Evaluating Water Conservation Opportunities in the Upper Colorado River

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Project Partners

Colorado Basin Roundtable

Colorado State University

The Nature Conservancy

Trout Unlimited

American Rivers
Rivers Connect Us

Utah State University

DRI
Desert Research Institute

OpenET

Audubon

Colorado
Colorado Water Conservation Board
Department of Natural Resources

lōtic hydrological

AMP Insights

Selected Project Tasks

- Task 2 – Perform remote sensing measurement and estimation of consumptive use (CU) and conserved consumptive use (CCU) on large irrigated pastures that are characterized by various grasses, forbs, and sedges under varying soil and groundwater conditions.
- Task 3 – Validate multiple remote sensing models for CU and CCU verification that is scientific based, replicable, scalable and can be used in conjunction with broader remote sensing platforms on high elevation pastures in Western Colorado.
- Task 4 – Construct water production functions for different grass, forb and sedge forages under varying soil and groundwater conditions in order to understand yields as a function of CU rates.

In theory there is no difference between theory and practice, while in practice there is.

~ Yogi Berra

Existing Literature

- Lysimetry (well-developed; reliable; advanced locational studies)
  - Walter *et al*. (1990). Evapotranspiration and Agronomic Responses in Formerly Irrigated Mountain Meadows in South Park, Colorado. Prepared for the Denver Board of Water Commissioners. 216 pp.
  - Carlson *et al*. (1991). Evapotranspiration in High Altitude Mountain Meadows in Grand County, Colorado. Prepared for the Denver Board of Water Commissioners. 243 pp.
  - Temple et al. (2000). Consumptive Water Use in Mountain Meadows, Upper Gunnison River Basin, CO. Report for the Upper Gunnison River Water Conservancy District. 9 pp.
- Remote Sensing (contemporary; translatable and scalable; improving)
  - Cuenca *et al*. (2013). Application of Landsat to Evaluate Effects of Irrigation Forbearance. Remote Sensing. 5: 3776-3802.
  - Useful to map heterogeneous CU (ETa) on fields experiencing irrigation management changes for which there are no equivalent Kc.

Existing Literature (cont.)

ADJUSTED MONTHLY CONSUMPTION (inches)							
SITE	YEAR	MAY	JUNE	JULY	AUG	SEPT	TOTAL
CC-1	1987	5.38	7.84	6.48	5.42	4.46	29.58
	1988	3.99	6.53	7.19	4.67	4.27	26.65
	1989	5.02	5.27	7.63	4.56	4.57	27.05
	1990	4.80	5.16	5.91	4.06	4.22	24.15
CC-2	1987	4.85	7.39	6.69	5.22	4.17	28.32
	1988	5.72	7.06	7.76	4.37	3.95	28.86
	1989	5.66	5.78	7.82	5.55	4.07	28.88
	1990	5.41	6.61	5.79	5.92	4.00	27.73
LR-1	1987	3.52	5.53	5.92	4.02	4.19	23.18
	1988	4.71	6.01	6.64	4.45	4.34	26.15
	1989	5.62	5.22	5.65	4.52	4.36	25.37
	1990	4.62	7.62	5.71	4.50	3.88	26.66
LR-2	1987	4.27	5.89	6.36	4.03	4.21	24.76
	1988	4.03	5.86	6.63	5.10	4.43	26.05
	1989	5.84	5.13	5.59	4.31	4.14	25.01
	1990	4.71	7.06	4.68	4.84	5.08	26.37

Carlson et al. (1991). Evapotranspiration in High Altitude Mountain Meadows in Grand County, Colorado. Prepared for the Denver Board of Water Commissioners. 243 pp.

