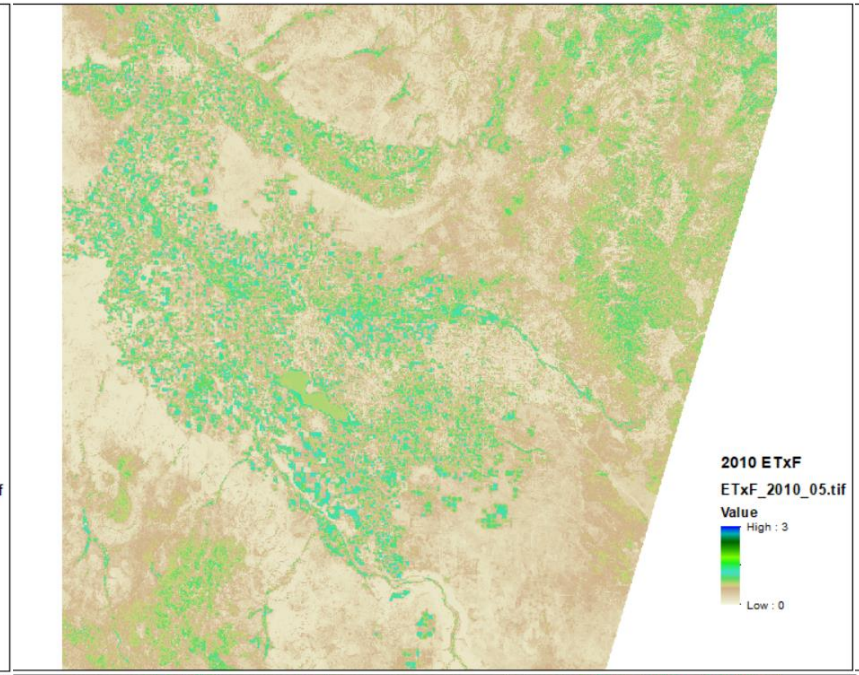
- ET_m METRIC ET
- ET_r ETIdaho reference ET daily or monthly
- ET_rF Fraction of reference ET, $sum(ET_m)/sum(ET_r)$
- ET_a ETIdaho ET for a crop/vegetation including E due to rain or irrigation and stress factors.
  $ET_a = (K_s * K_{cb} + K_e) * ET_r$
- ET_x Index ET that includes E_s from irrigation and precipitation.
  ET_x = Weighted average of ET_a for alfalfa, corn, grain
- ET_xF Ratio of ET_m to ET_x

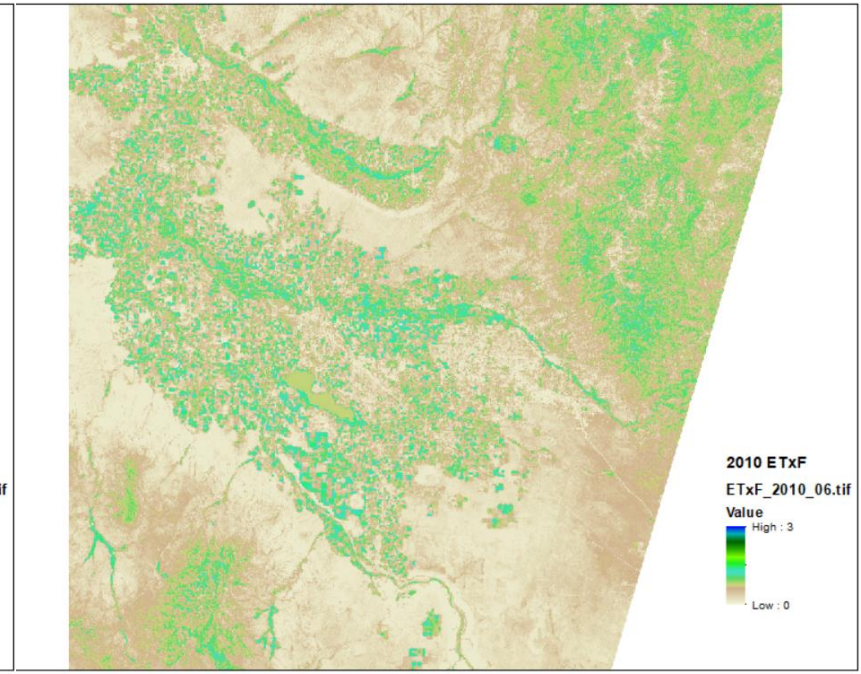
ET_xF from METRIC ET_m and ETIdaho ET_a

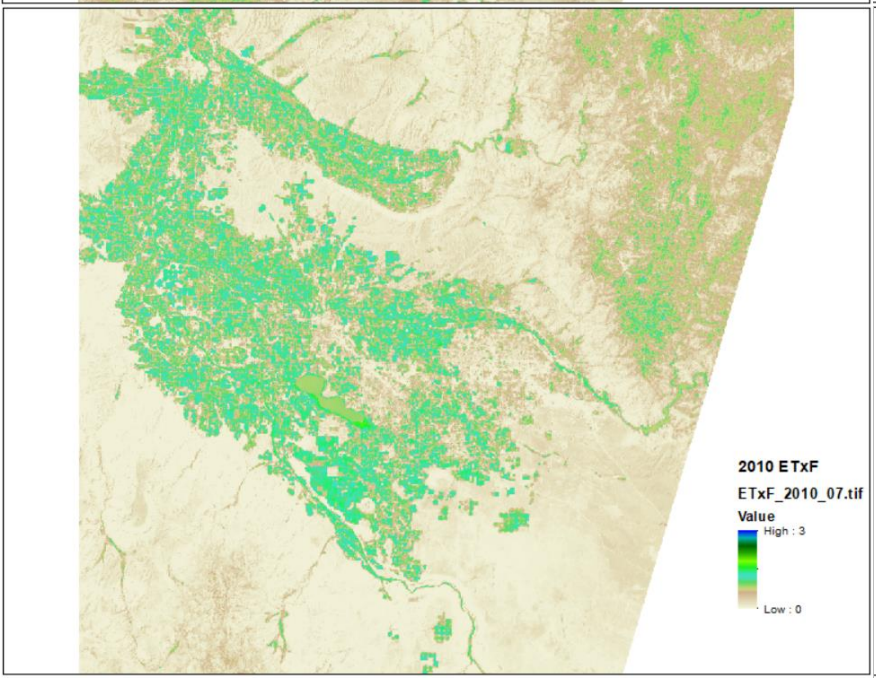
- ET_x = 0.5*Alfalfa + 0.3*Field Corn + 0.2 * Winter Grain
  - Alfalfa -- a full season,
    field corn -- late season
    winter grain -- early season
- ET_m METRIC ET product.
- ET_xF: $^{ET_m}/_{ET_x}$
- Developed ET_xF surfaces for each METRIC year month. (next slide examples)

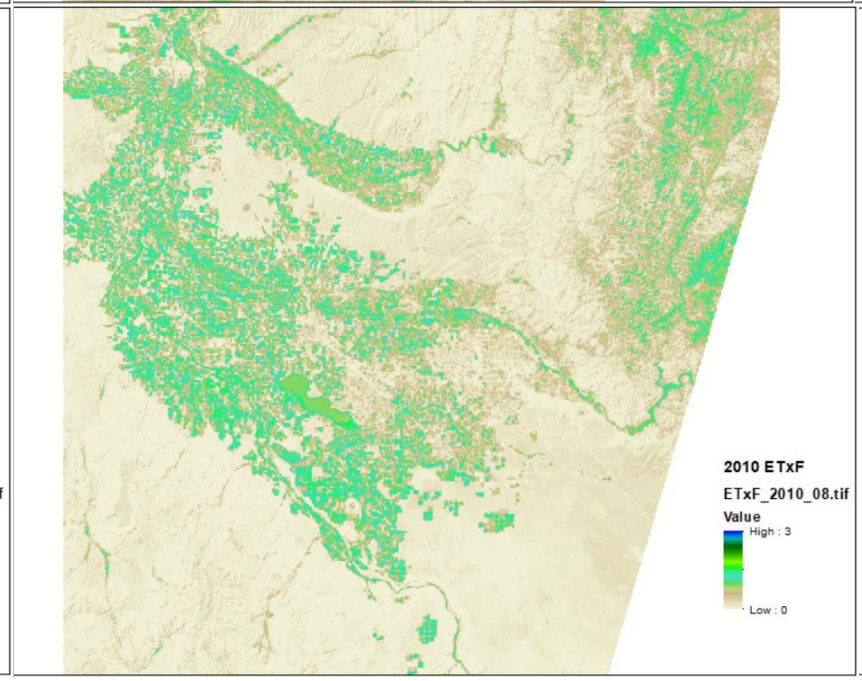


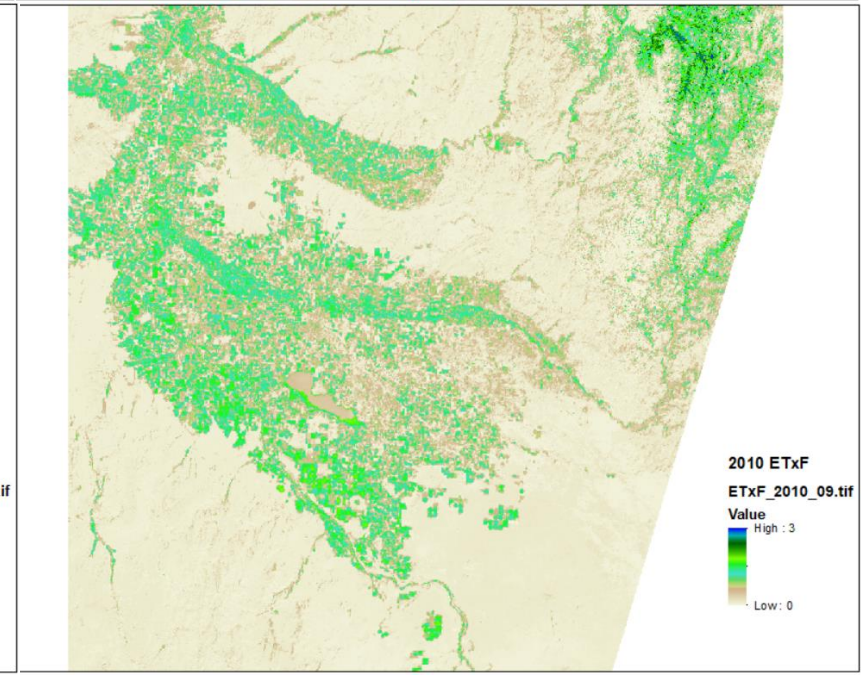

2010 ETxF
ETxF_2010_04.tif
Value
High : 3
Low : 0


2010 ETxF
ETxF_2010_05.tif
Value
High : 3
Low : 0


2010 ETxF
ETxF_2010_06.tif
Value
High : 3
Low : 0


2010 ETxF
ETxF_2010_07.tif
Value
High : 3
Low : 0


2010 ETxF
ETxF_2010_08.tif
Value
High : 3
Low : 0


2010 ETxF
ETxF_2010_09.tif
Value
High : 3
Low : 0

Crops

- CDL (Cropscape) only available for 2007 to present.
  - 2007 has issue with alfalfa is low compared to 2008 to present.
- USDA Agricultural Statistics
  - Only county level statistics, no spatial distribution within counties.
  - Survey (yearly) incomplete and crops acreages vary between years with some crops not reported.
  - Census (every 5 years) more complete; however, still issues with consistent reporting.
- From CDL over the past decade: 2007-2018
  - Primary cultivated: Alfalfa, Corn and Winter Grain
- Usage of USDA crop information would not yield the spatial and temporal resolution desired.

Normalized Difference Vegetation Index (NDVI)

- NDVI is a vegetation index that quantifies plant growth and vigor.
- NDVI approaches 0.1 for “bare” soils and 0.9 for fully vegetated actively growing vegetation.
- NDVI has been used to estimate K_{cb} (basal crop coefficient) used with alfalfa or grass reference evapotranspiration to determine evapotranspiration associated with a land surface.
- It does not account for “wetness” due to irrigation and precipitation.
- It does not account for vegetation “stomatal” control (stress).

$$K_{cb} \propto NDVI$$

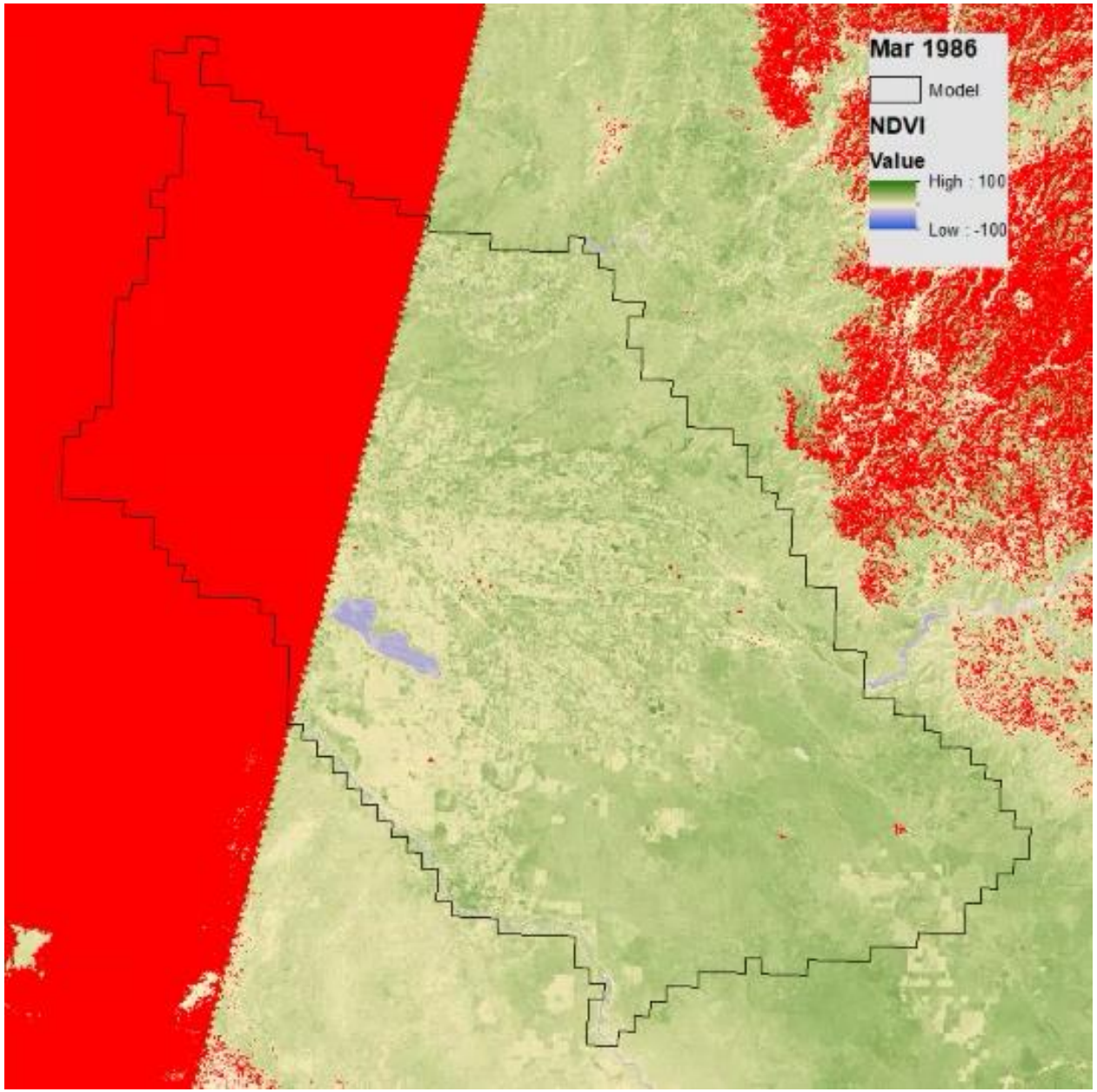
Relate ET_xF to NDVI.

- Others have related K_{cb} to NDVI and then to ET.
- Research has indicated that the relationships may change with time and vegetation type.
- ET_xF ~ a + b*NDVI

  ET_xF: $^{ET_m}/_{ET_x}$ so that ET_xF includes evaporation effects
- Determined for each active ground water modelling cell to account for spatial differences in vegetation types.
- Linear regression of cell and neighbors.
- For nonMETRIC years:
  - ET = ET_xF from regression * ET_x for that year based on interpolation from nearest METRIC years.

Average Monthly NDVI

- Derived from Landsat platforms from 1986 through 2015.
- “Average” monthly NDVI is non-cloudy mean NDVI from the 15th of the prior month to the 15th of the following month.
- Yields seasonal change in vegetation.
- Yields year to year change in vegetation.
- Need to deal with months where unable to determine average NDVI (red).



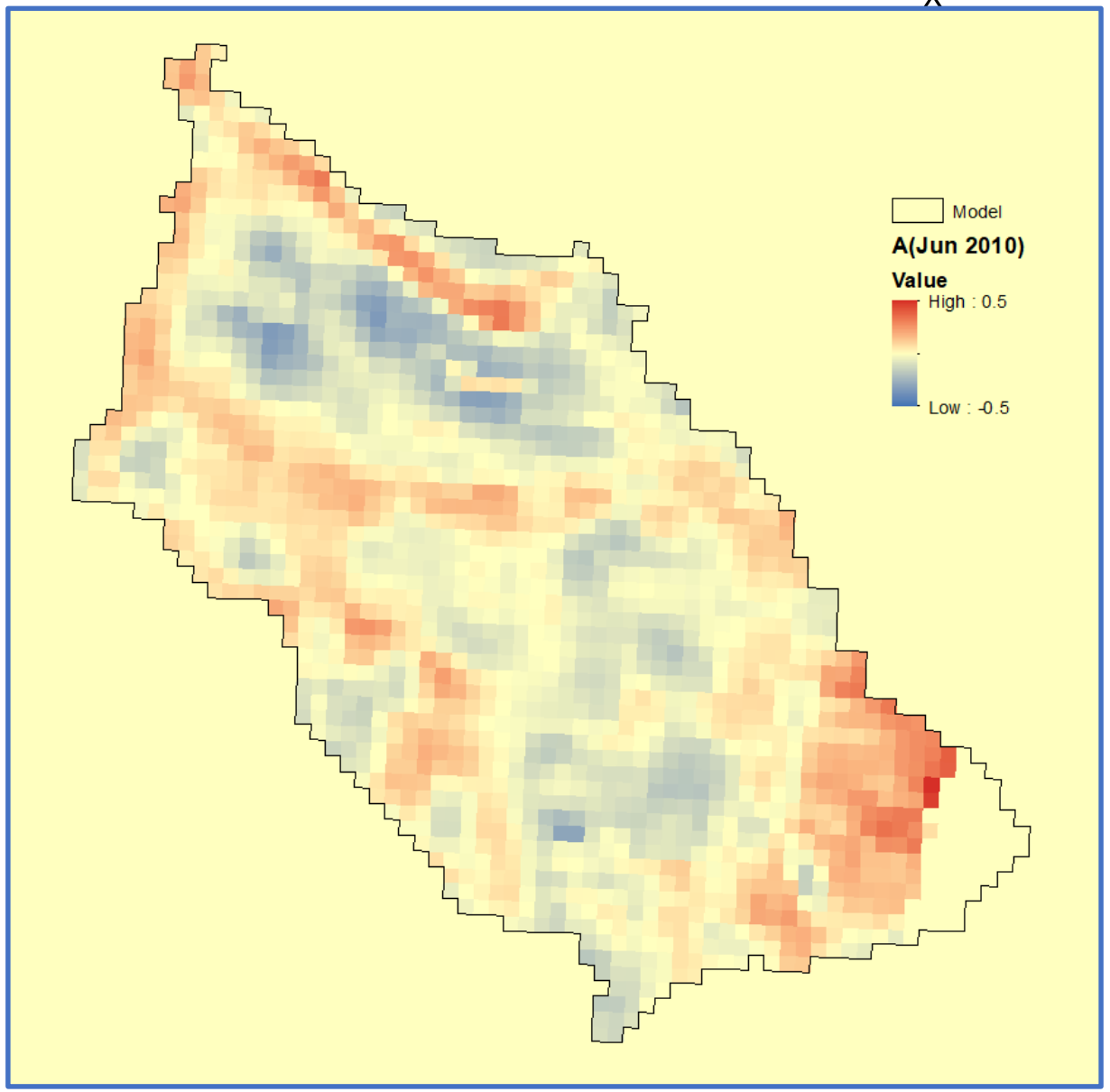
Relate ET_xF to "Average Monthly" NDVI

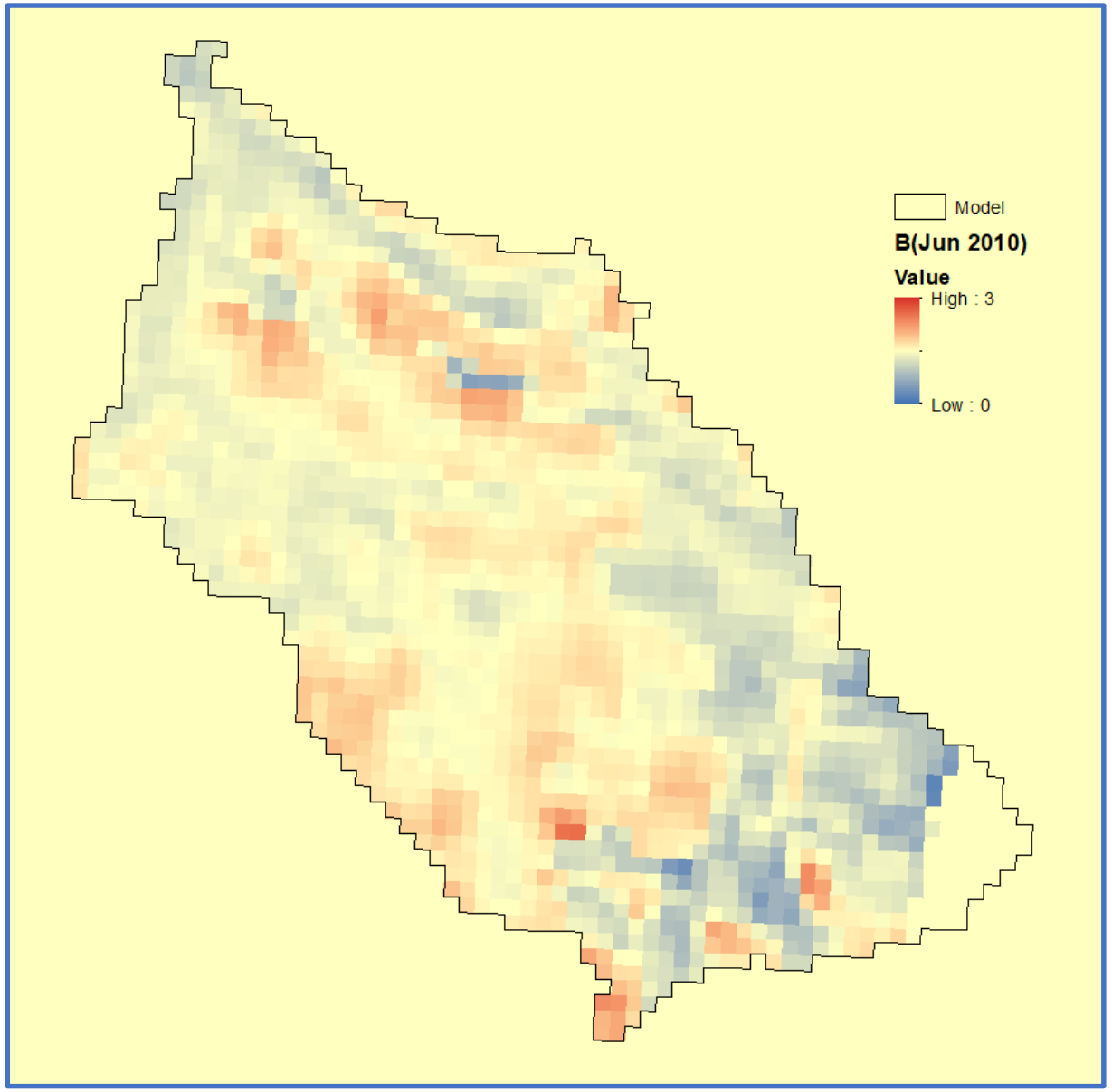
- Determined 1861 active cell relationships for each METRIC ET month and year product.
- Estimated domain relationship from cells where $r^2 > 0.3$
- Cells where NDVI was missing or regression with negative slope or $r^2<0.3$, assumed to be domain relationship.

