Evapotranspiration from Natural Vegetation in the Central Valley of California

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Introduction

- Evapotranspiration estimates for natural vegetation are important for:
  - Restoration activities
  - Hydrologic evaluations/modeling
    - Historical water consumption
    - Potential future water consumption
- Concurrent evaluation of pre-developed natural flow out of the Delta
  - Requires ET estimates of vegetation in pre-developed CA (area that flows to the Delta)

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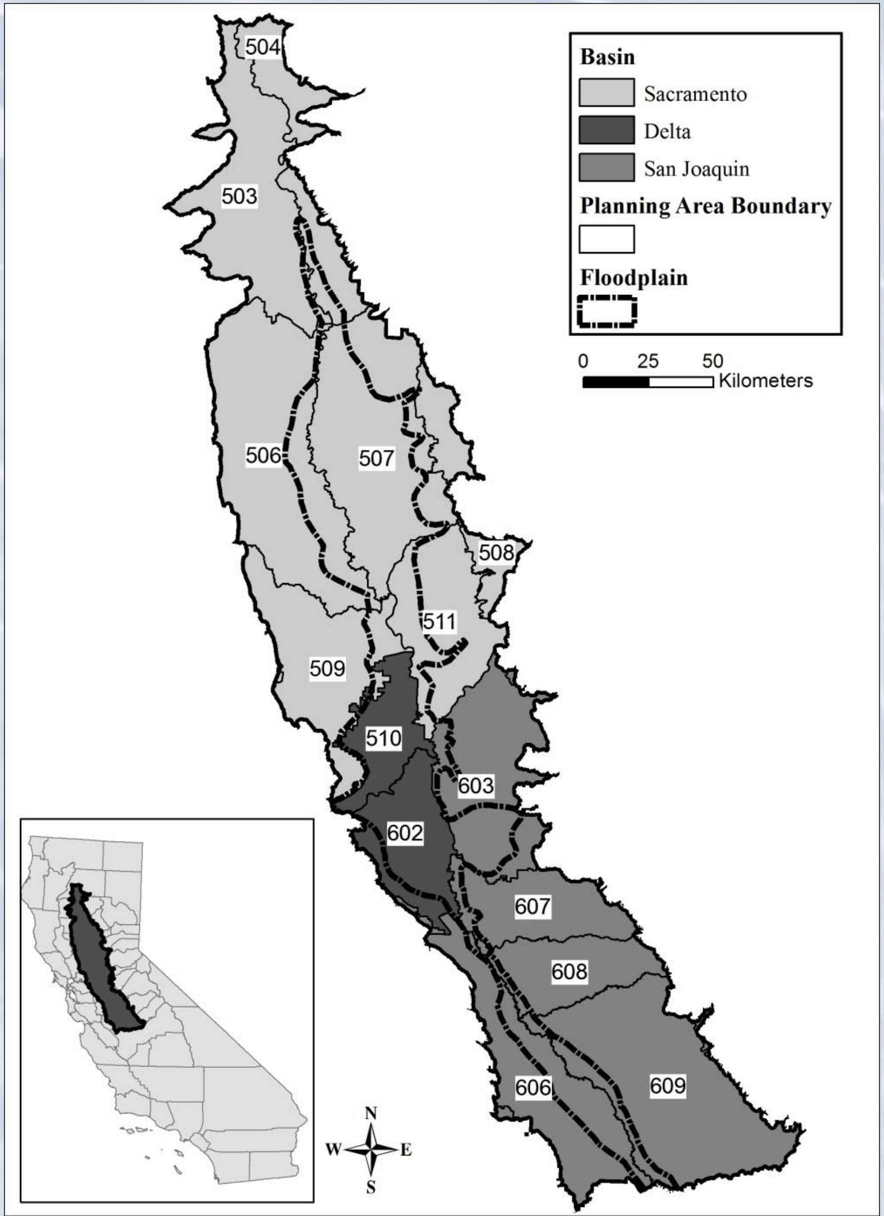
Central Valley Floor

Planning Areas
(CDWR, 2005)



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Introduction

- Direct measurement of plant evapotranspiration is challenging and there is a need to estimate ET in different time periods and locations

- Measurements in one location are not directly transferable to another (climate, management, soils, etc.)