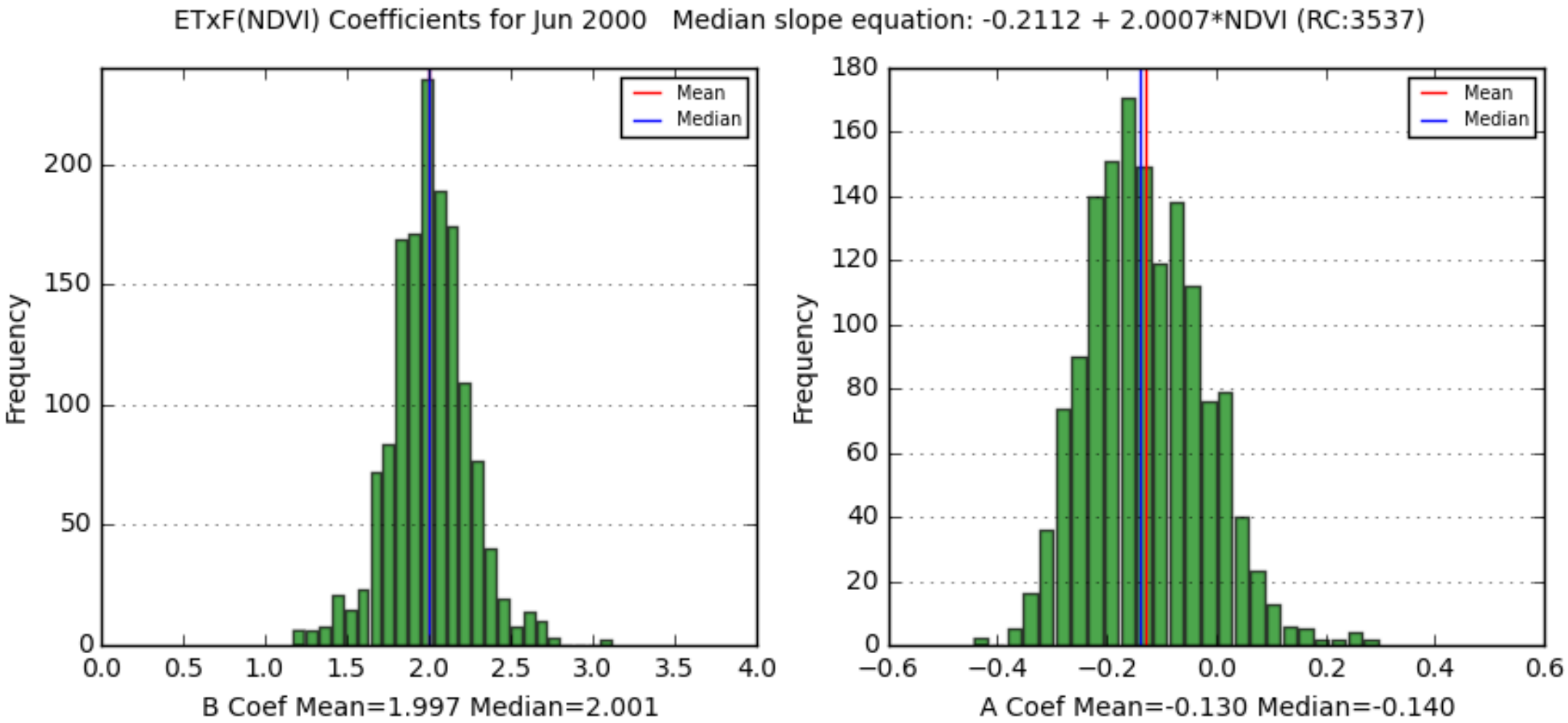
ETa	I:/TValley/TV_Metric\2015\ET_P42_2015v2_05.img/Layer_1							I:/TValley/TV_Metric\2015\ET_P42_2015v2_06.img/Layer_1						
ETx	I:/TValley/TV_NonMetric/ETx\2015\ETx_2015_05.tif							I:/TValley/TV_NonMetric/ETx\2015\ETx_2015_06.tif						
NDVI	I:/TValley/TV_NonMetric/NDVI_Monthly\2015\sMon_NDVI_05.tif							I:/TValley/TV_NonMetric/NDVI_Monthly\2015\sMon_NDVI_06.tif						
Min	0.00	1.72	-0.56	-1.10	0.00	0.40	-0.89	0.00	1.58	-0.78	-2.68	0.00	0.21	-0.30
Max	0.39	26.13	0.61	3.82	0.89	2.33	0.88	0.22	28.08	0.61	4.14	0.93	2.50	0.87
Average	**0.01**	**11.38**	**-0.09**	**1.78**	**0.53**	**1.49**	**0.49**	**0.01**	**13.16**	**-0.14**	**2.01**	**0.55**	**1.43**	**0.49**
	May ETxF to NDVI ... y = A + B*x or y = B'*x							June ETxF to NDVI ... y = A + B*x or y = B'*x						
Cell	3x3 Cell Window with NDVI >= 0.1							3x3 Cell Window with NDVI >= 0.1						
RCIndex	Min	Max	A	B	RSQ	B'	RSQ'	Min	Max	A	B	RSQ	B'	RSQ'
109	0.0000	22.1736	-0.0557	1.8694	0.6808	1.7485	0.6776	0.0000	19.2328	-0.0637	1.7262	0.5097	1.5927	0.5063
308	0.0000	22.1736	-0.0498	1.7506	0.6209	1.6476	0.6185	0.0000	19.5882	-0.0446	1.7835	0.6058	1.6984	0.6042
309	0.0000	22.1736	-0.1343	1.8489	0.6322	1.5671	0.6156	0.0000	19.2328	-0.1471	1.8916	0.6147	1.6047	0.5987
408	0.0000	16.1665	-0.1396	1.9031	0.6960	1.6232	0.6787	0.0000	19.5882	-0.1296	1.9488	0.6907	1.7007	0.6779
409	0.0000	16.1665	-0.1598	1.9092	0.6631	1.5894	0.6420	0.0000	18.3915	-0.1550	1.9586	0.6540	1.6620	0.6370
410	0.0000	16.1665	-0.2536	2.0277	0.6908	1.4948	0.6364	0.0000	17.7416	-0.2863	2.1558	0.7071	1.5669	0.6460
411	0.0000	14.1194	-0.3274	2.1128	0.7533	1.3782	0.6489	0.0000	17.0207	-0.3899	2.3106	0.7792	1.4362	0.6448
508	0.0000	13.6777	-0.2308	1.9953	0.7285	1.5091	0.6759	0.0000	18.3915	-0.2410	2.1157	0.7470	1.6195	0.6967
509	0.0000	14.1194	-0.2053	1.9609	0.7189	1.5373	0.6784	0.0000	18.3915	-0.2050	2.0396	0.7122	1.6239	0.6764
510	0.0000	14.1891	-0.2243	2.0074	0.7123	1.5412	0.6675	0.0000	17.7416	-0.2107	2.0441	0.6936	1.6129	0.6574
511	0.0000	14.1891	-0.2578	2.0724	0.7473	1.5311	0.6881	0.0000	23.0321	-0.2550	2.1214	0.7250	1.5948	0.6723
512	0.0000	15.1860	-0.2117	1.9975	0.7319	1.5521	0.6898	0.0000	23.0321	-0.2805	2.2840	0.7613	1.7172	0.7063
513	0.0000	15.1860	-0.1971	1.9678	0.7690	1.5579	0.7292	0.0000	23.0321	-0.2753	2.2581	0.7746	1.6888	0.7154
609	0.0000	18.0842	-0.2351	1.9886	0.7261	1.4659	0.6628	0.0000	18.3915	-0.2026	1.9682	0.6603	1.5127	0.6158
610	0.0000	18.0842	-0.2375	1.9996	0.7064	1.4974	0.6538	0.0000	17.7416	-0.1943	1.9698	0.6368	1.5574	0.6040

Spatial Distribution Linear Coefficients

$ET_xF = A + B*NDVI$





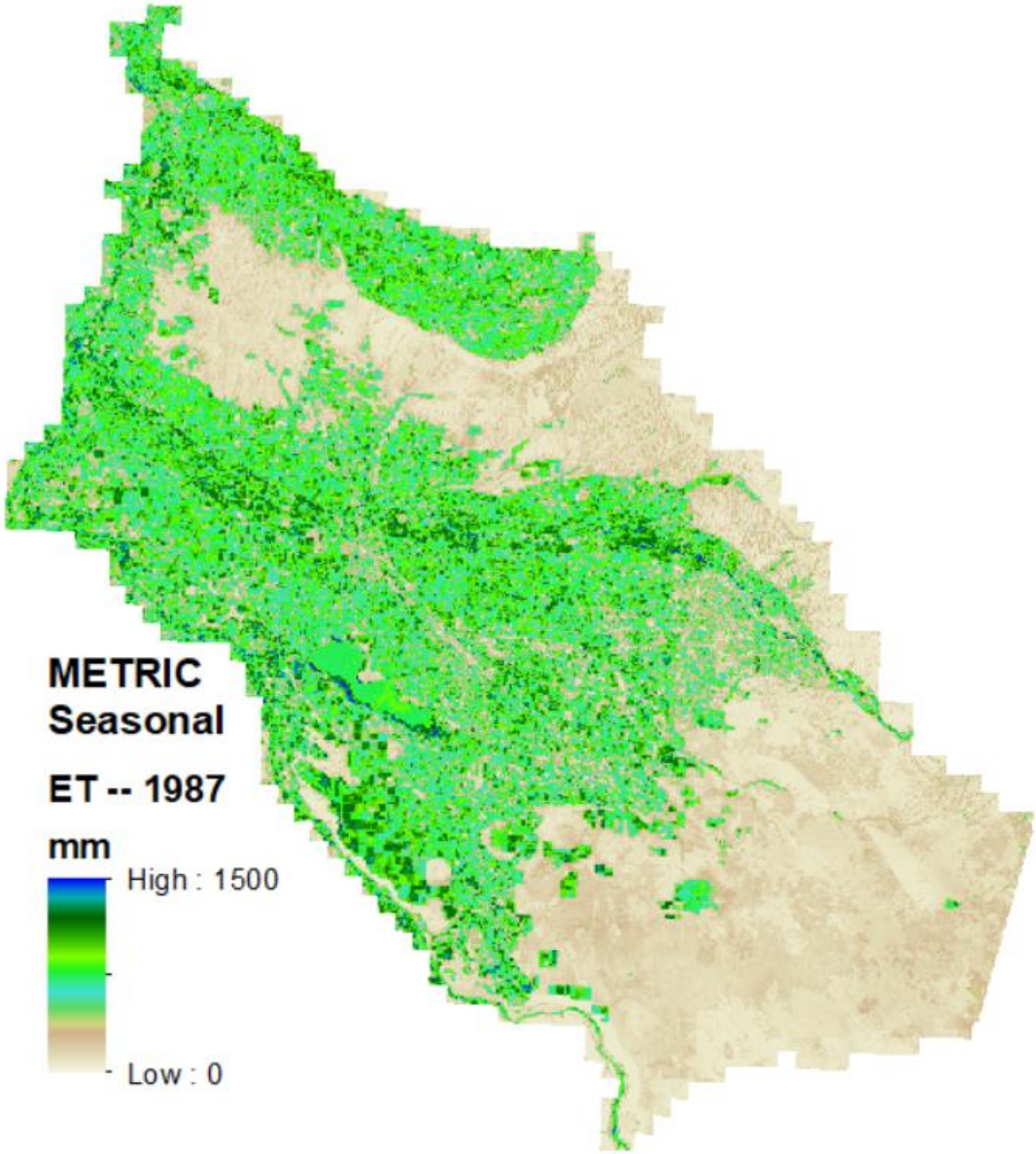

ETxF(NDVI) Coefficients for Jun 2000 Median slope equation: -0.2112 + 2.0007*NDVI (RC:3537)
Mean
Median
Frequency
B Coef Mean=1.997 Median=2.001
A Coef Mean=-0.130 Median=-0.140

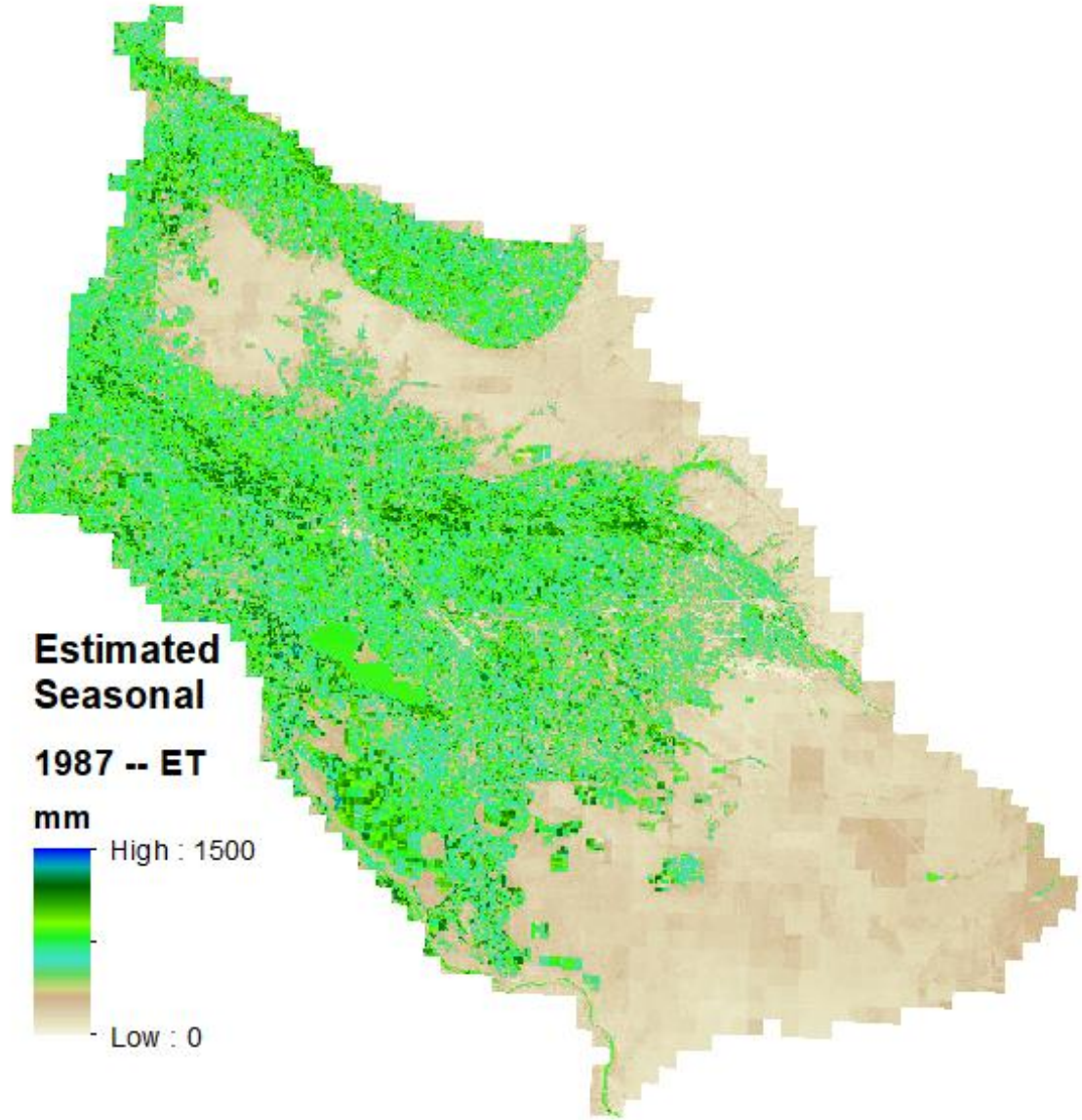
Comparison of Estimated ET to METRIC ET for METRIC Years

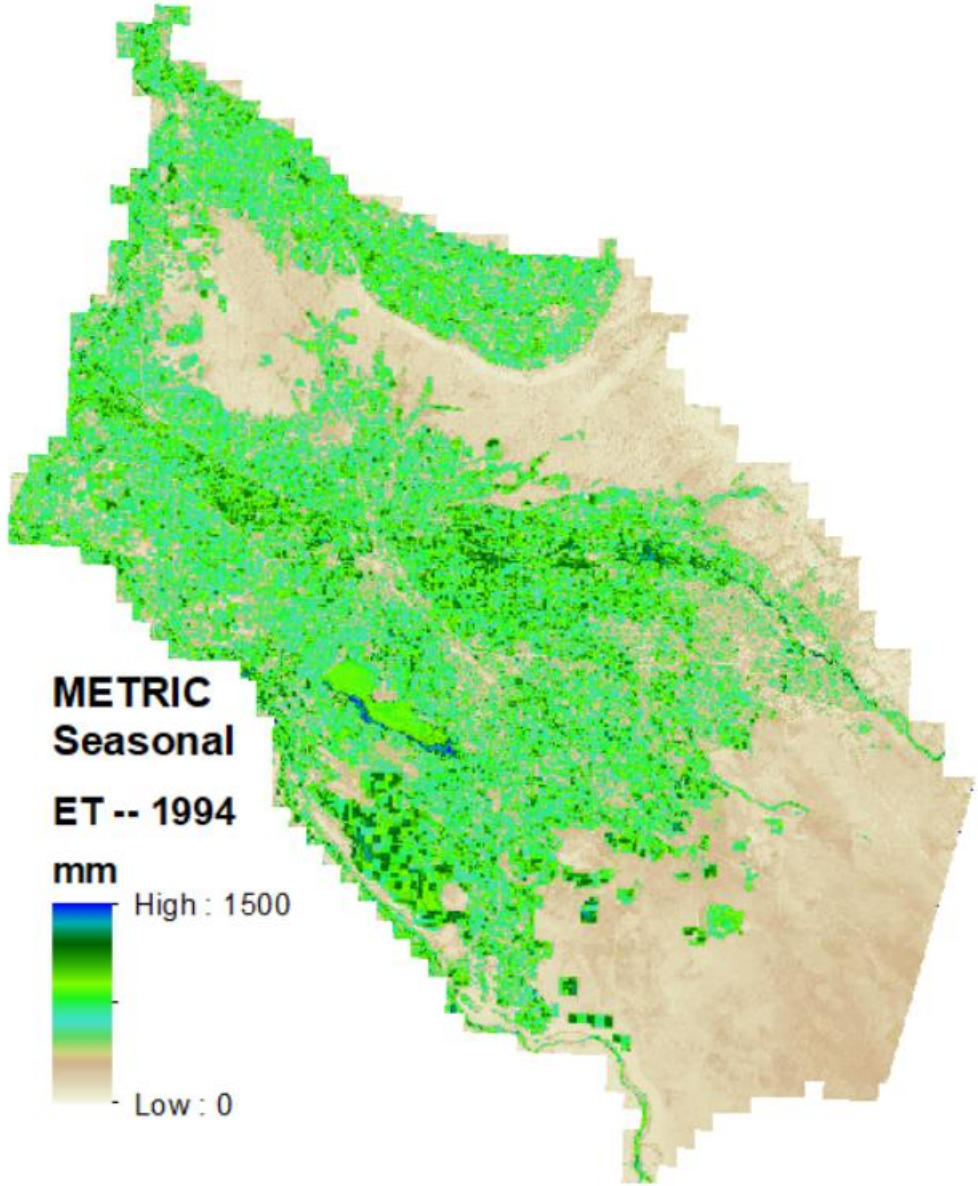
Comparisons of estimated ET for each METRIC year are based that METRIC year's coefficients.

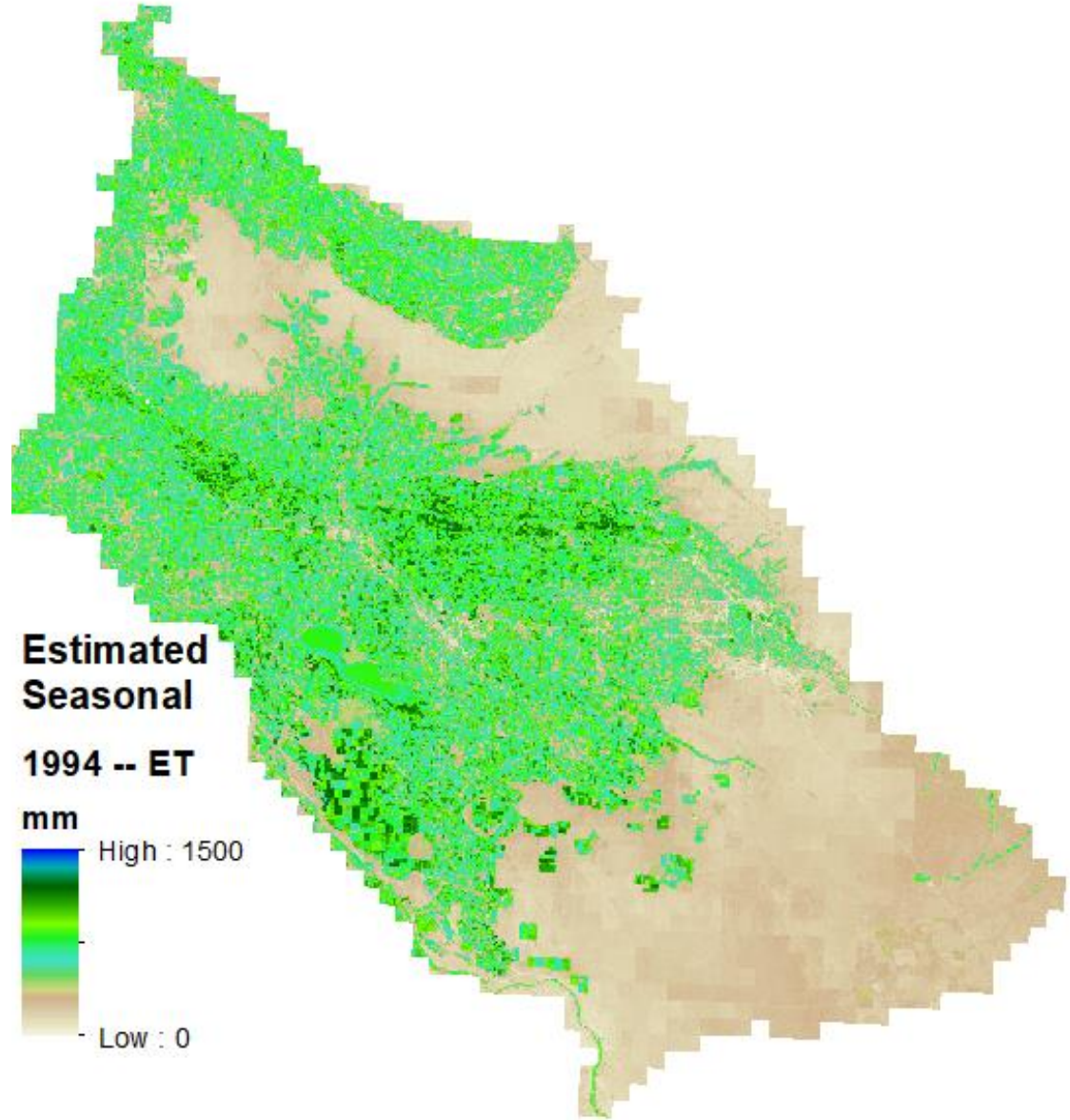
Therefore, comparisons are not truly independent; but indicate reproducibility of original data.