Issues

- Agriculture has standardized on the use of reference evapotranspiration/crop coefficient methodology to achieve transferability
  - (standard equations for reference crop evapotranspiration: ASCE 2005 Modified Penman-Monteith)
- Same standardization is not found for estimating ET of natural or native vegetation
- Researchers base the reference on:
  - Evaporation pans
  - Priestley-Taylor
  - Blaney-Criddle
  - Jensen-Haise
  - One of the Penman-Monteith versions

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Issues Continued

- Quality of the reference data, lack of standardization, and issues with transferability limits the direct use of research measurements by other users
- Quality E pan data for example can be very limited
- With the increase in weather station networks and standards for site maintenance, following the agriculture standards seems like a logical step forward for natural vegetation
  - Spatial ETo estimates (e.g. SpatialCIMIS)
- This will promote further work and use of existing research for modeling and computation of natural vegetation ET

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ETc for Ag Crops

- Standard Reference Crops
  - Alfalfa or tall crop (ETr)
  - Grass or short crop (ETo) (*California*)

- Special reference evapotranspiration weather station networks are proliferating
  - CIMIS
  - Agrimet
  - CoAgMet and others

Objectives of This Study

- Estimate the evapotranspiration from natural vegetation in California's Central Valley using:
  - Estimated grass reference based vegetation coefficients (Kv's) for non-water stressed vegetation based on past research
  - For vegetation relying on rainfall, a daily soil water balance with the dual crop coefficient method
  - Daily and monthly ETo and precip for each planning area from 1922-2009 (CDWR – Orang et al. 2013)

Methodology – Kv approach

- Reviewed over 120 references on evapotranspiration from a variety of natural vegetation types
- Limited results to data:
  - presented monthly or more frequently
  - measured within surrounding vegetation using a standard/verified approach
  - most were from 1950 to present
  - focused on studies in the western U.S. (arid/semi-arid environments)

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Methodology - Kv (cont.)

- Computed vegetation coefficients on a monthly basis

$$Kv = \frac{ETc}{ETo}$$

- ETo = grass reference evapotranspiration
- In some cases, ETo weather stations were not available in the area where the study was conducted
- Used a calibrated Hargreaves Equation to compute ETo for those cases

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Methodology – Soil Water Balance

- Vegetation relying on rainfall
- ETv depends on rainfall and is low in summer
- Soil water balance using the FAO 56 dual crop coefficient approach
- Model calibrated based on measured data from other studies
  - Rainfed grasses and foothill oak savannas (Baldocchi et al. 2004)
  - Chaparral (Claudio et al. 2006)

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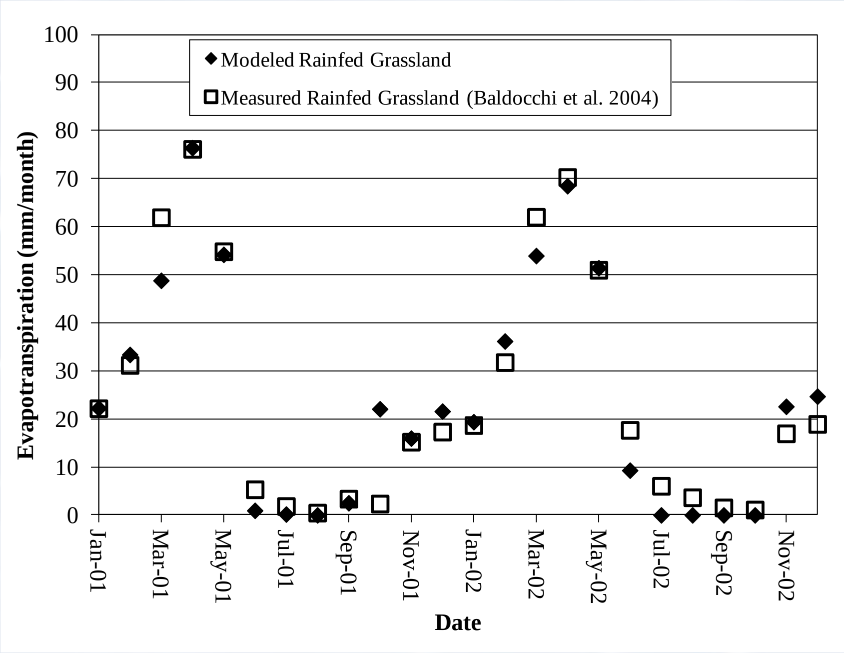
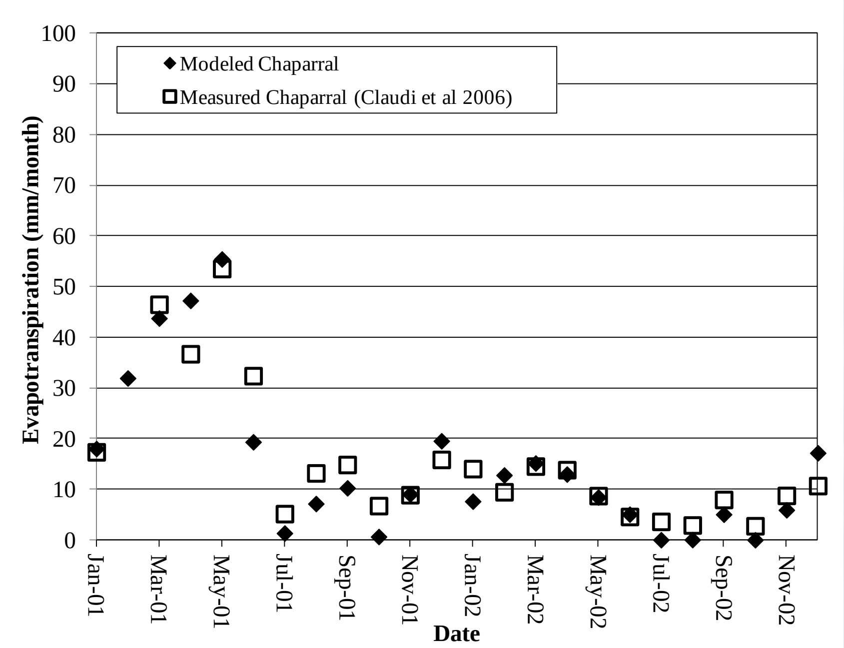
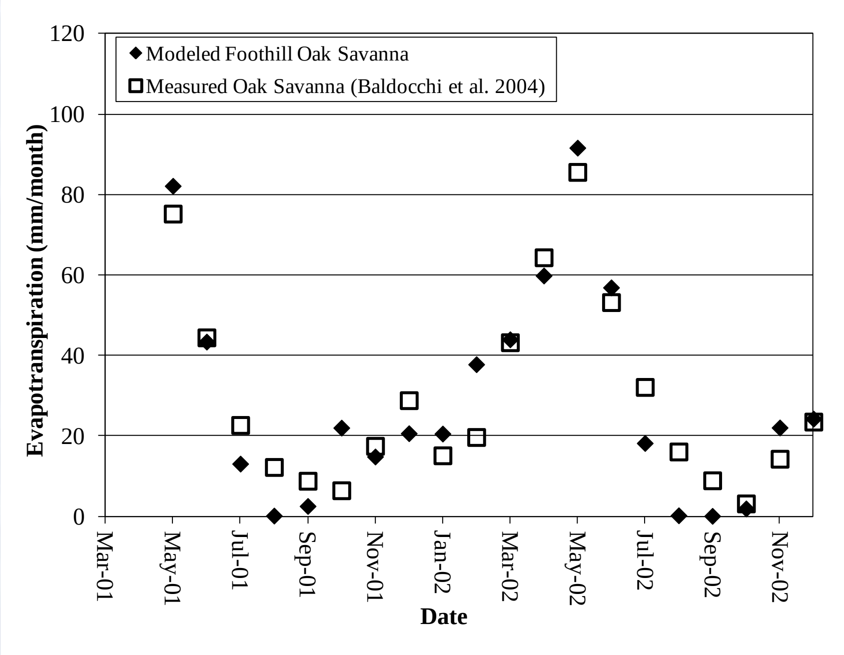
SWB Calibration

- Adjusting
  - Basal Kv (canopy)
  - Development period
  - SMD at onset of stress