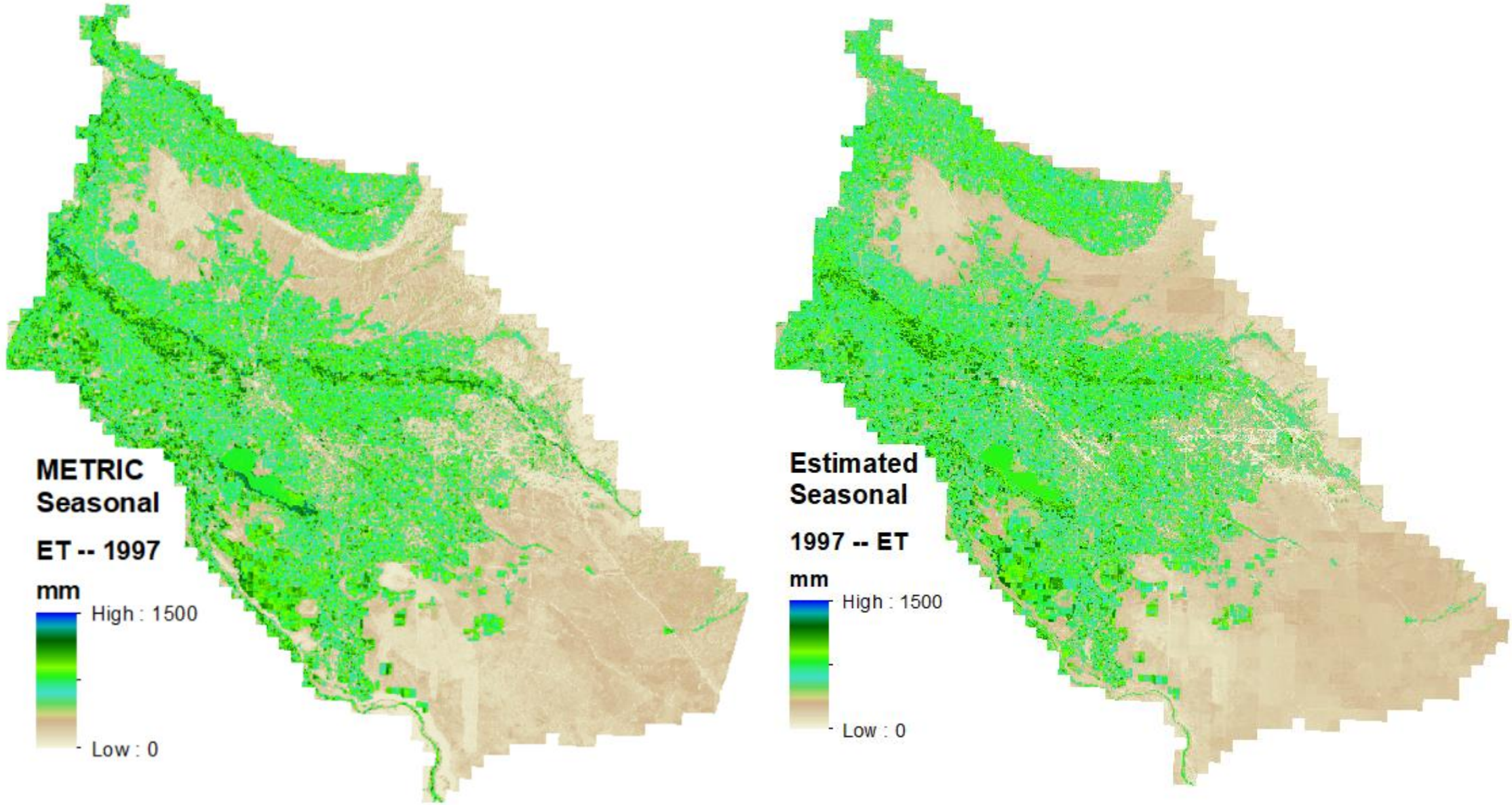
To quantify the cell differences visually box plots will be shown. The box plot shows the median, midrange (~interquartile), outer range, and "outliers". Asterisks represent observations that are greater than 1.5*midrange. Circles represent observations that are greater then 3.0*midrange.

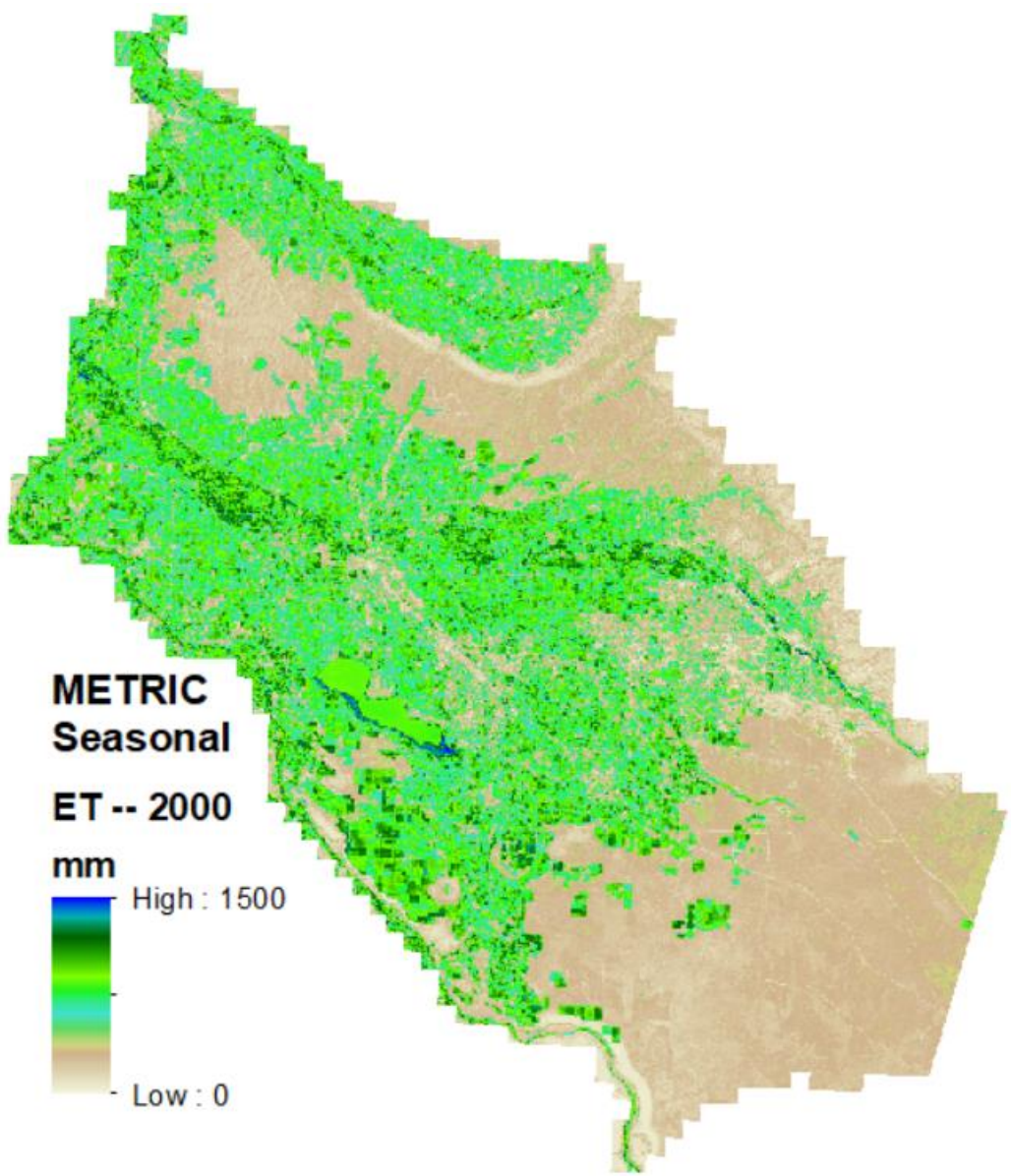

METRIC
Seasonal
ET -- 1987
mm
High : 1500
Low : 0

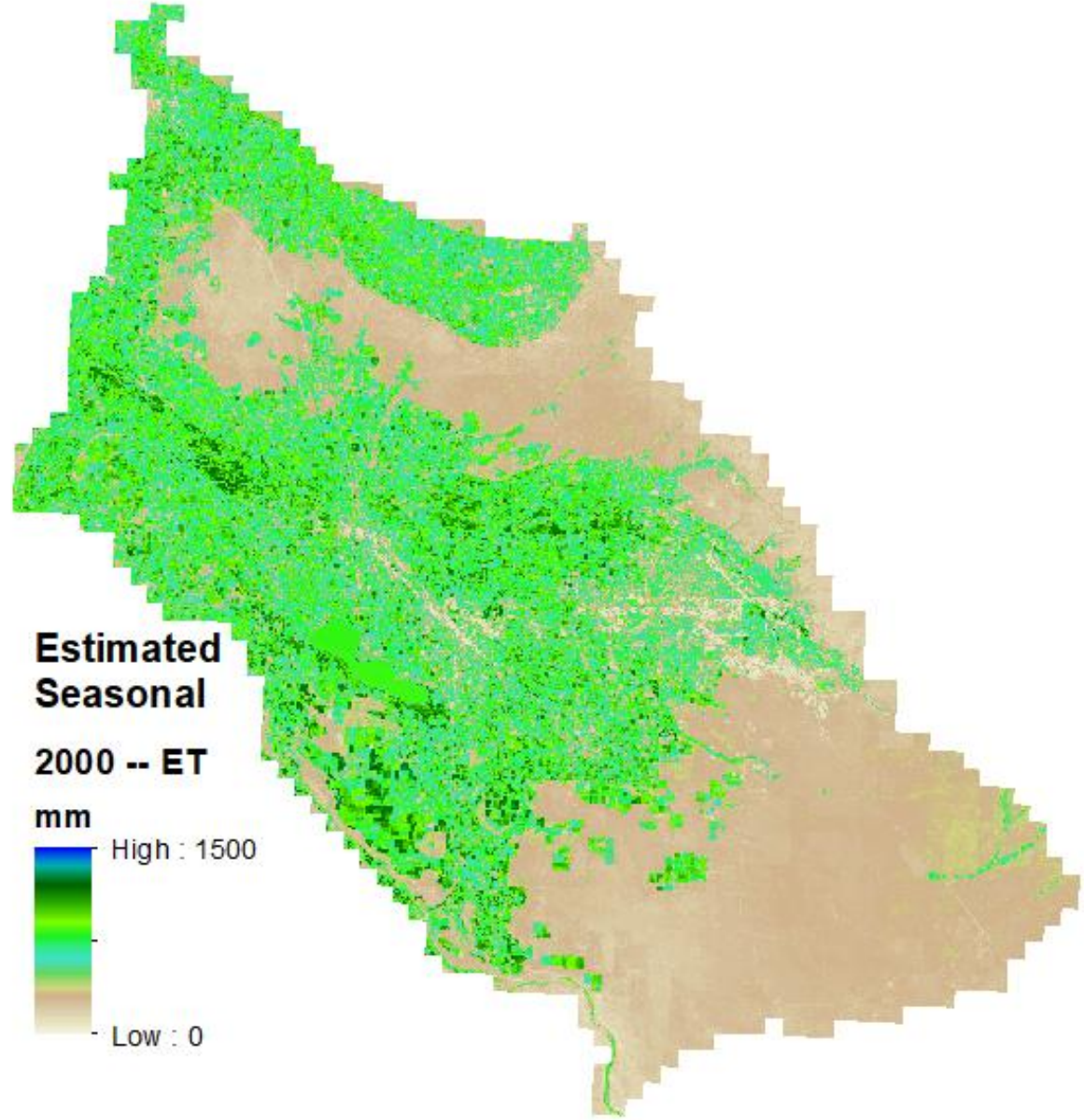

Estimated
Seasonal
1987 -- ET
mm
High : 1500
Low : 0

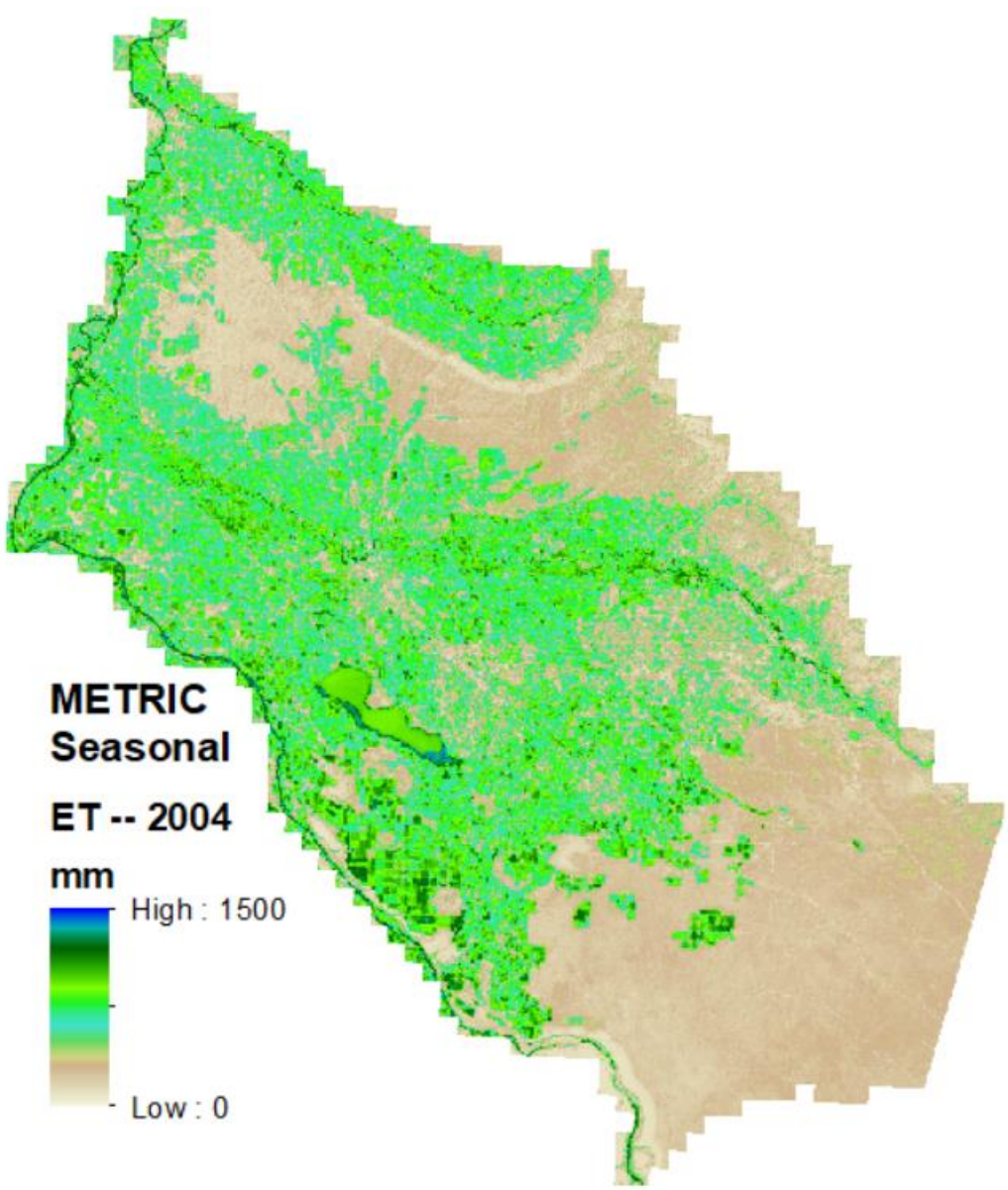

METRIC
Seasonal
ET -- 1994
mm
High : 1500
Low : 0

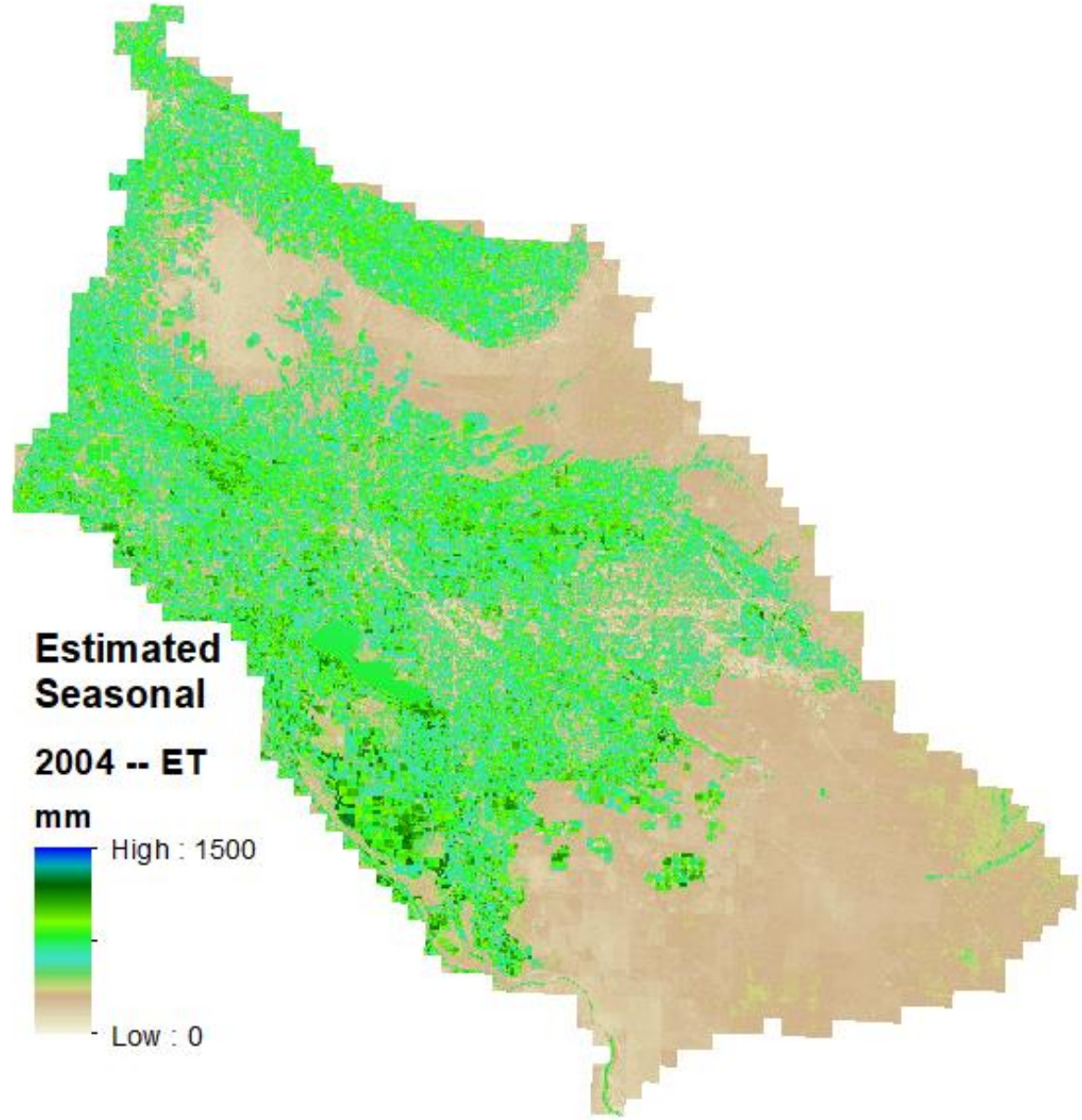

Estimated
Seasonal
1994 -- ET
mm
High : 1500
Low : 0

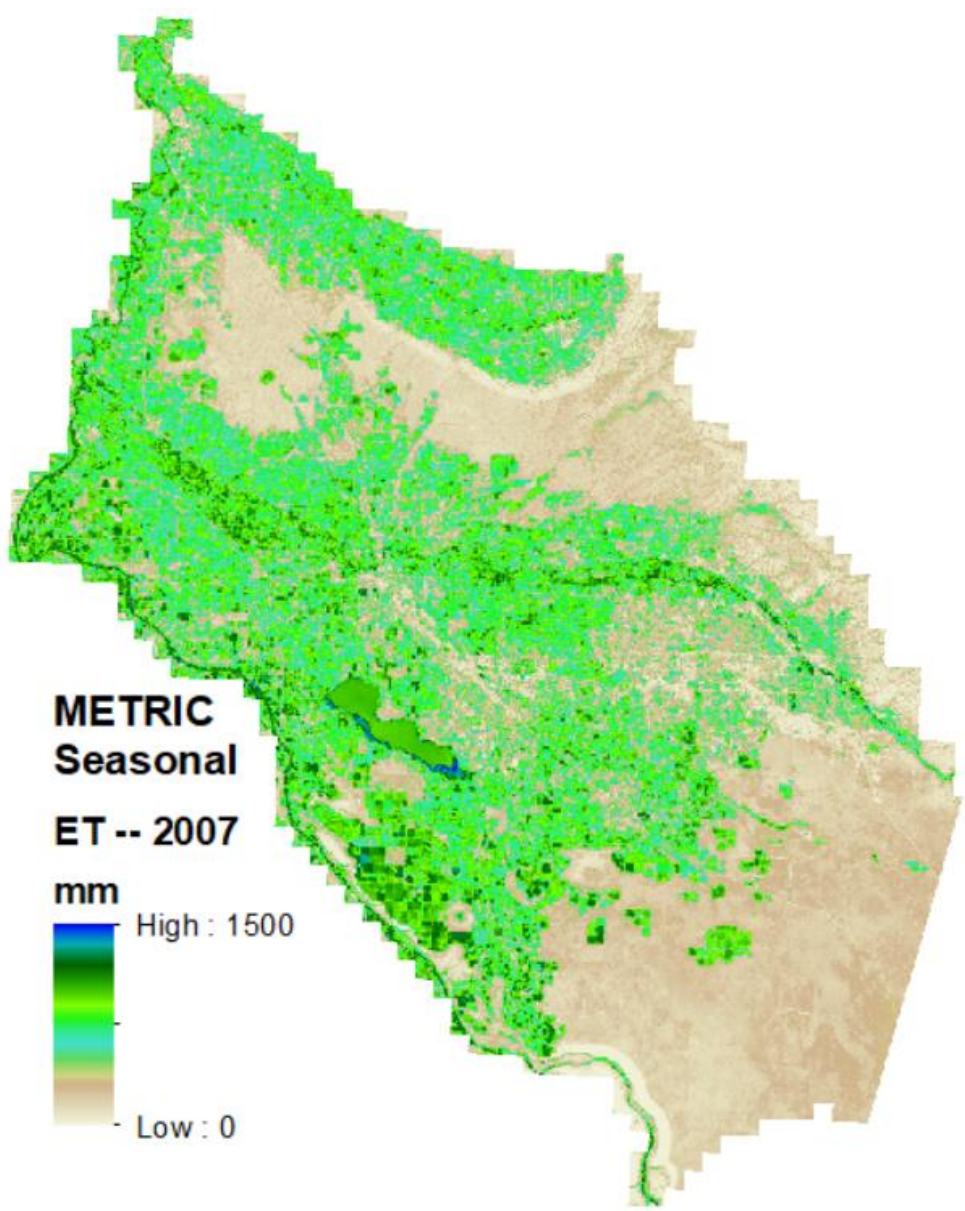

METRIC
Seasonal
ET -- 1997
mm
High : 1500
Low : 0
Estimated
Seasonal
1997 -- ET
mm
High : 1500
Low : 0