Results – Kv values

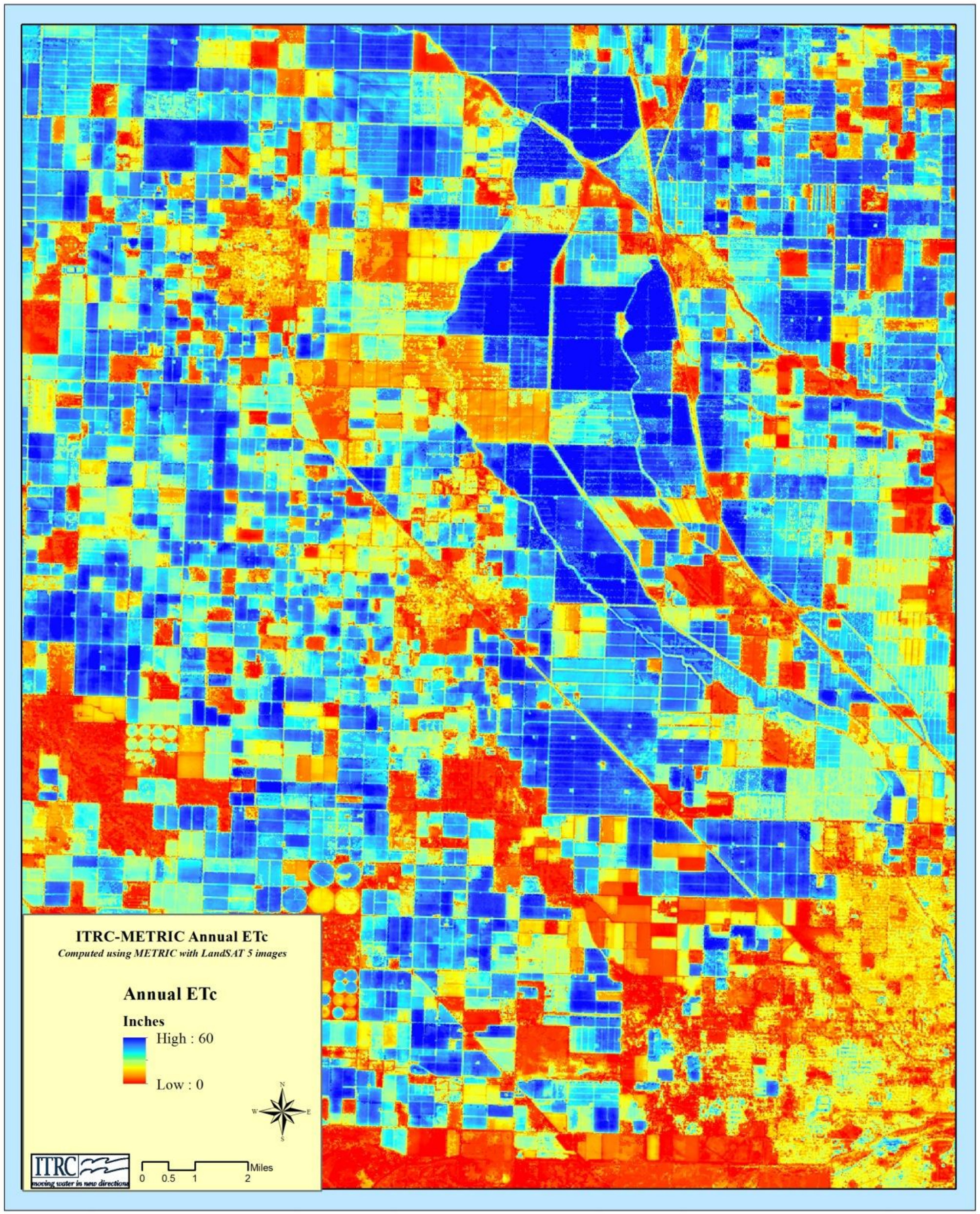
- Comprehensive tables in future paper
  - Large stand wetlands (5 studies)
  - Seasonal wetlands (2 studies)
  - Small stand wetlands (5 studies)
  - Large stand riparian forest (4 studies)
  - Smaller stand riparian forest (1 study)
  - Perennial grasses (5 studies)
  - Saltbush (4 studies)
  - Shallow open water (3 studies)

Category	ID	Vegetation	Long-Term Winter Freeze	Water Table Depth	Location	Measurement Method	ET_o Method	Source
Large Stand Wetland	1	Cattails	No	Standing	Fort Drum, FL	tank within vegetation	1	(Mao et al. 2002)
	2	Cattails	No	“	Southern FL	“	1	(Abtew and Obeysekera 1995)*
	3	Tules and Cattails	No	“	Twitchell Island, CA	surface renewal	1	(Drexler et al. 2008)
	4	Tules/Bulrush	No	“	Bonsall, Ca	tank within vegetation	5	(Muckel and Blaney 1945)
	5	Cattails	Yes	“	Logan, UT	Bowen ratio	1	(Allen 1998)
Seasonal Large Stand Wetland	6	Tules, Cattails, Wocus Lilly	Yes	Standing to 0.8 m	Upper Klamath NWR, OR	eddy covariance	1	(Stannard 2013)
	7	Tules/Bulrush	Yes	Standing to 0.8 m	“	eddy covariance	1	“
Small Stand Wetland	8	Cattails	No	Standing	King Island, CA	tank within vegetation	5	(Young and Blaney 1942)
	9	Tules/Bulrush	No	“	“	tank within vegetation	5	“
	10	Tules/Bulrush	No	“	Victorville, CA	tank within vegetation	5	“
	11	Cattails	Yes	“	Logan, UT	Bowen Ratio	1	(Allen 1998)
	12	Tules/Bulrush	Yes	“	“	Bowen Ratio	1	“
Large Stand Riparian Forest	13	Willow	No	High	Santa Ana, CA	tank within vegetation	4	(Young and Blaney 1942)
	14	Cottonwood	Yes	Variable	Middle Rio Grande, NM	SEB/METRIC	1	(Allen et al. 2005)
	15	R.Olive	Yes	Variable	“	SEB/METRIC	1	“
	16	Willow	Yes	Variable	“	SEB/METRIC	1	“
Smaller Stand Riparian Forest (508m by 120m)	17	Reed, Willow, Cottonwood	Yes	0.9 m	Central City, NE	Bowen ratio	1	(Irmak et al. 2013)
Large Stand Pasture with High Water Table	18	Native Pasture	Yes	High	Alturas, CA	tank within vegetation	5	(MacGillivray 1975)
	19	Native Pasture	Yes	High	Shasta County, CA	“	5	“
	20	Irrigated Pasture	Yes	0-0.6m	Carson Valley, NV	eddy covariance	5	(Maurer et al. 2006)
	21	Irrigated Pasture	Yes	0.6-1.5m	“	Bowen ratio	5	“
	22	Meadow Pasture	Yes	0.3-1.2m	Upper Green River, WY	tank within vegetation	1	(Pochop and Burman 1987)
Large Stand Saltbush	23	Saltbush	Minor	.2-.8 m	Owens Valley, CA	stomatal conductance	1	(Steinwand et al. 2001)
	24	Saltbush	Minor	0.4-0.7m	Owens Valley, CA	eddy covariance	2	(Duell 1990)
	25	Saltbush	No	1.6m	Yuma, AZ	tank within vegetation	4	(McDonald and Hughes 1968)
	26	Saltbush	No	1.1m	Yuma, AZ	tank within vegetation	4	“
Open Water	27	Shallow Open Water	No		Fort Drum, FL	tank	1	(Mao et al. 2002)
	28	Shallow Open Water	No		Delta Region, CA	tank	5	(Matthew 1931)
	29	Shallow Open Water	No		Lake Elsinore, CA	water balance	5	(Young 1947)
Rainfed Vegetation	30	Oak-Grass Savanna	No	No	Near Iona, CA	eddy covariance	2	(Baldocchi et al. 2004)
	31	Chaparral - Old Stand	No	N/A	near Warner Springs, CA	eddy covariance	2	(Claudio et al. 2006)
	32	Chaparral - Young Stand	No	N/A	near Warner Springs, CA	eddy covariance	2	(Ichii et al. 2009)
	33	Chaparral	Yes	N/A	Sierra Ancha Forest, AZ	tank within vegetation	5	(Rich 1951)