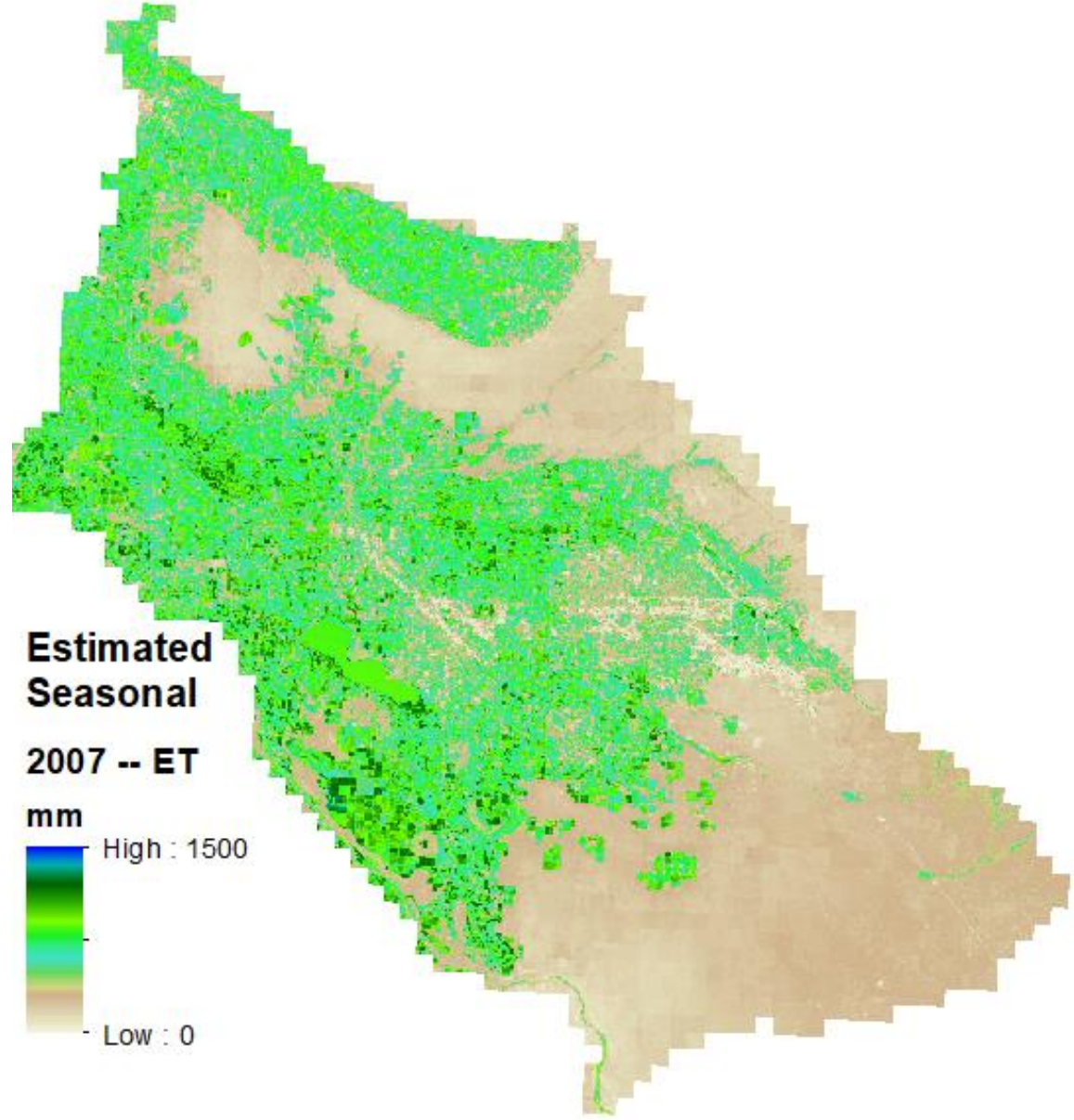

METRIC
Seasonal
ET -- 2000
mm
High : 1500
Low : 0

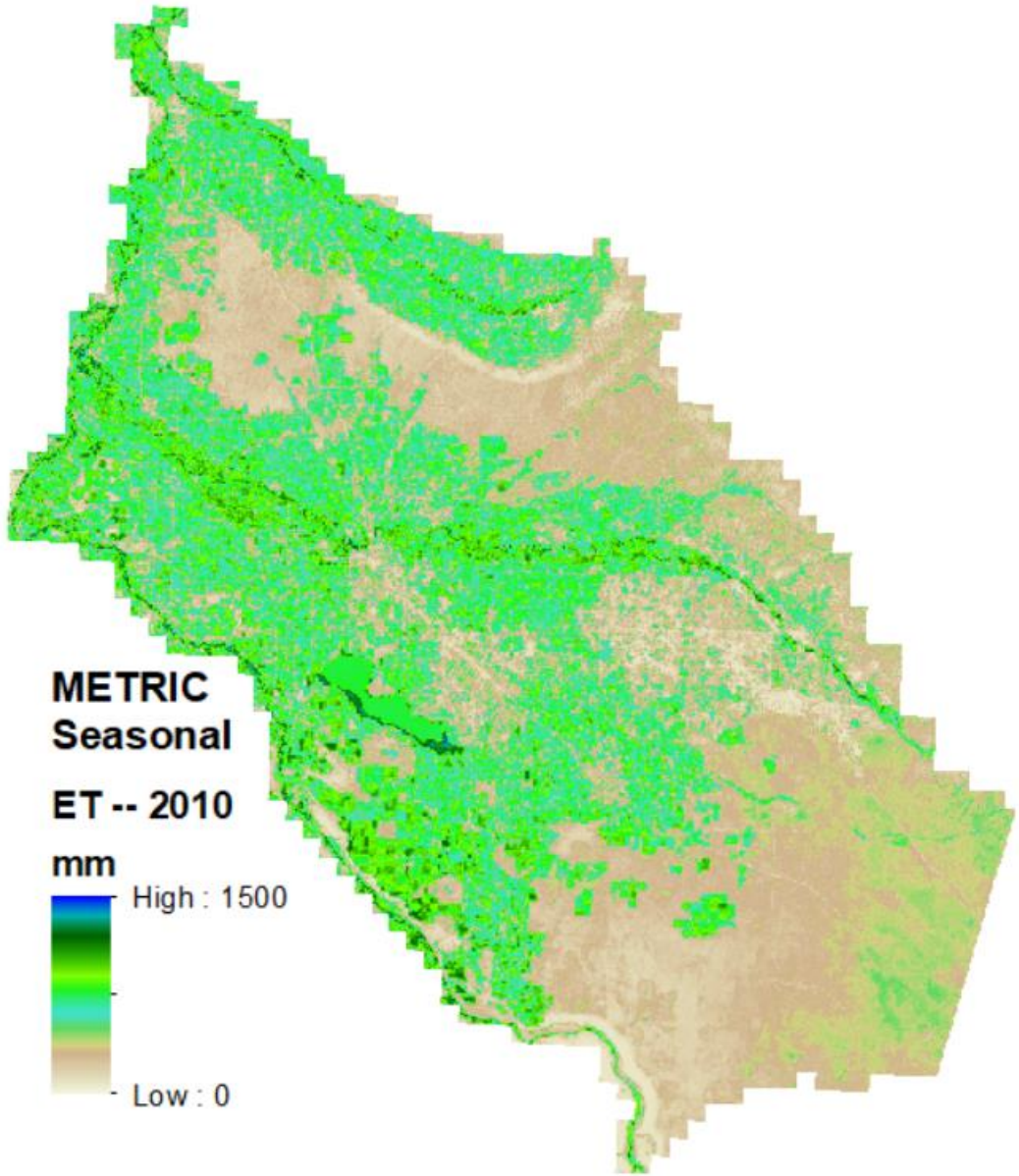

Estimated
Seasonal
2000 -- ET
mm
High : 1500
Low : 0

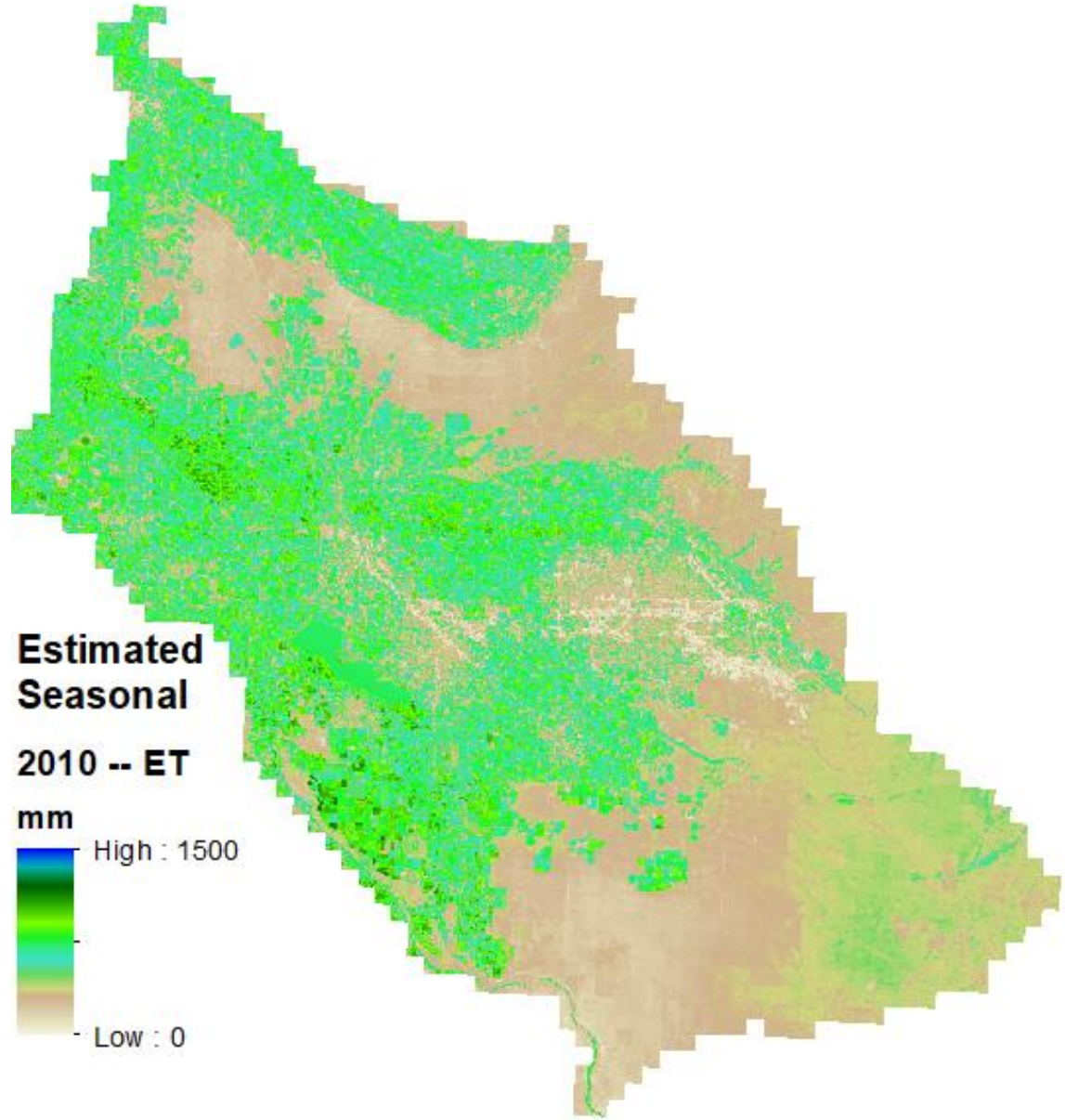

METRIC
Seasonal
ET -- 2004
mm
High : 1500
Low : 0

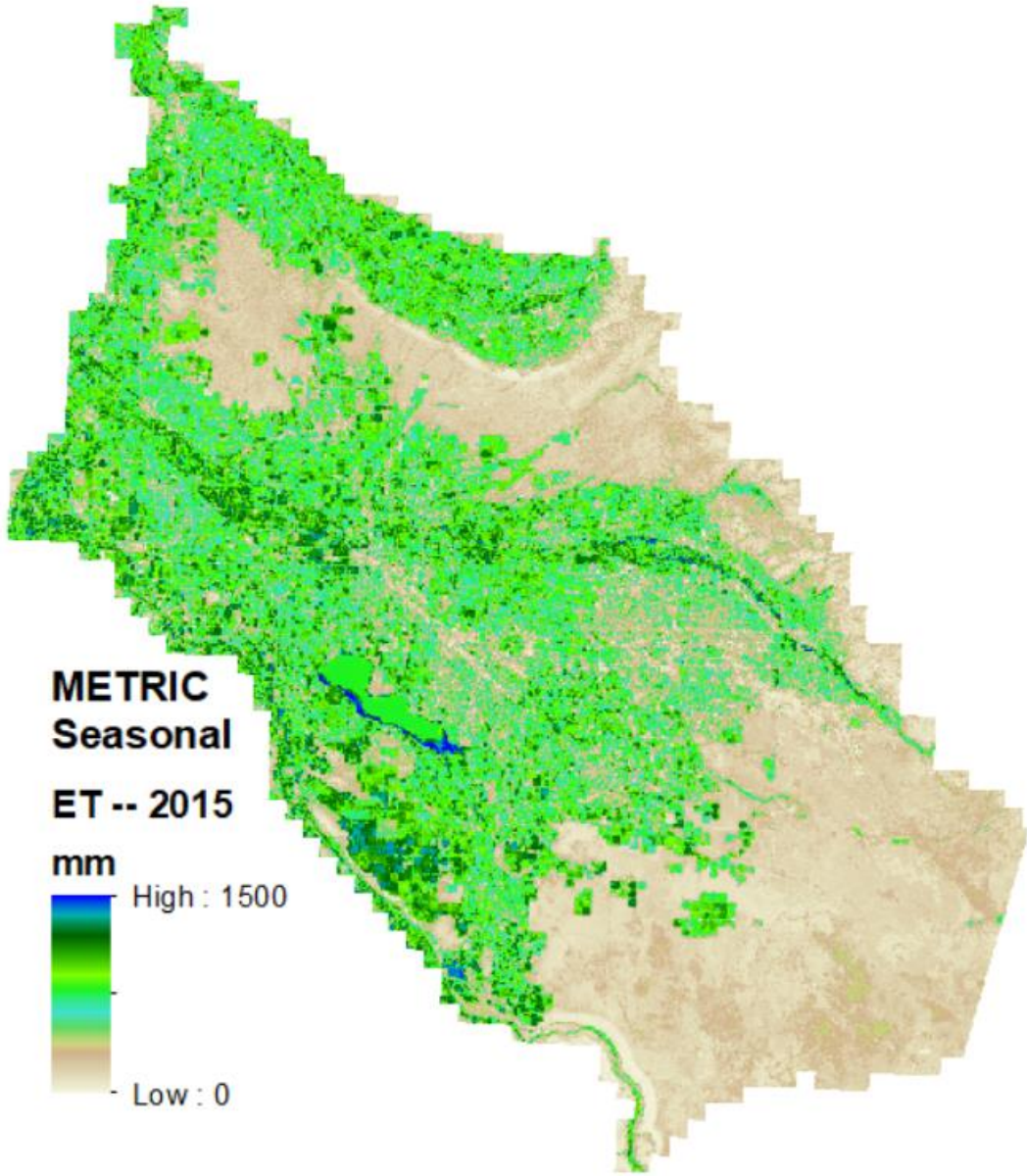

Estimated
Seasonal
2004 -- ET
mm
High : 1500
Low : 0

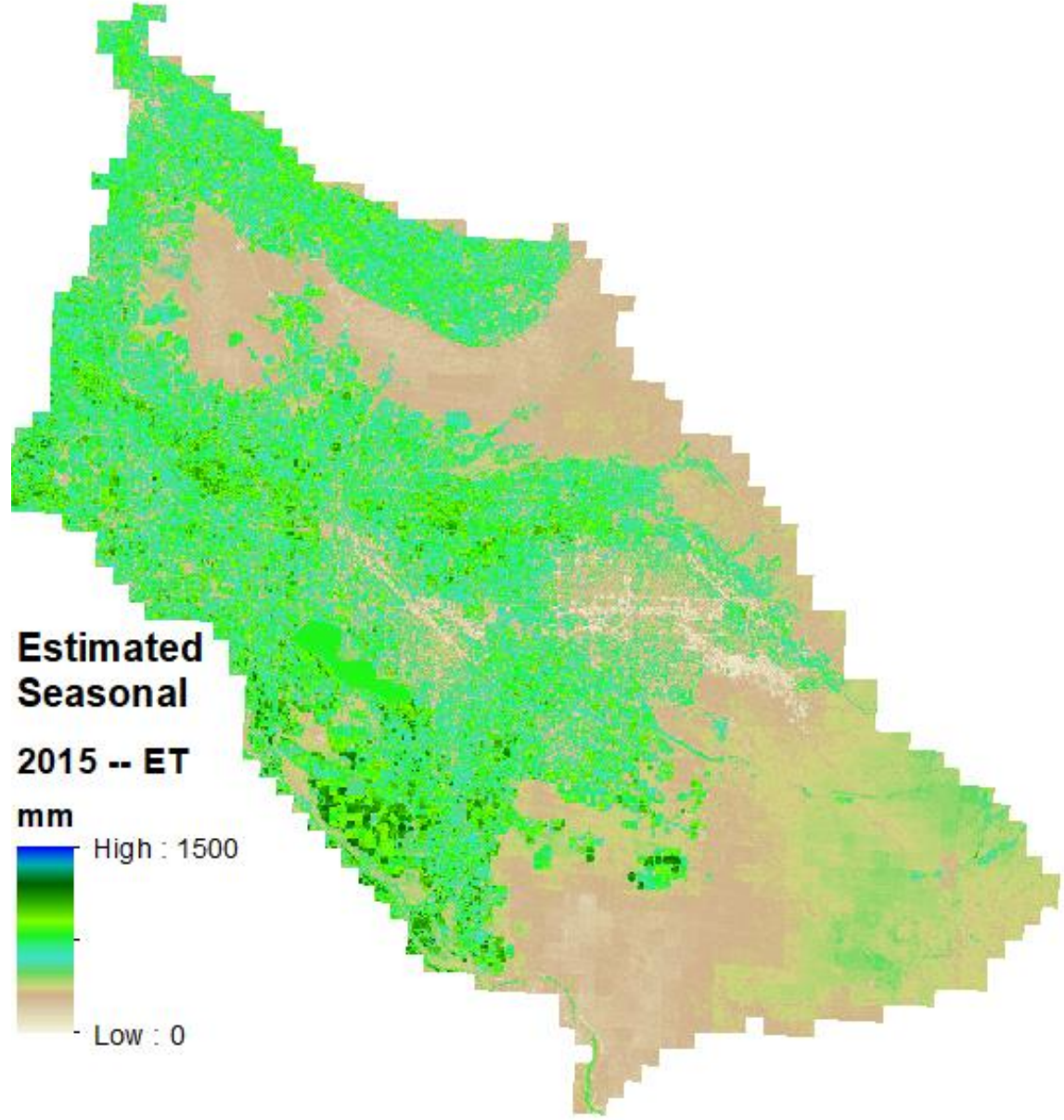

METRIC
Seasonal
ET -- 2007
mm
High : 1500
Low : 0


Estimated
Seasonal
2007 -- ET
mm
High : 1500
Low : 0


METRIC
Seasonal
ET -- 2010
mm
High : 1500
Low : 0


Estimated
Seasonal
2010 -- ET
mm
High : 1500
Low : 0

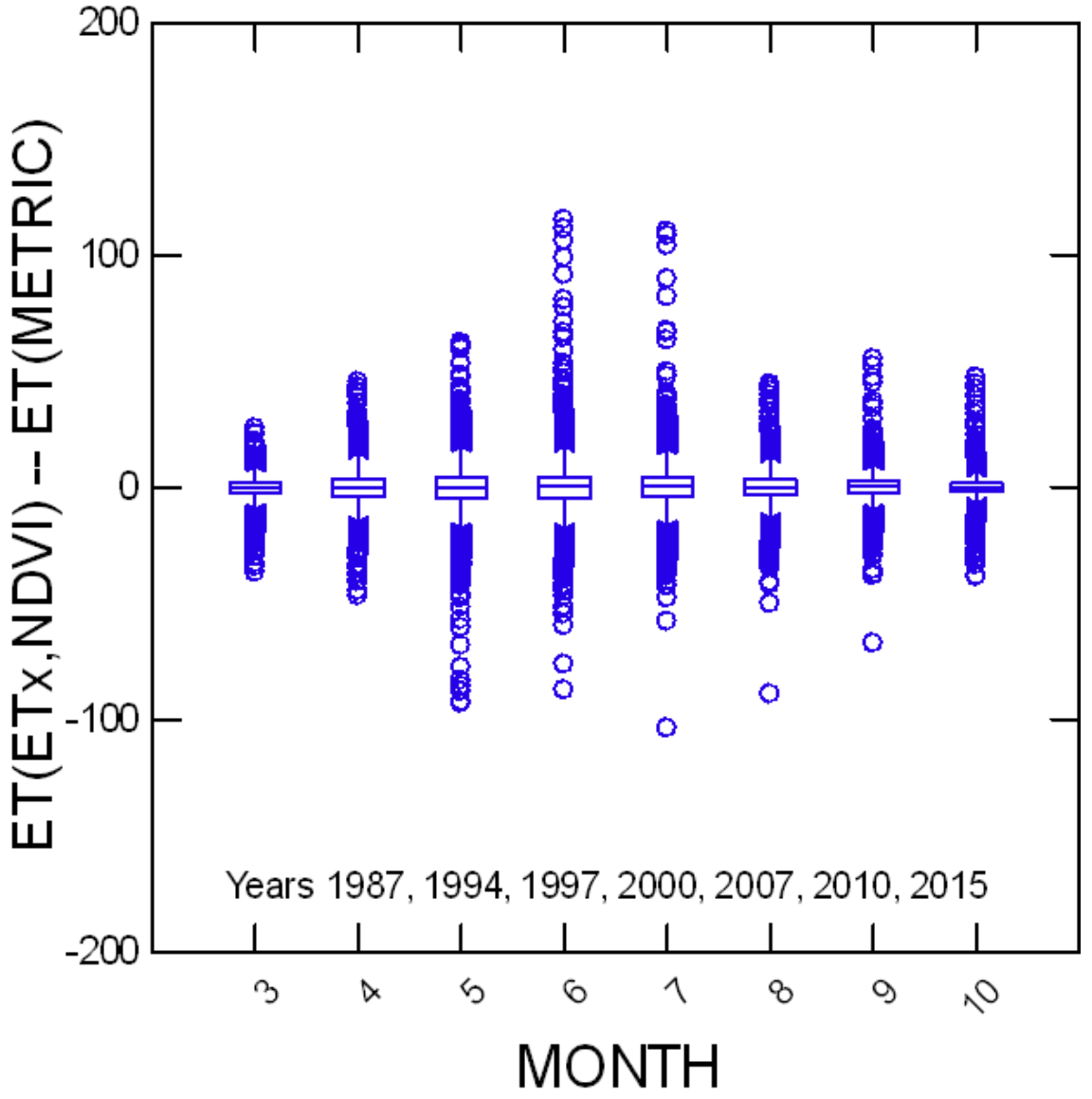

METRIC
Seasonal
ET -- 2015
mm
High : 1500
Low : 0


Estimated
Seasonal
2015 -- ET
mm
High : 1500
Low : 0

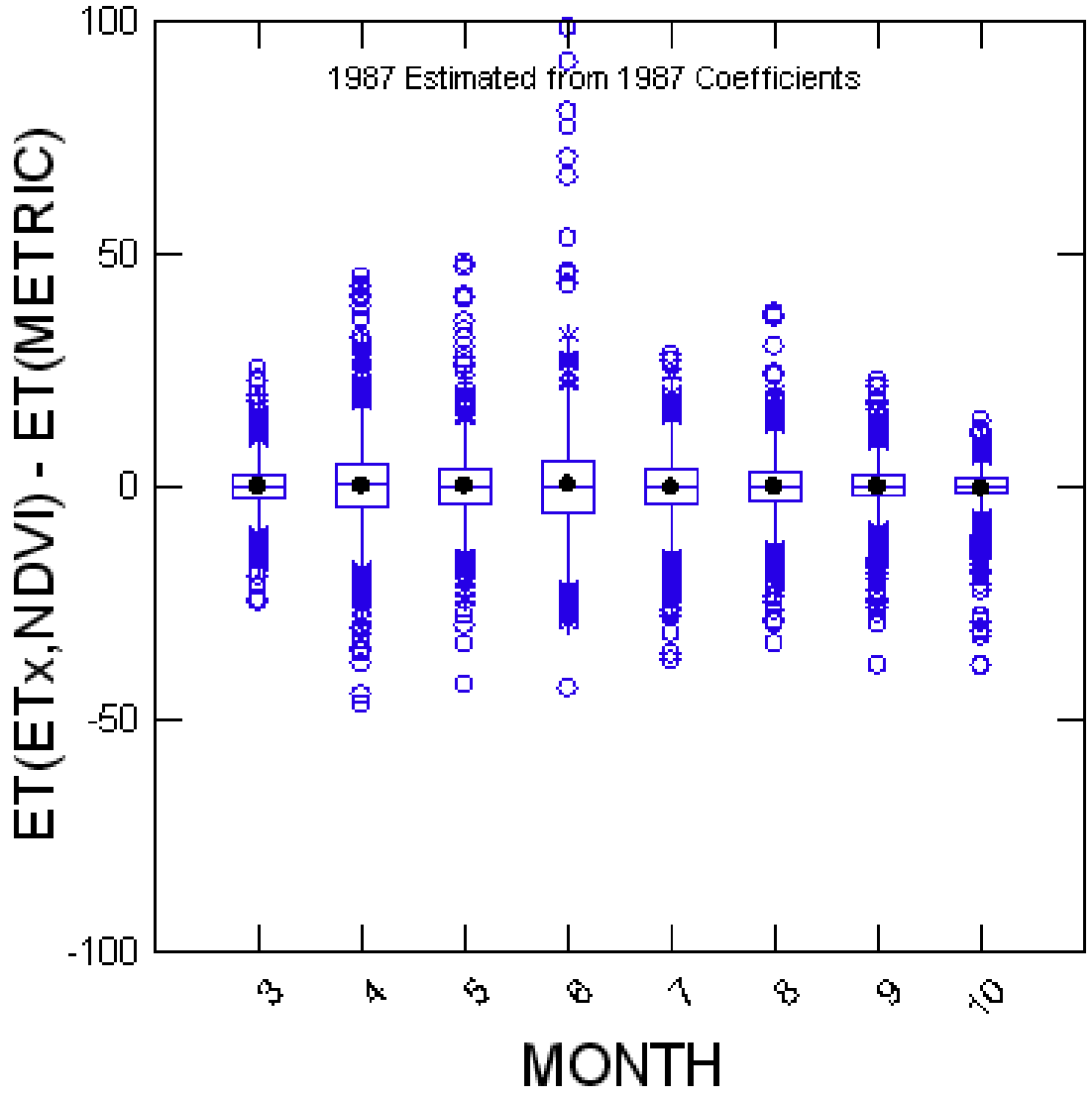
Evaluated Performance based on ground water cells for the model domain and for agricultural pixels.

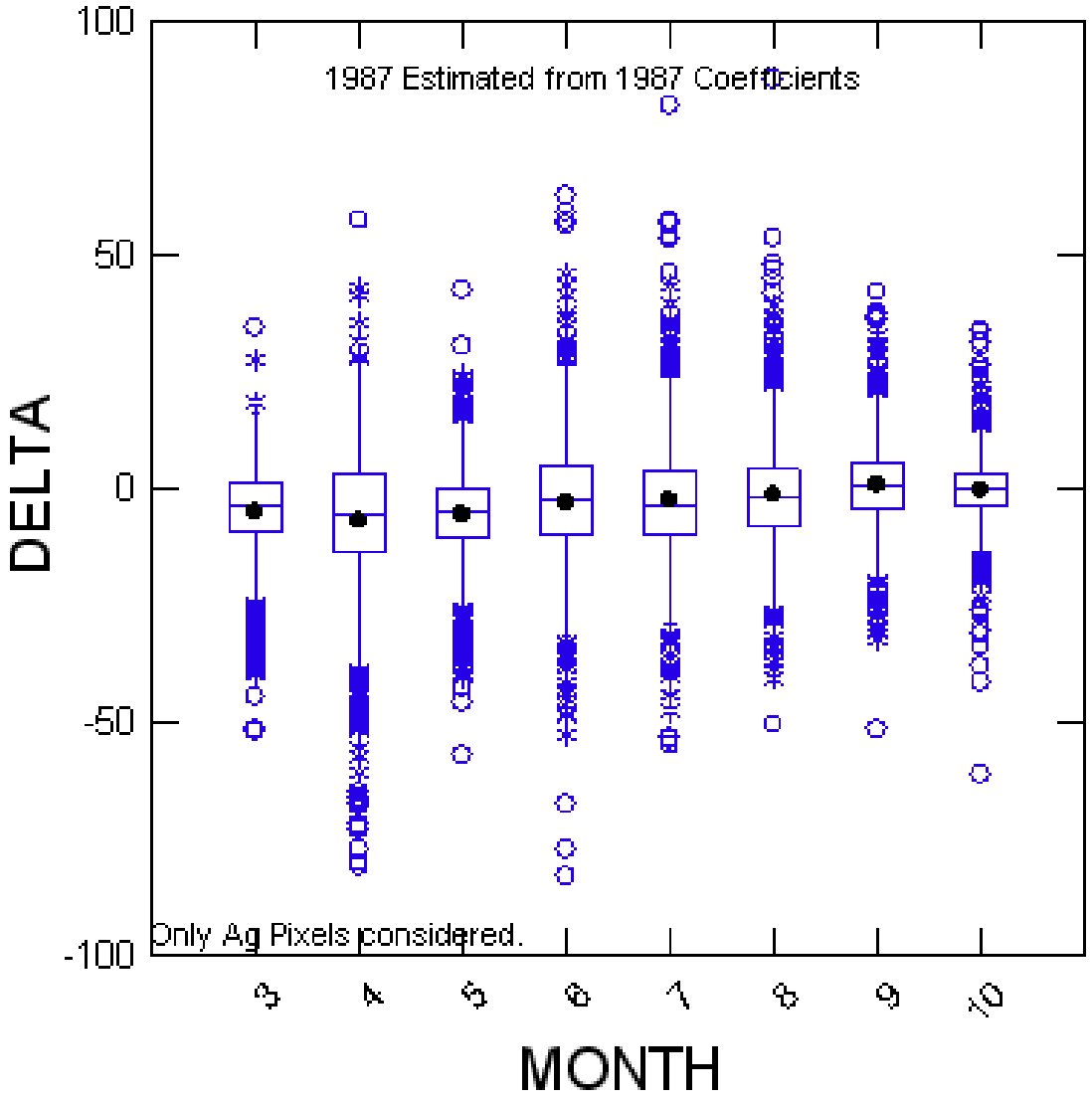
Individual years show more spread.

Units are in mm/month

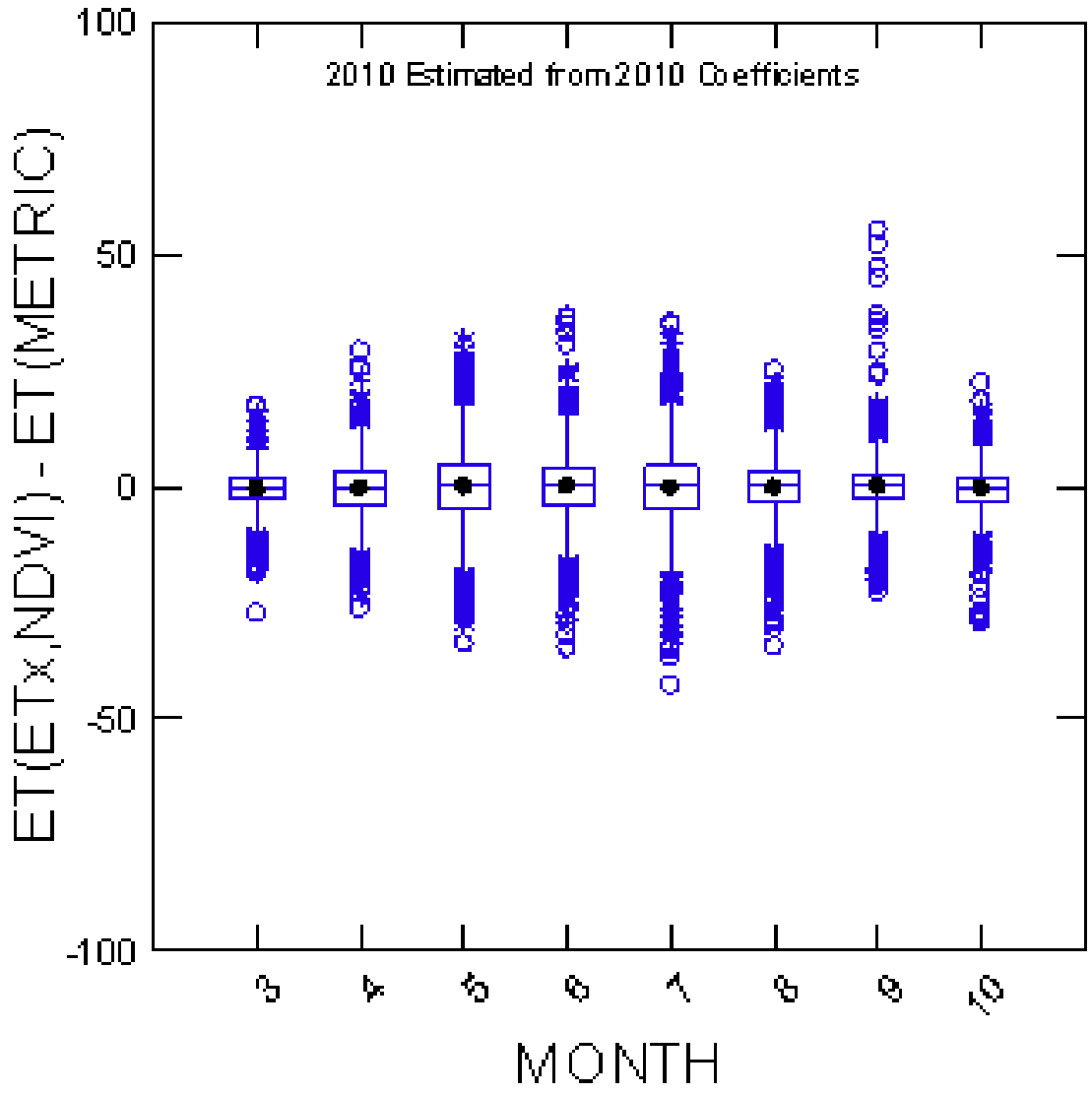


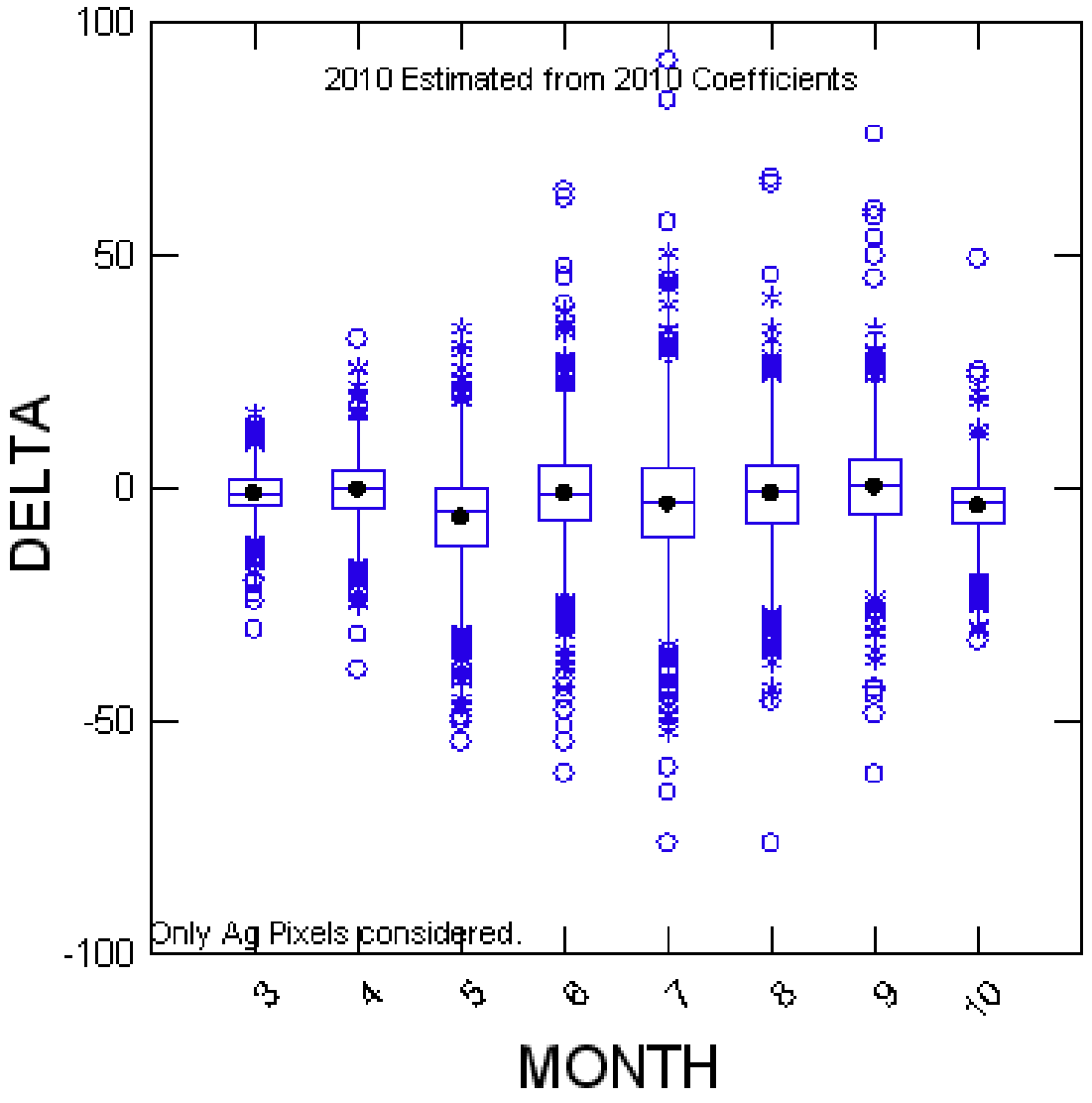
The box plot shows the median, midrange (~interquartile), outer range, and "outliers". Asterisks represent observations that are greater than 1.5*midrange. Circles represent observations that are greater then 3.0*midrange..





1987 (black dot is mean)

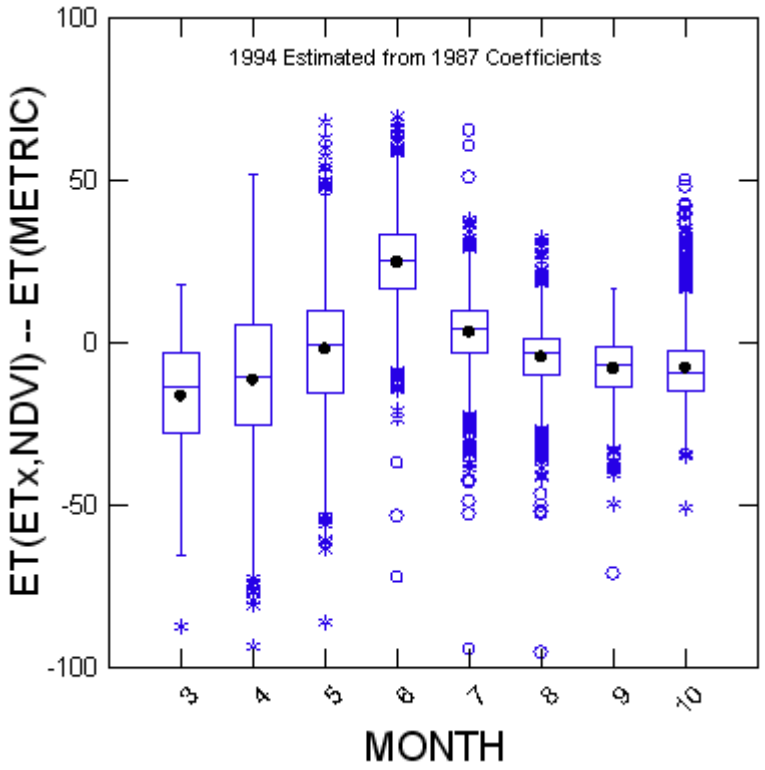


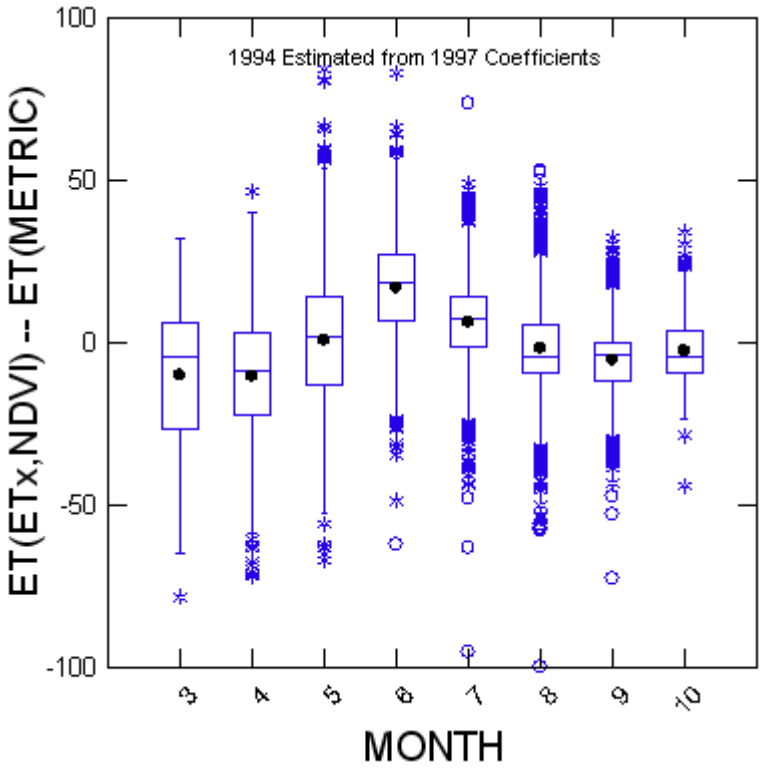


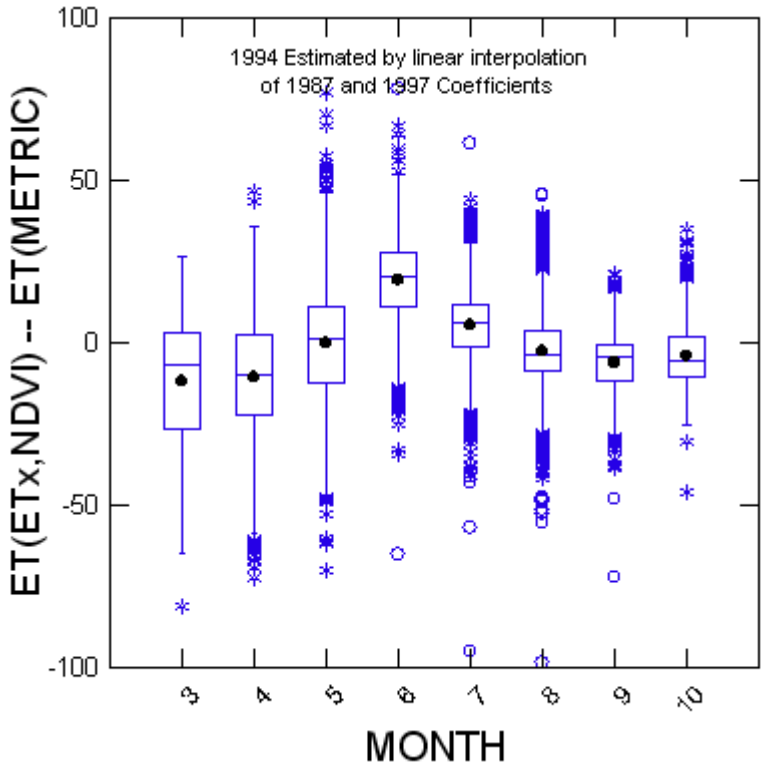
2010 (black dot is mean)

Test for Extrapolation of ET_xF to non-METRIC Years

Uses Nearest other METRIC Year(s) for ET_xF coefficients.