Monthly Kv Values

Month	Shallow Open Water Aquatic	High Water Table Perennial Grass	Riparian	Large Stand Wetland	Small Stand Wetland	Seasonal Wetland	Saltbush	Vernal Pool
January	0.65	0.55	0.80	0.70	1.00	0.70	0.30	0.65
February	0.70	0.55	0.80	0.70	1.10	0.70	0.30	0.70
March	0.75	0.60	0.80	0.80	1.50	0.80	0.30	0.80
April	0.80	0.95	0.80	1.00	1.50	1.00	0.35	1.00
May	1.05	1.00	0.90	1.05	1.60	1.05	0.45	1.05
June	1.05	1.05	1.00	1.20	1.70	1.10	0.50	0.85
July	1.05	1.10	1.10	1.20	1.90	1.10	0.60	0.50
August	1.05	1.15	1.20	1.20	1.60	1.15	0.55	0.15
September	1.05	1.10	1.20	1.05	1.50	0.75	0.45	0.10
October	1.00	1.00	1.15	1.10	1.20	0.80	0.35	0.10
November	0.80	0.85	1.00	1.00	1.15	0.80	0.40	0.25
December	0.60	0.85	0.85	0.75	1.00	0.75	0.35	0.60

Kv Check – Remote Sensing of ET



ITRC – METRIC Procedure

- Large riparian forest east of Lake Isabella
- Wetland in Kern Wildlife Refuge
- Part of separate projects previously evaluated

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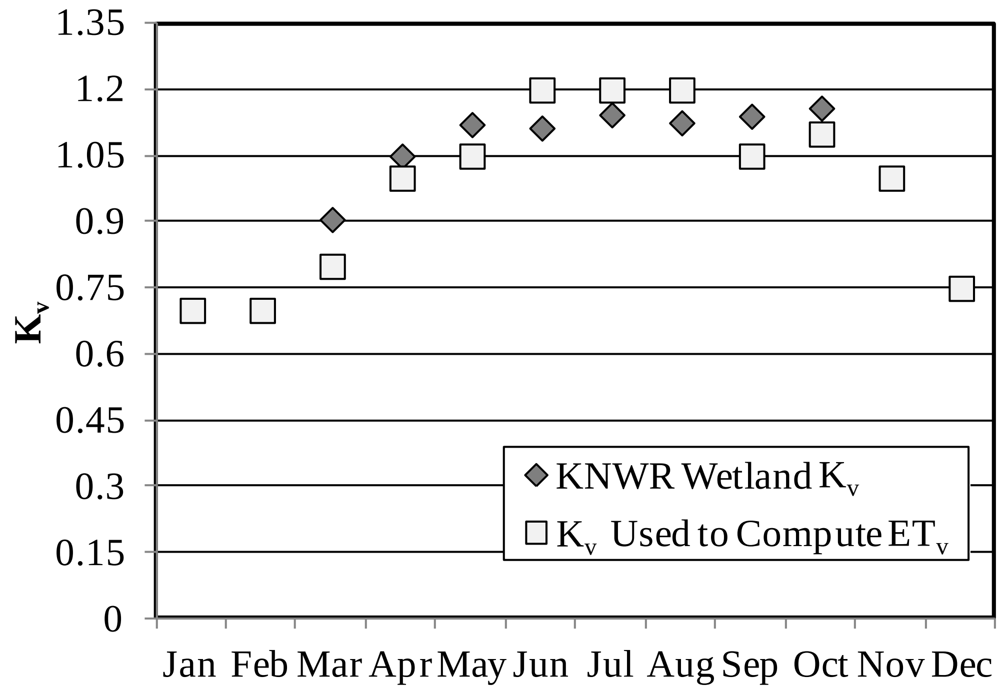
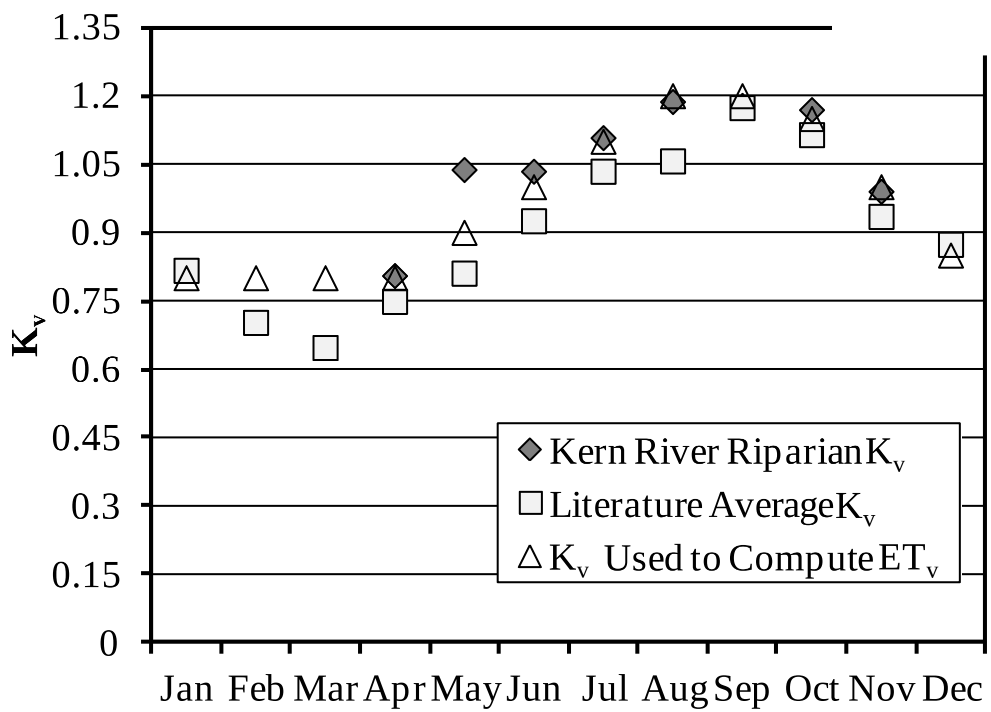
Kv Check