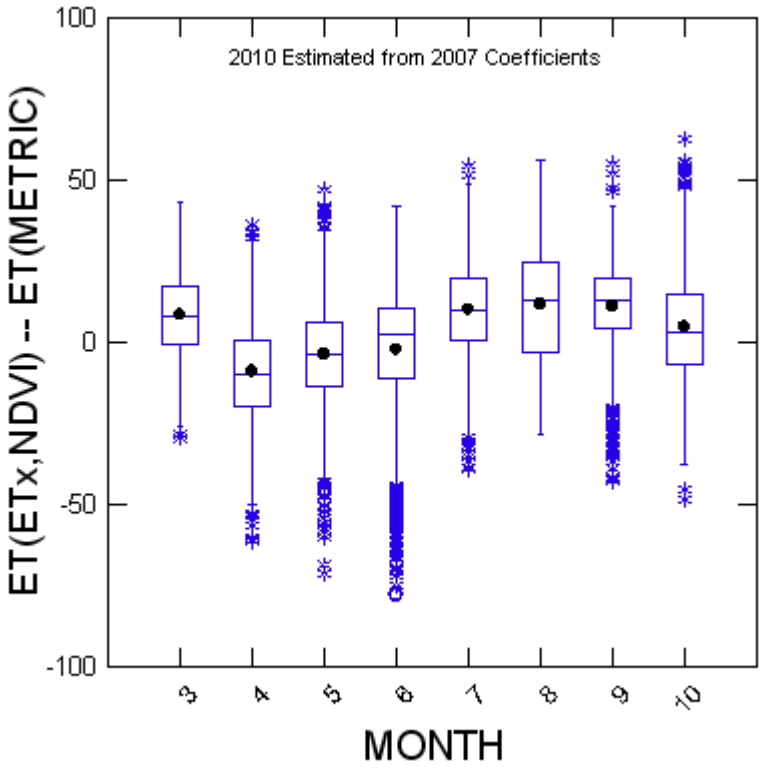


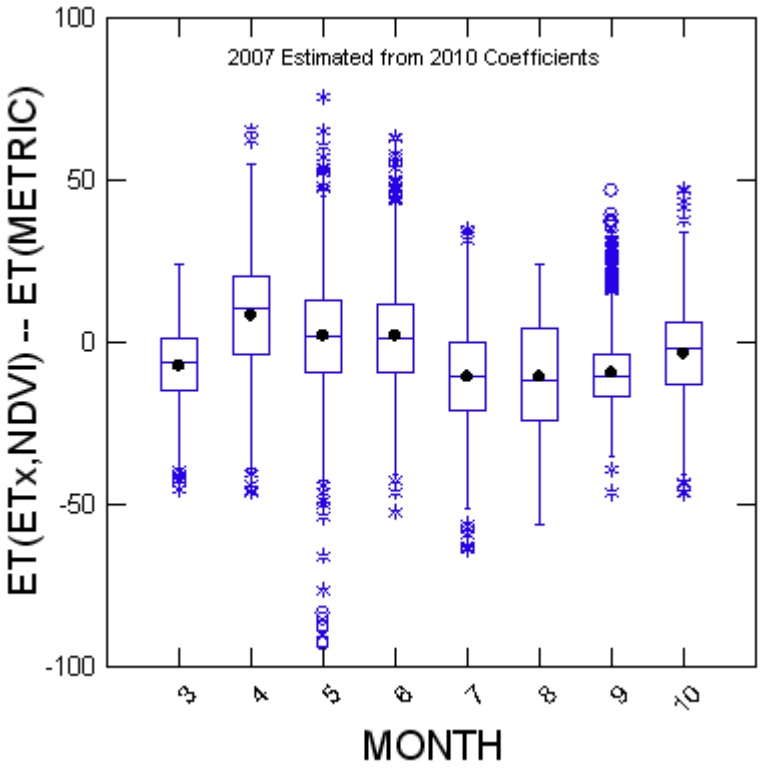


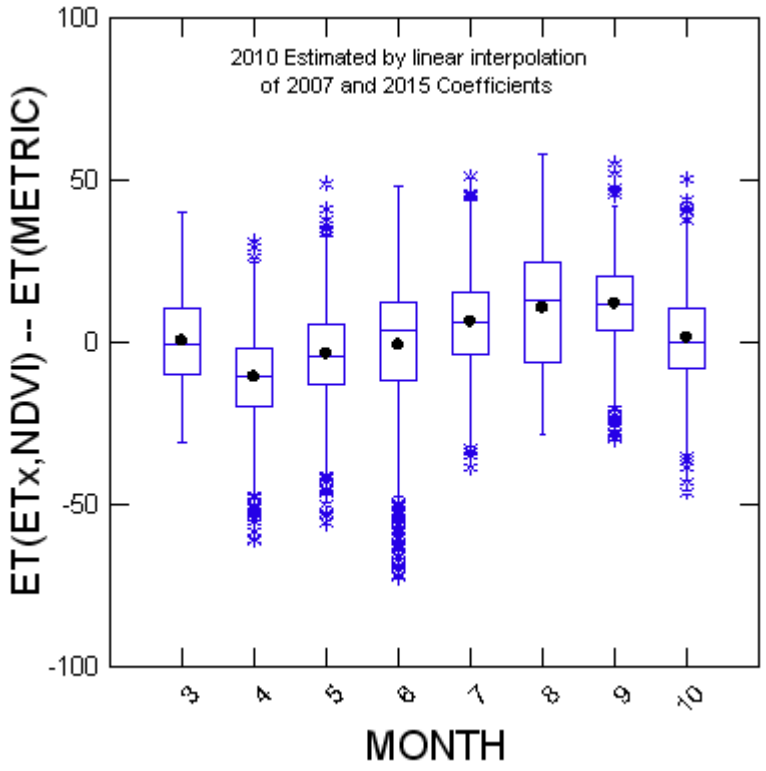


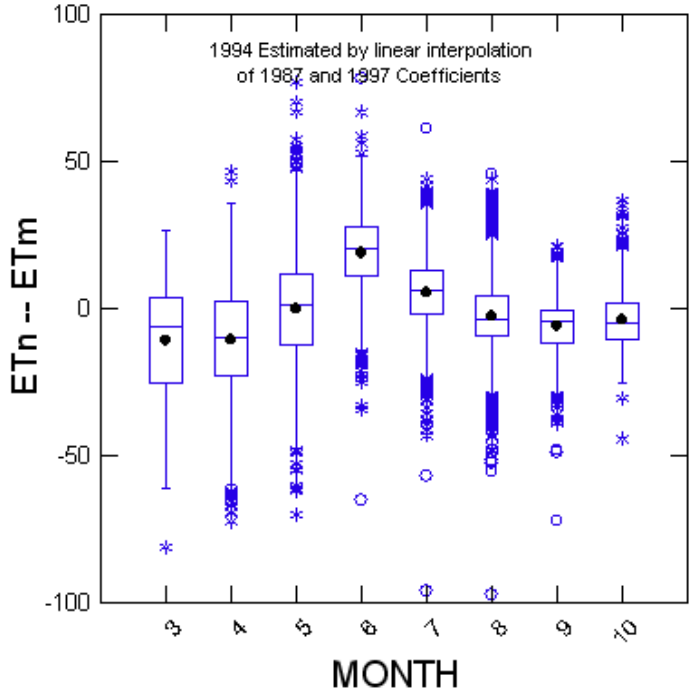
Test for Extrapolation of ET_xF to non-METRIC Years

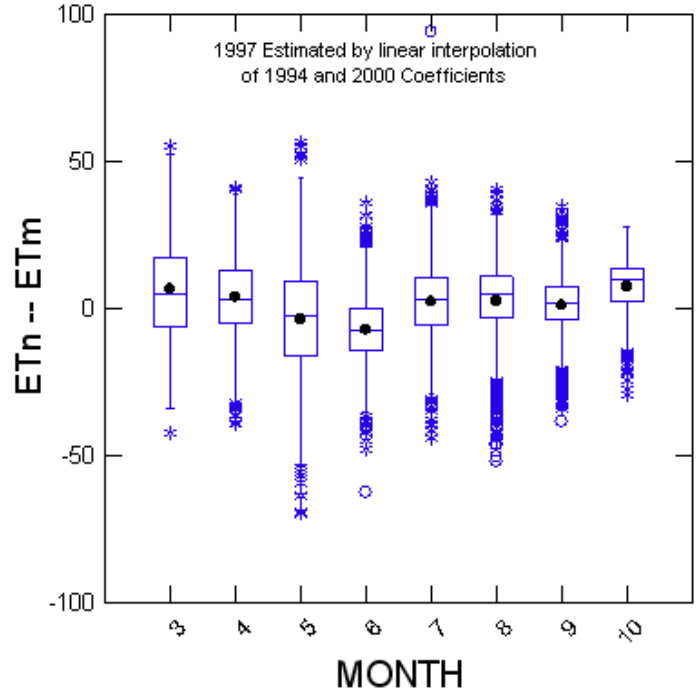
Uses Nearest other METRIC Year(s) for ET_xF coefficients.

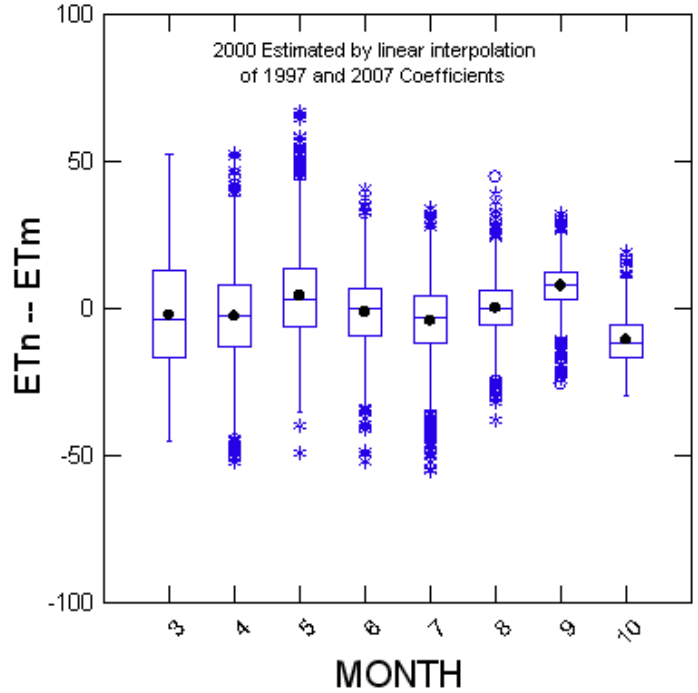


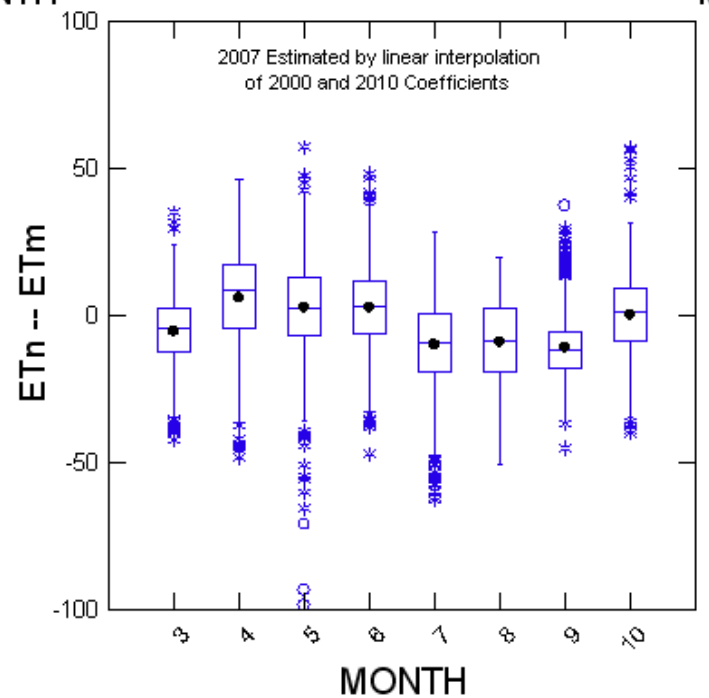


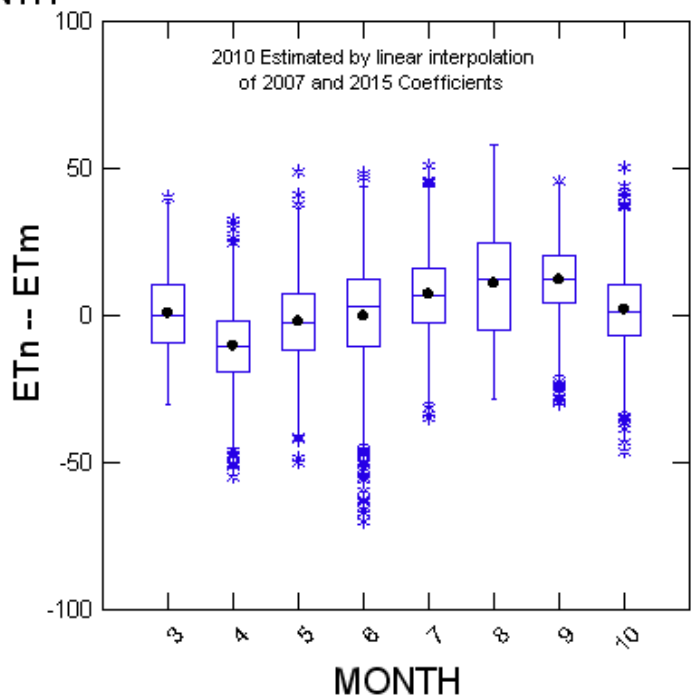








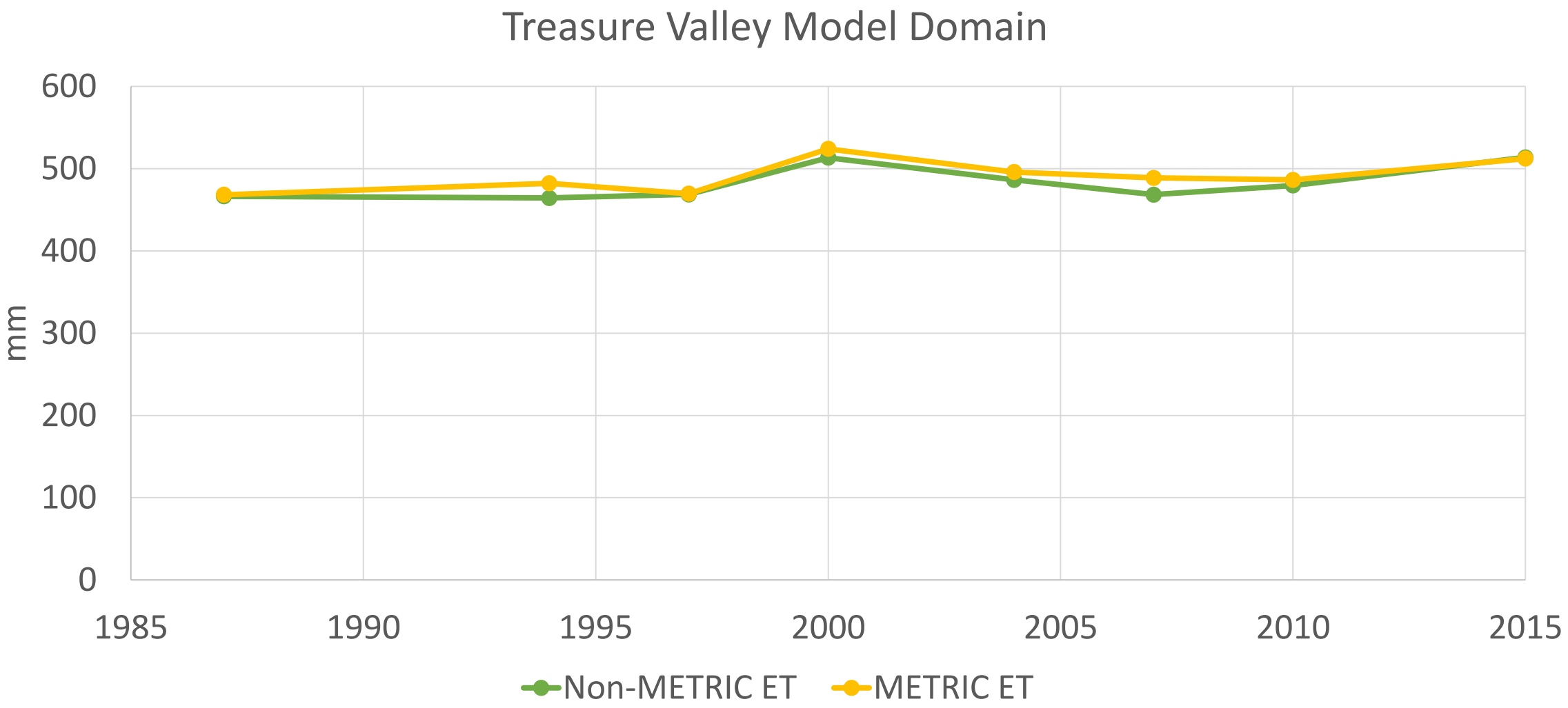




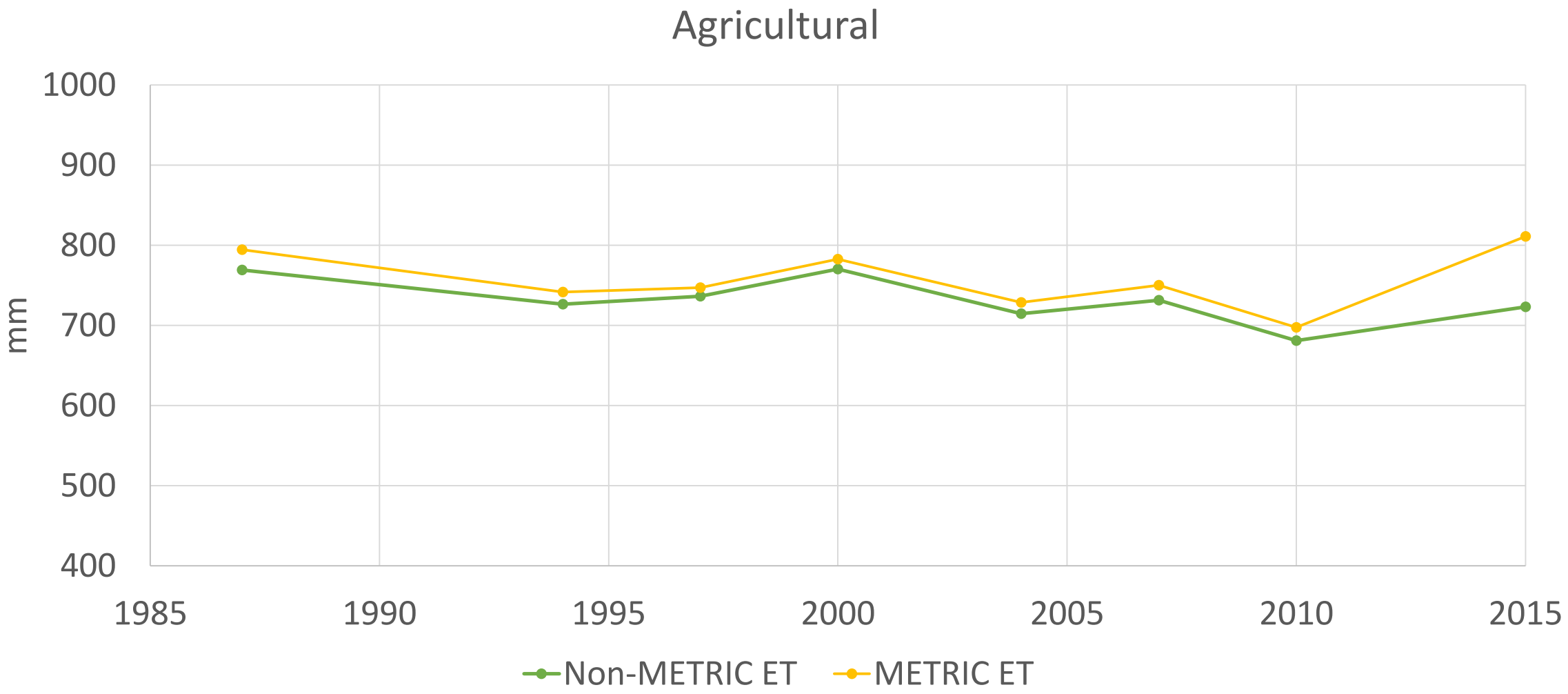
More independent because the METRIC year estimated ET is based on other METRIC years.

Monthly differences are different between years.

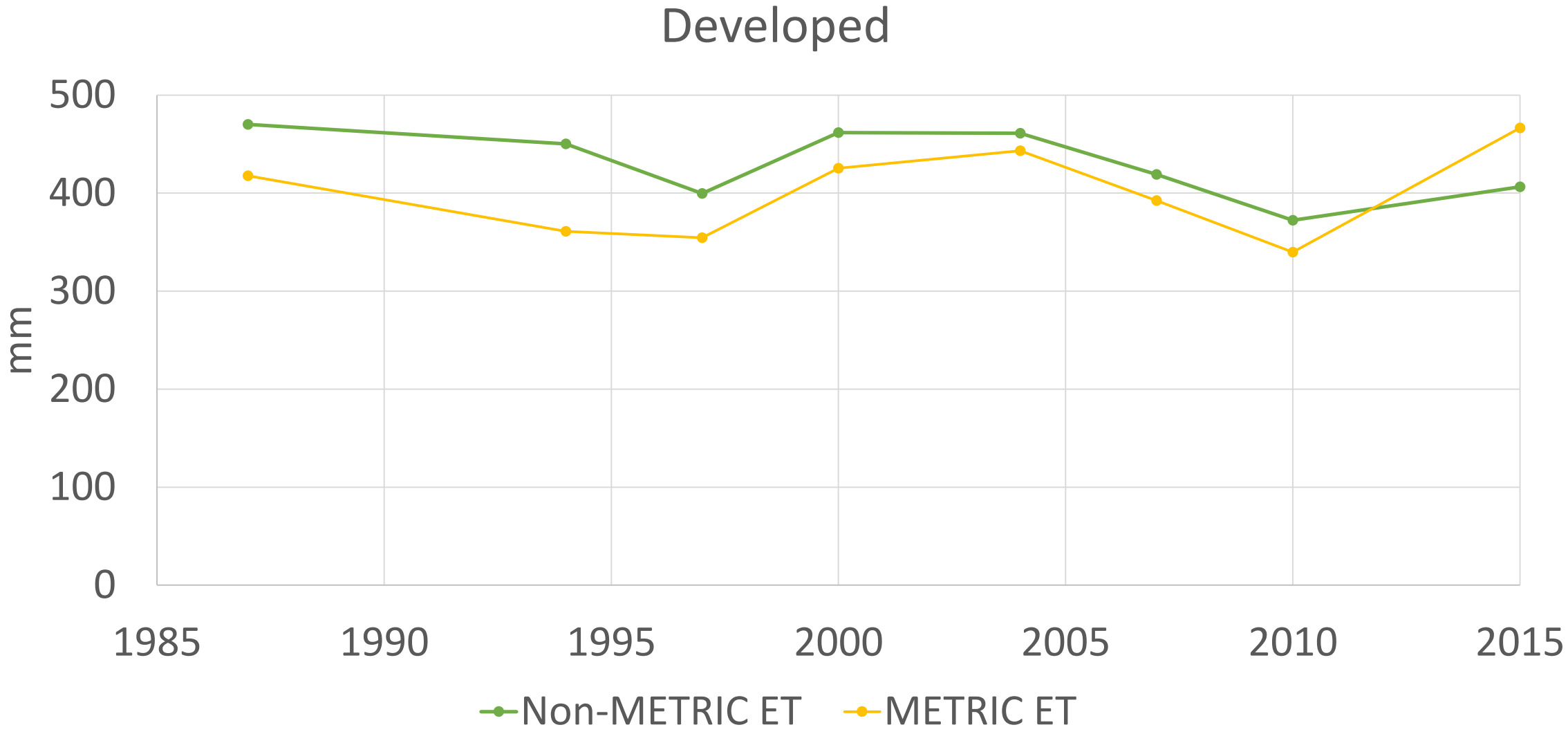
Seasonal ET


Treasure Valley Model Domain
600
500
400
300
200
100
0
mm
1985
1990
1995
2000
2005
2010
2015
Non-METRIC ET
METRIC ET

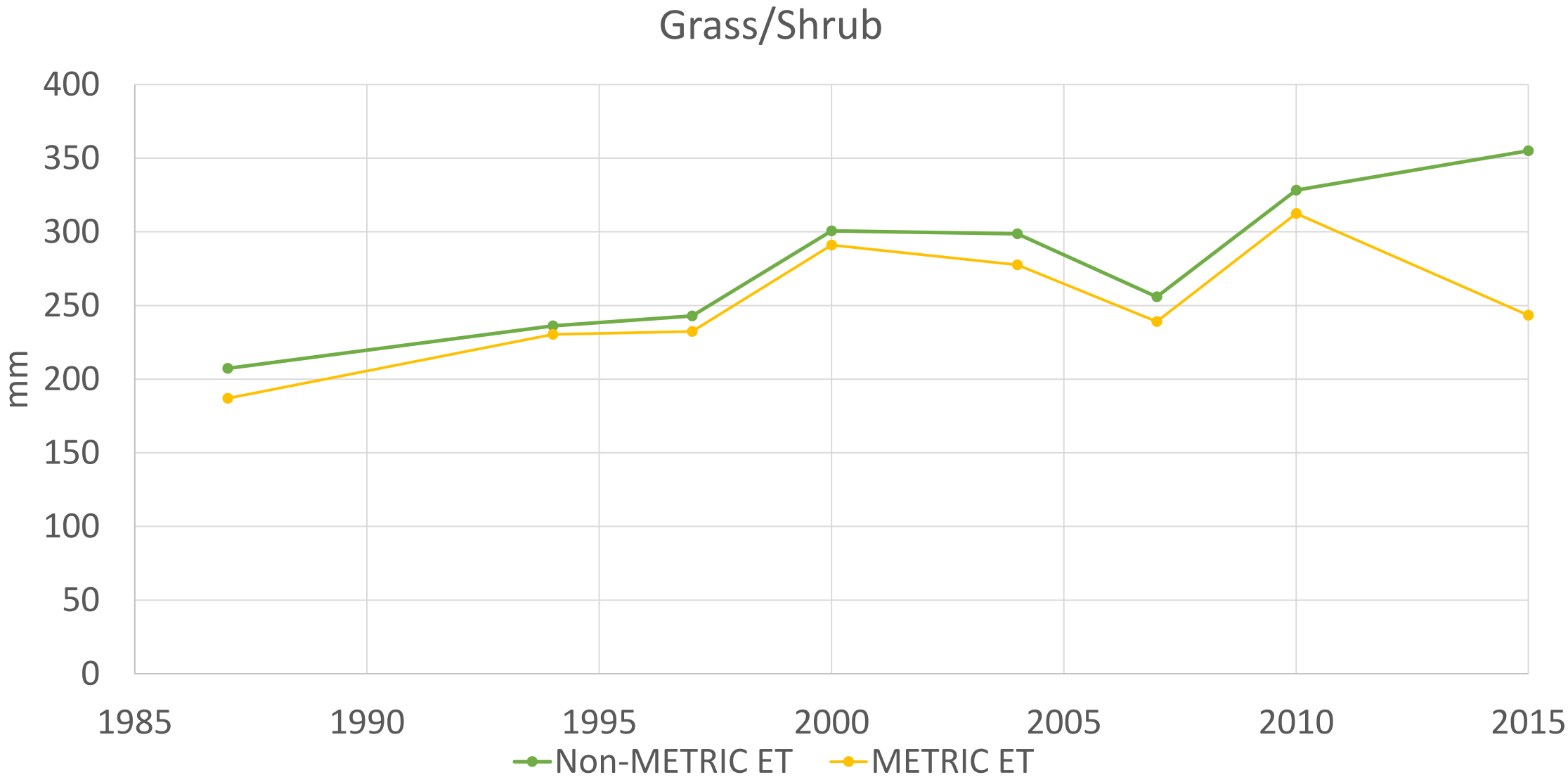
Seasonal ET


Agricultural
1000
900
800
700
600
500
400
mm
1985
1990
1995
2000
2005
2010
2015
Non-METRIC ET
METRIC ET

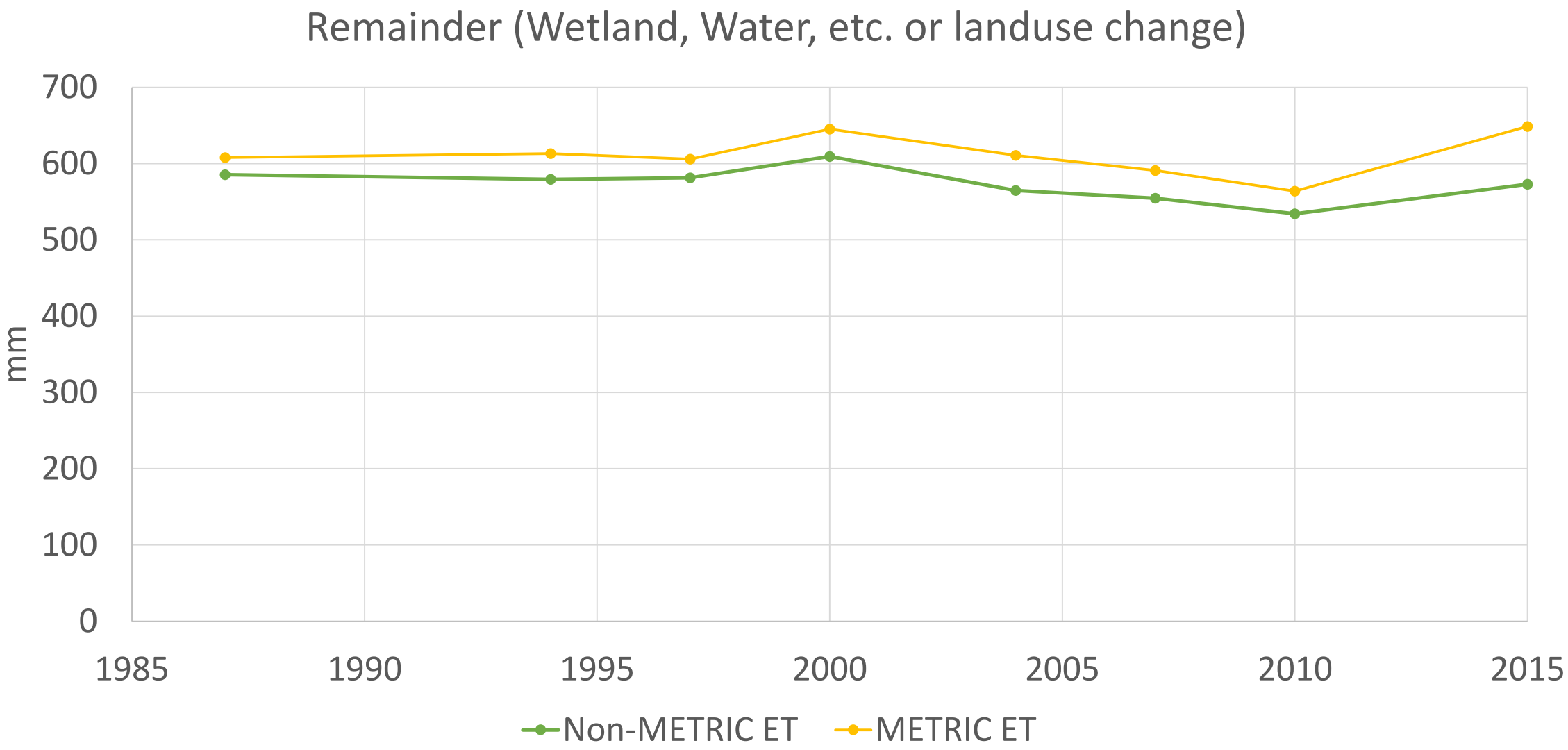
Seasonal ET


Developed
500
400
300
200
100
0
mm
1985
1990
1995
2000
2005
2010
2015
Non-METRIC ET
METRIC ET

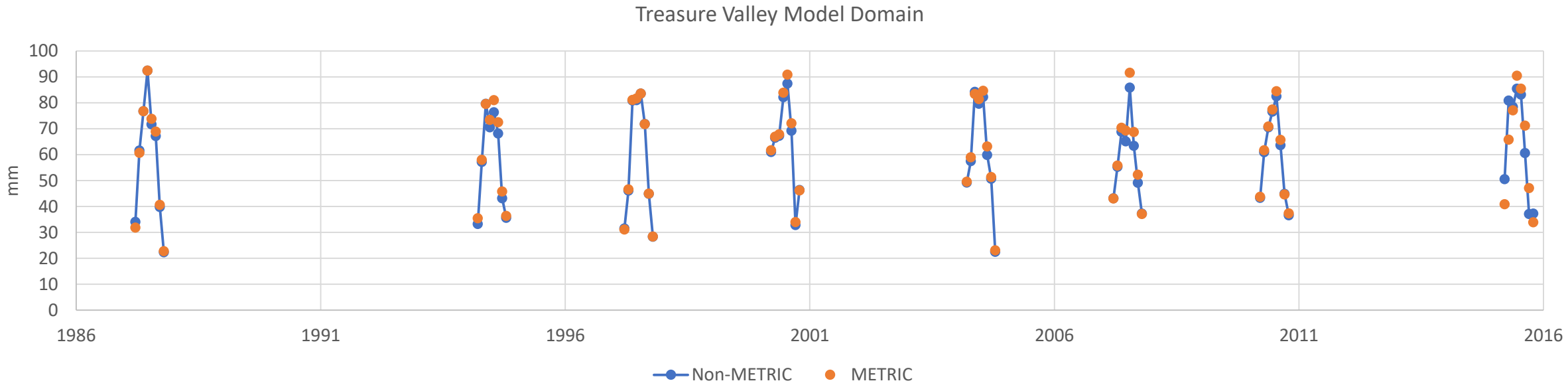
Seasonal ET

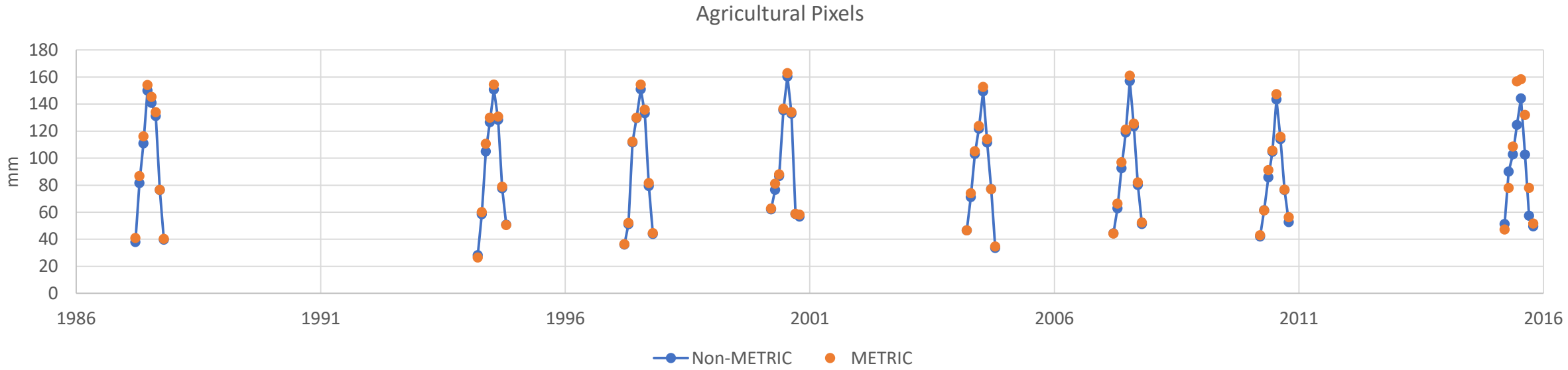

Grass/Shrub
400
350
300
250
200
150
100
50
0
mm
1985
1990
1995
2000
2005
2010
2015
Non-METRIC ET
METRIC ET

Seasonal ET

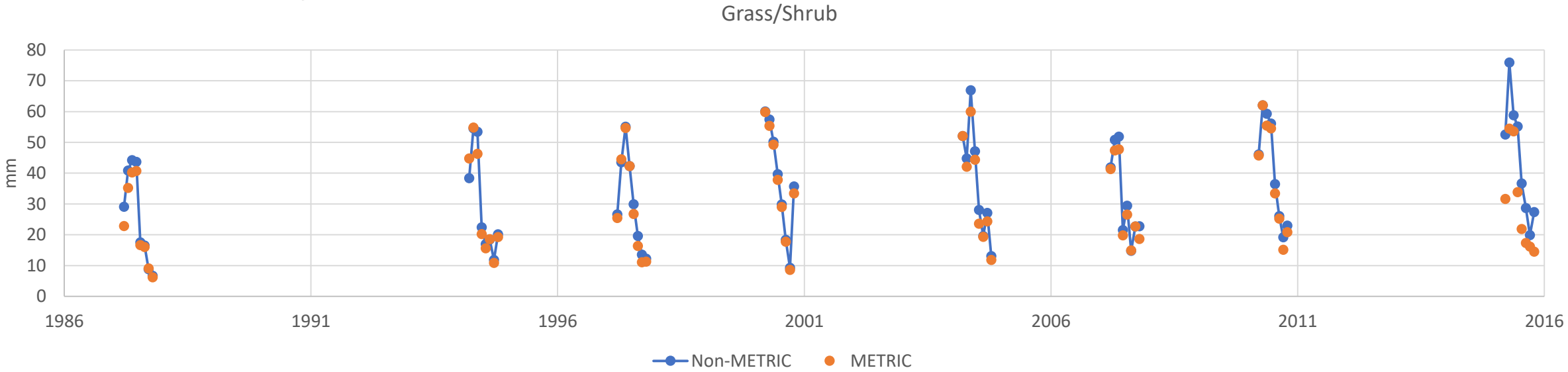

Remainder (Wetland, Water, etc. or landuse change)
700
600
500
400
300
200
100
0
mm
1985
1990
1995
2000
2005
2010
2015
Non-METRIC ET
METRIC ET

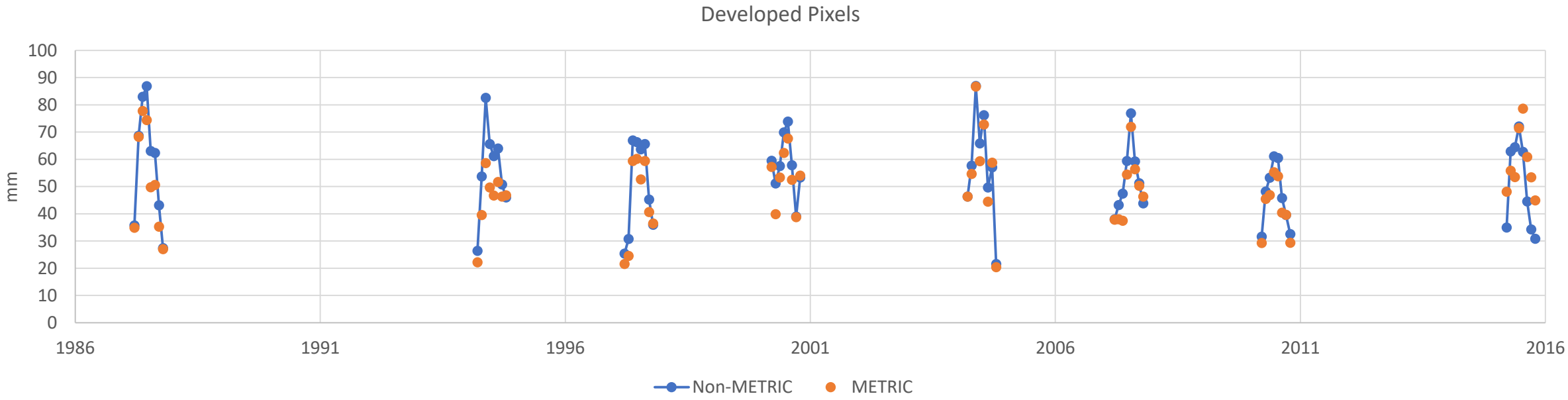
Monthly ET


Treasure Valley Model Domain
mm
100
90
80
70
60
50
40
30
20
10
0
1986
1991
1996
2001
2006
2011
2016
Non-METRIC
METRIC

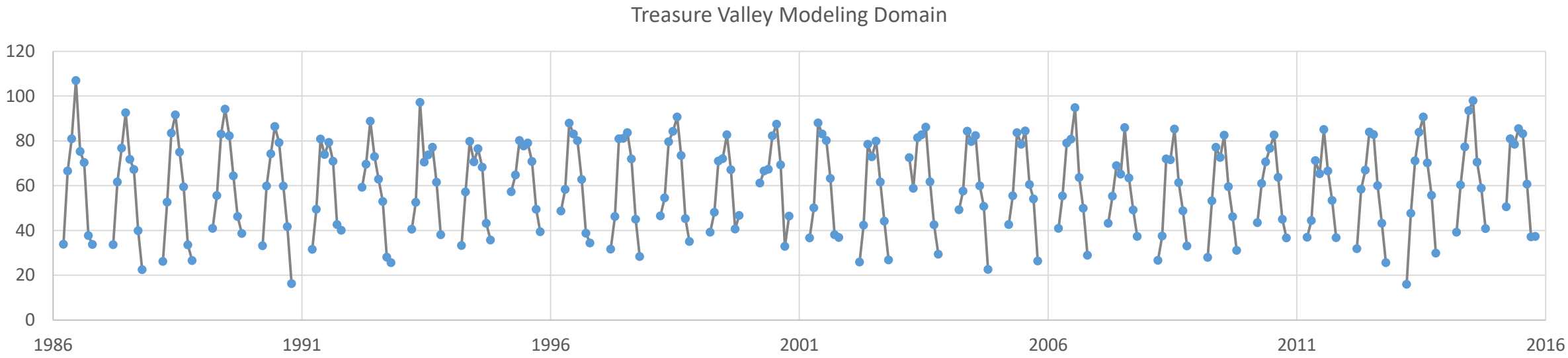

Agricultural Pixels
mm
180
160
140
120
100
80
60
40
20
0
1986
1991
1996
2001
2006
2011
2016
Non-METRIC
METRIC

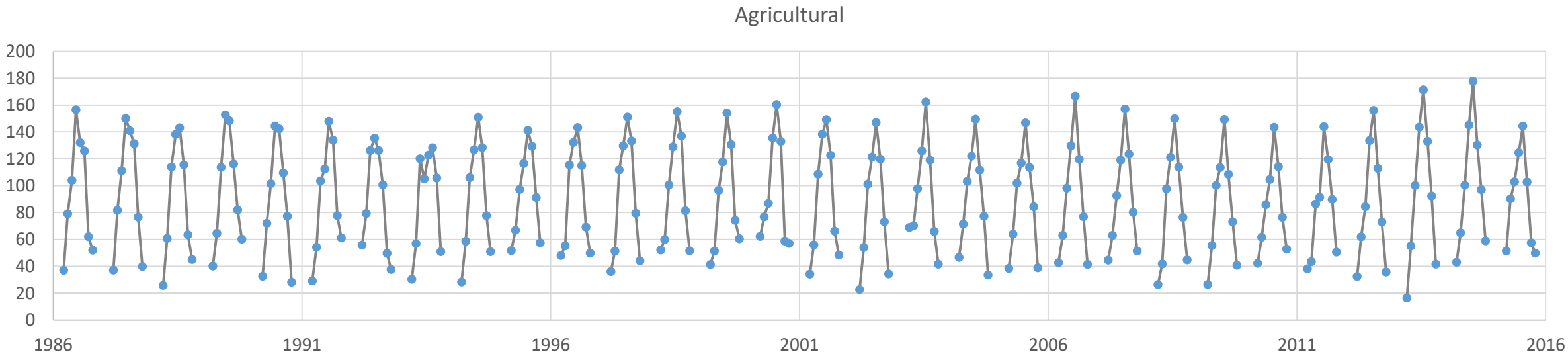
Monthly ET


Grass/Shrub
mm
80
70
60
50
40
30
20
10
0
1986
1991
1996
2001
2006
2011
2016
Non-METRIC
METRIC

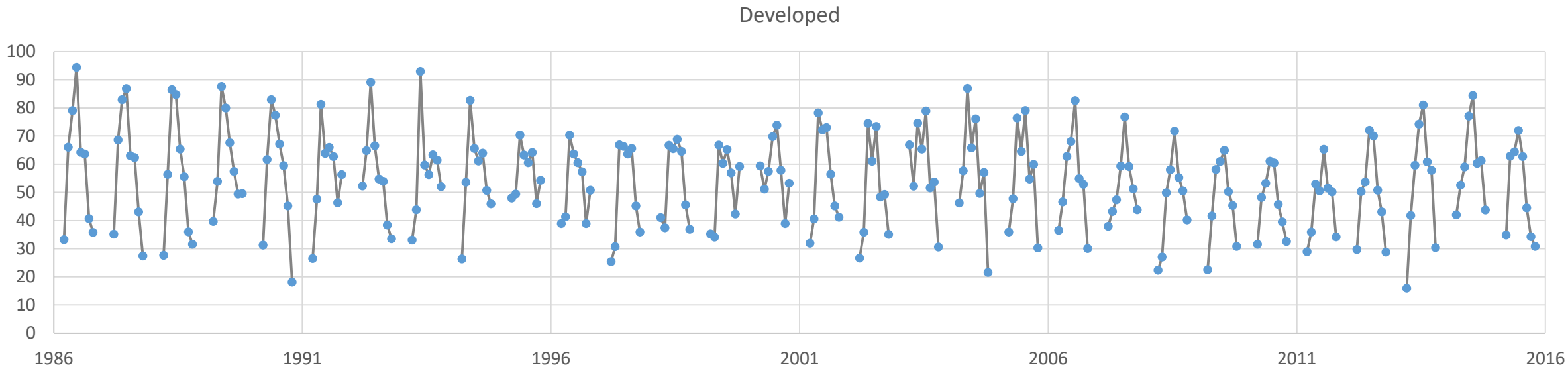

Developed Pixels
mm
100
90
80
70
60
50
40
30
20
10
0
1986
1991
1996
2001
2006
2011
2016
Non-METRIC
METRIC