Remote Sensing SEB compared to Kv used in this study





Kv from LandSAT 5 processed for riparian and wetlands in Kern County, CA independent investigation by author

Good Agreement

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Rainfed 88-year average Kv

Month	Rainfed Grassland	Foothill Hardwoods	Valley Oak Savanna	Chaparral
January	0.78	0.80	0.80	0.55
February	0.72	0.77	0.77	0.61
March	0.64	0.69	0.69	0.54
April	0.58	0.61	0.62	0.40
May	0.35	0.52	0.54	0.22
June	0.06	0.20	0.40	0.03
July	0.00	0.01	0.40	0.01
August	0.00	0.01	0.40	0.01
September	0.03	0.03	0.40	0.03
October	0.16	0.15	0.41	0.14
November	0.47	0.46	0.55	0.40
December	0.73	0.71	0.71	0.57

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Long-Term Average ETv by Planning Area

1922-2009 Average Annual Evapotranspiration, mm/year

Planning Area	Large Stand Riparian	Large Stand Wetland	Small Stand Wetland	Seasonal Wetland	Vernal Pools	Perennial Grasses	Salt-bush	Rainfed Grass	Chaparral	Foothill Oak	Valley Oak	Open Water Evap.
503	1,341	1,413	2,043	1,288	755	1,305	602	391	295	451	685	1,274
504	1,325	1,395	2,017	1,271	741	1,289	596	340	288	402	640	1,258
506	1,387	1,461	2,113	1,331	779	1,350	623	324	250	398	672	1,317
507	1,430	1,506	2,179	1,373	803	1,392	643	352	269	427	702	1,358
509	1,396	1,469	2,125	1,339	781	1,359	627	328	247	402	679	1,325
510	1,404	1,478	2,138	1,347	787	1,368	631	312	232	386	673	1,333
511	1,471	1,549	2,241	1,412	820	1,433	662	348	264	426	717	1,397
601	1,166	1,227	1,774	1,118	657	1,135	523	274	190	323	560	1,106
602	1,246	1,312	1,898	1,196	705	1,213	559	272	193	333	590	1,183
603	1,464	1,543	2,233	1,407	821	1,427	659	337	255	415	710	1,391
606	1,392	1,466	2,121	1,337	786	1,356	626	240	174	312	625	1,322
607	1,438	1,516	2,195	1,383	812	1,402	647	293	216	368	673	1,367
608	1,482	1,564	2,264	1,427	841	1,446	667	289	215	366	686	1,410
609	1,558	1,644	2,380	1,499	879	1,521	702	290	220	372	715	1,482
Average	1,393	1,467	2,123	1,338	783	1,357	626	314	236	384	666	1,323

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Conclusions

- For non-water stressed vegetation, Kv values showed good agreement between independent studies
- A list of grass reference based Kv values have been generated from past research for use in estimating vegetation in arid/semi arid climates
- **For vegetation relying on rainfall, a soil water balance model was used to estimate ET**
  - **Calibration of the model based on measured values**

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Work Supported by:

San Luis-Delta Mendota Water Authority and State Water Contractors

Thank You

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