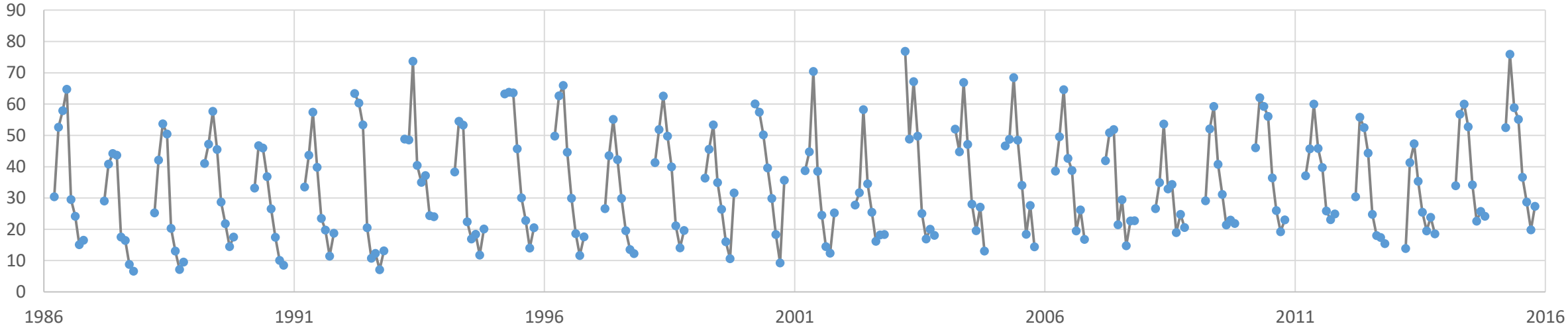
Estimated Monthly ET 1986 -- 2015



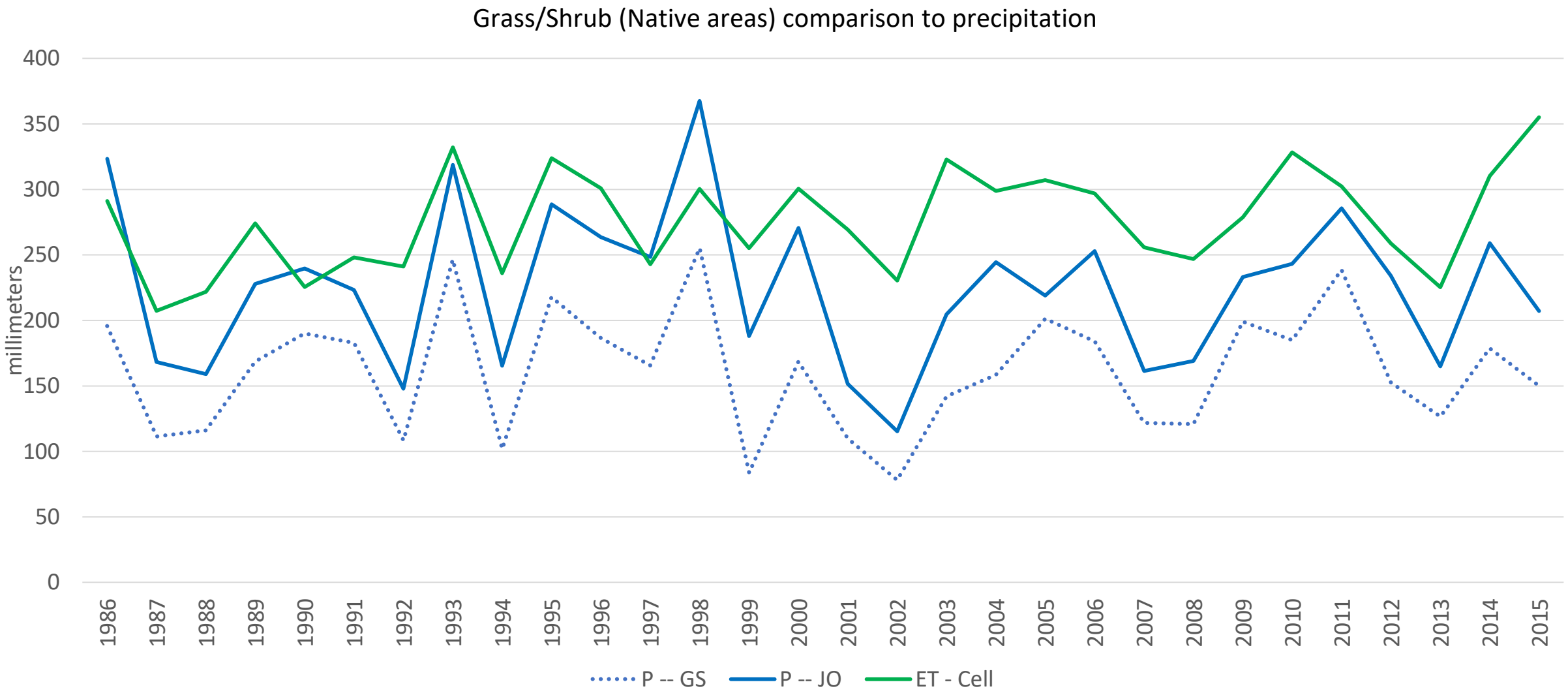


Estimated Monthly ET 1986 -- 2015





Comparison to Precipitation



Method Summary

For each METRIC Year/month:

- Generate ET_xF surfaces — $ET_xF = ET_m/ET_x$
- Determine ET_xF(NDVI) coefficients for cells — $ET_xF = a + b*NDVI$
- Generate surfaces of ”a” and “b”

Apply to non-METRIC year/months:

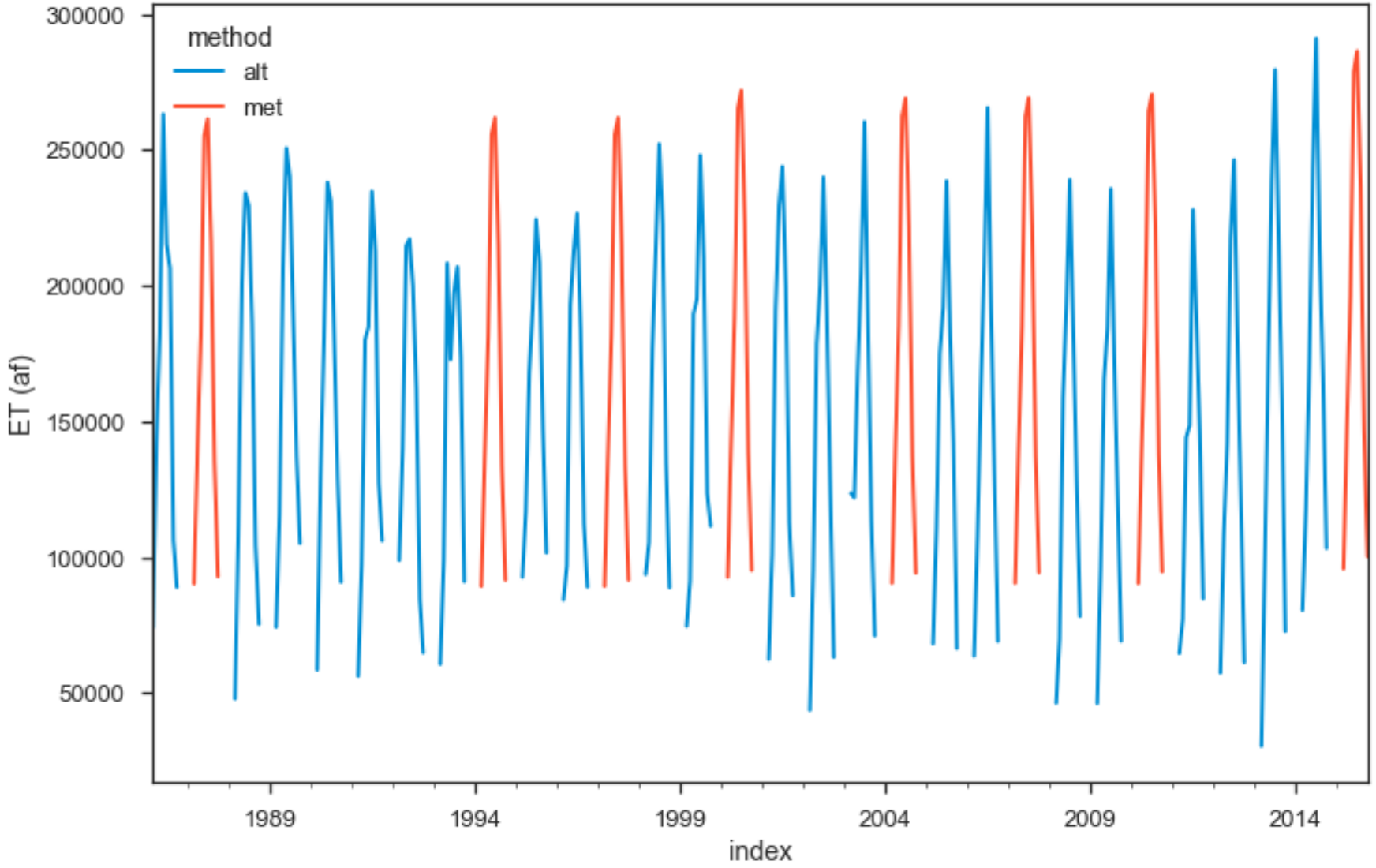
- Interpolate “a” and “b” from nearest METRIC years.
- Calculate ET_xF using interpolated “a” and “b” and NDVI.
- Calculate ET from ET_xF and ET_x — $ET = ET_xF * ET_x$
- Calculate ET_rF — $ET_rF = ET/ET_r$
- Limit ET based on ET_rF range 0.01 -- 1.1
  - If $ET_rF < 0.01$ then $ET = 0.01 * ET_r$
  - If $ET_rF > 1.10$ then $ET = 1.10 * ET_r$

Overall Performance -- ET_xF(NDVI) ET to METRIC

- Monthly differences change from year to year based on interpolation from the METRIC based ET_xF regression.
- For the Treasure Valley modeling domain the ET_xF(NDVI) based season ET is 1% lower than METRIC and ranges between 95 to 103% of METRIC on a monthly basis
- For agricultural pixels, the ET_xF(NDVI) based ET is lower than METRIC by 3% on a seasonal basis and ranges between 96 to 101% of METRIC on a monthly basis.
- For developed pixels, the ET_xF(NDVI) based ET is 8% higher than METRIC for a season and ranges between 97 to 116% of METRIC on a monthly basis.
- For native (grass/shrub) the ET_xF(NDVI) based seasonal ET is 13% higher than METRIC and ranges between 108 to 120% of METRIC on a monthly basis.

Comparison based on irrigation status

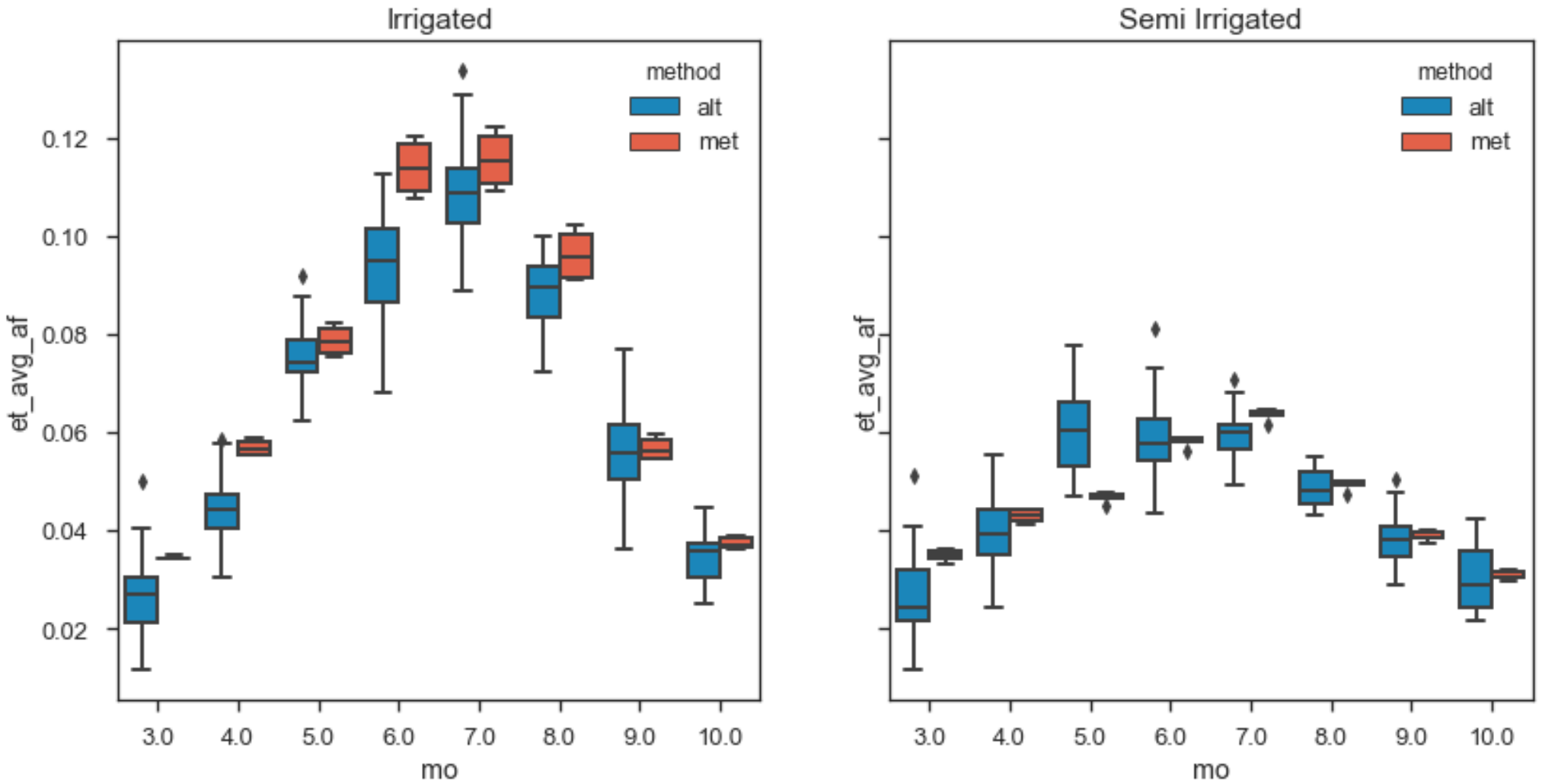
(From Alex Moody, All irrigation statuses: Irrigated and Semi)



Comparison based on irrigation status

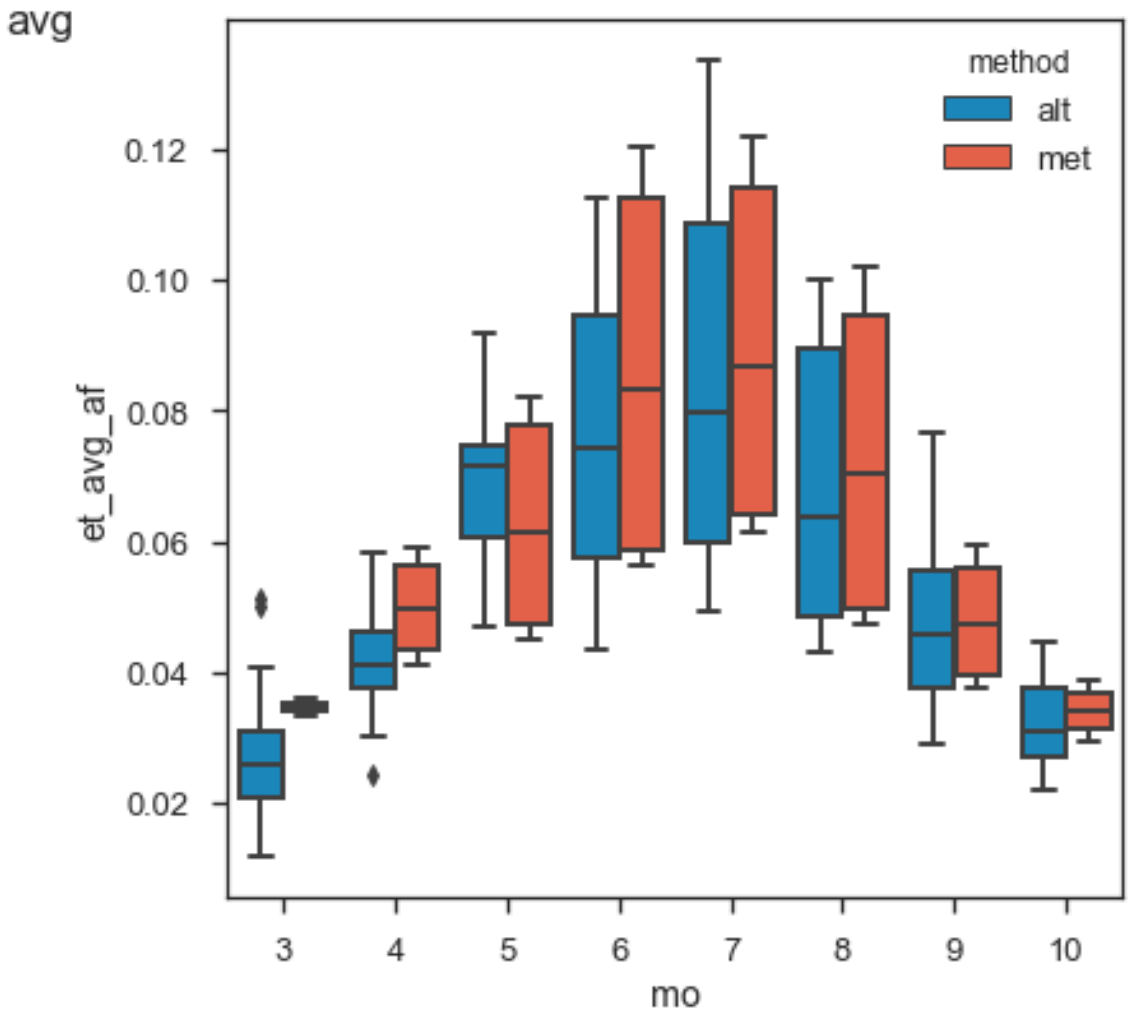
(From Alex Moody, for METRIC years.)

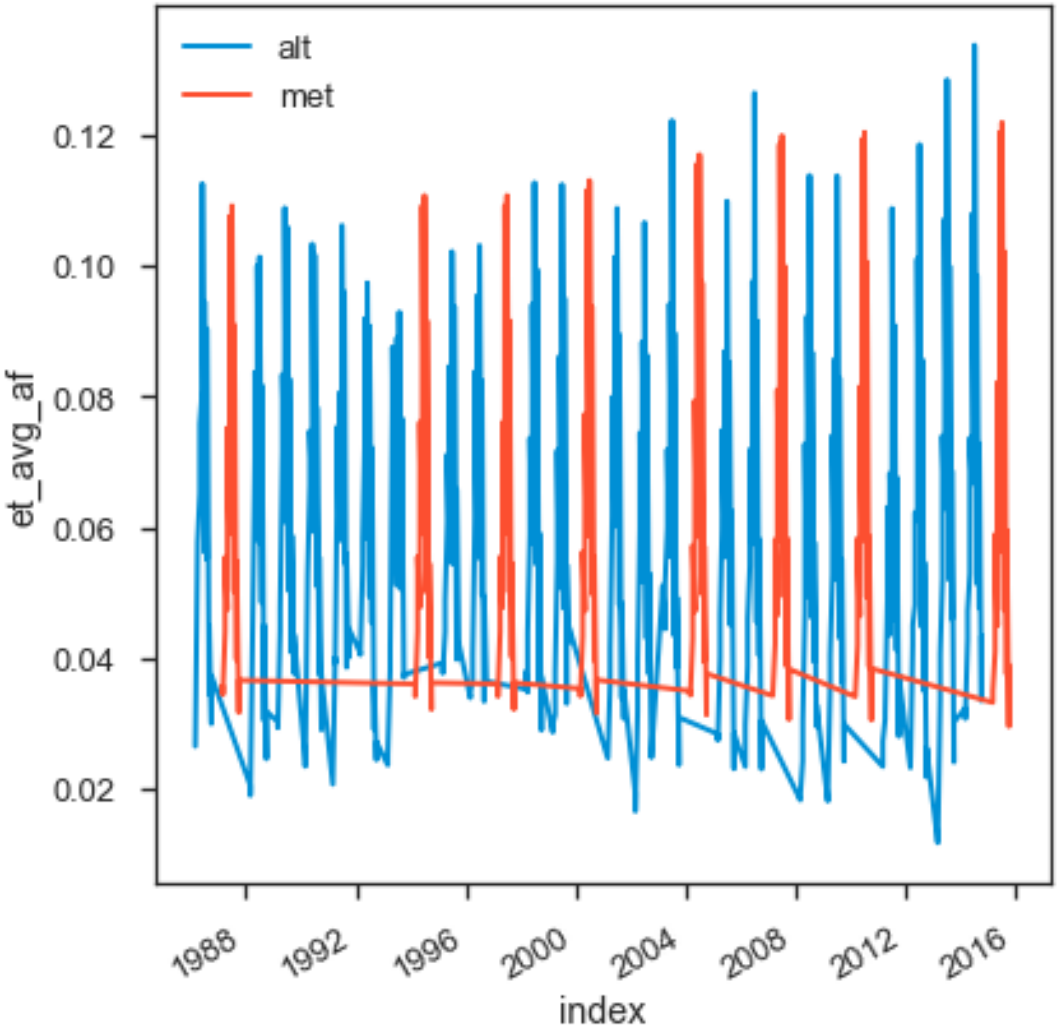
avg



Comparison based on irrigation status

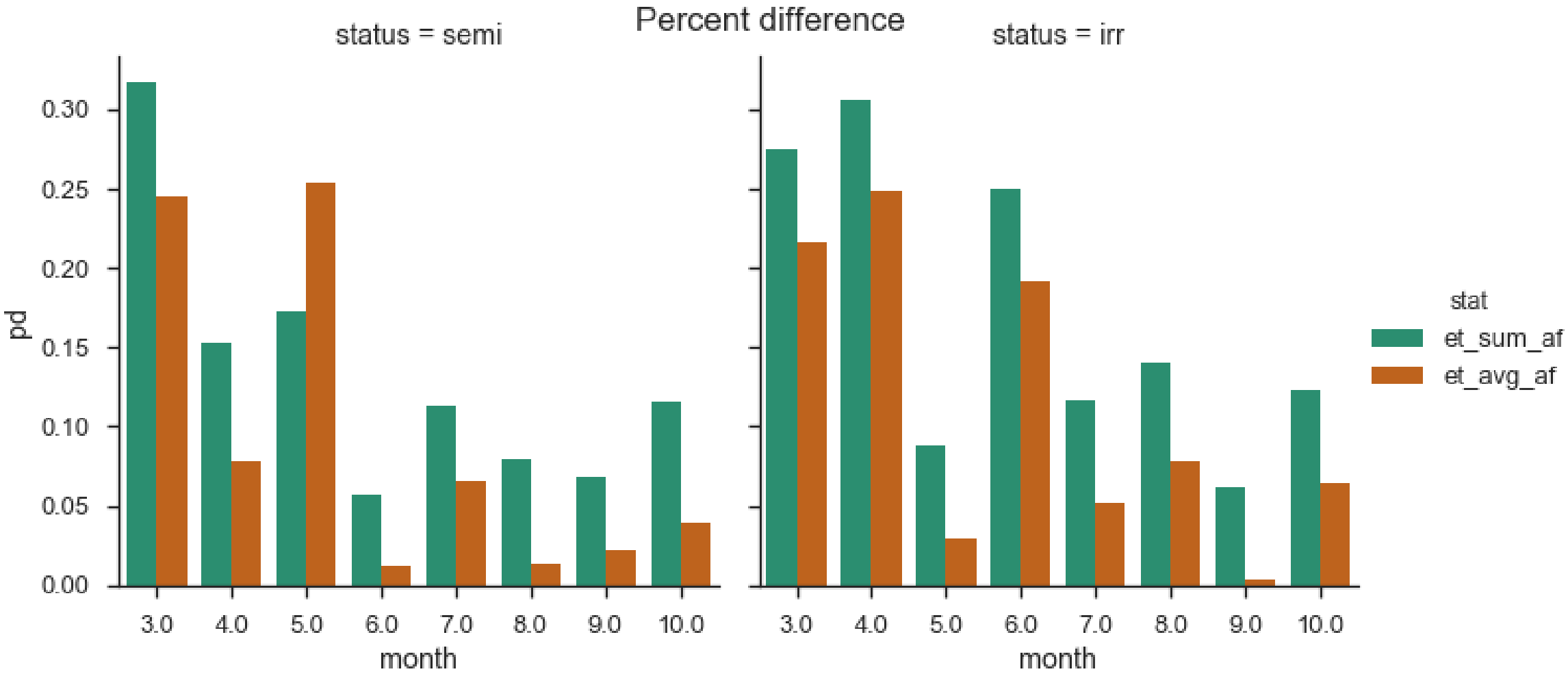
(From Alex Moody)





Comparison based on irrigation status

(From Alex Moody, METRIC years)



Bias Correction may be needed when applied to Irrigated and Semi-Irrigated polygons

- IDWR irrigated land polygons are not pure agricultural pixels.
- Neither are semi irrigated polygons pure developed or grass/shrub.

Thanks for listening
Any Questions?