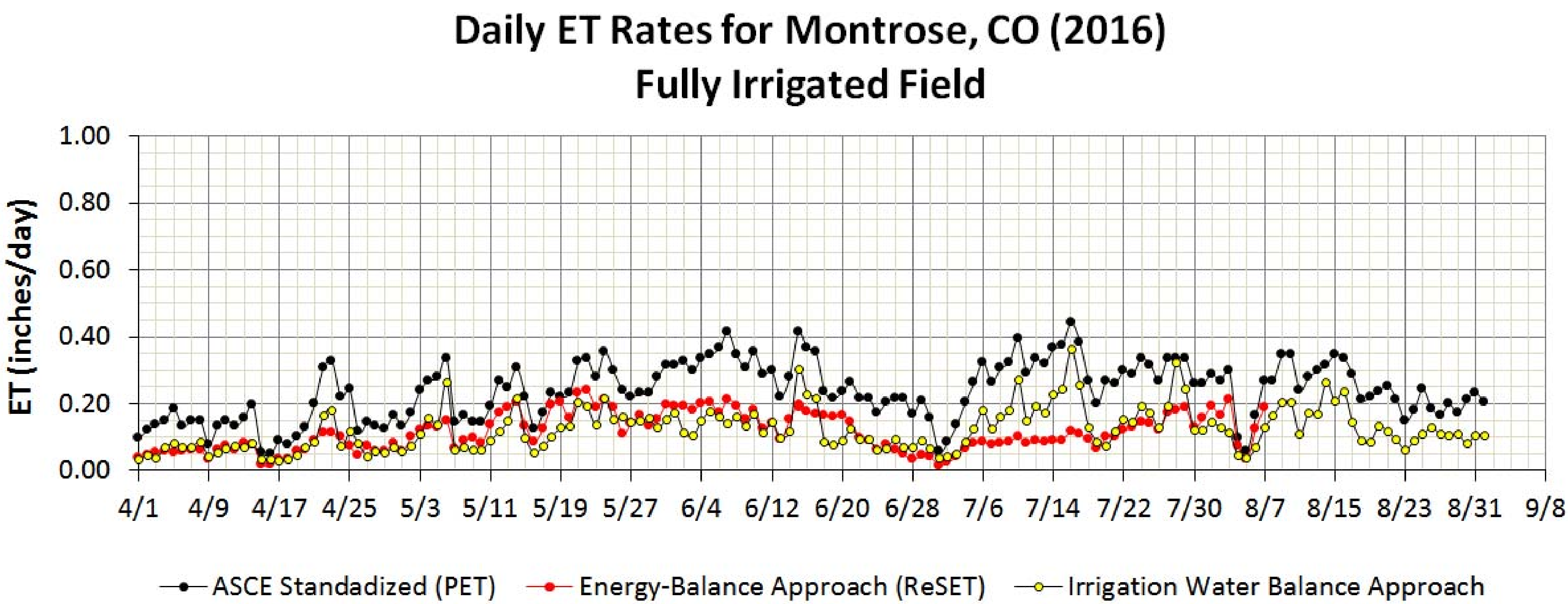
Table 3. **Total consumptive use (irrigation requirement plus effective rainfall, inches) for 8 sites within the upper Gunnison River basin over 4 months during 1999.**

	Site								
Month	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)	Average
Lysimeter water table set at 4 in. or 8 in. below soil surface to simulate full irrigation									
June	5.94	6.39	6.3	5.23	6.47	7.53	5.62	7.23	6.34
Jul	5.11	6.03	5.97	4.90	5.48	5.14	3.86	4.75	5.16
2 mo. Total	**11.05**	**12.42**	**12.27**	**10.13**	**11.95**	**12.67**	**9.48**	**11.98**	**11.49**
Lysimeter water table set at 22 in. below soil surface to simulate no irrigation									
Aug	2.66	4.94	2.93	3.97	2.88	2.66	1.97	2.77	3.10
Sep	1.94	2.88	1.73	4.38	3.40	2.23	1.03	2.48	2.51
4 mo. Total	**15.65**	**20.24**	**16.93**	**18.48**	**18.23**	**17.56**	**12.48**	**17.23**	**17.10**

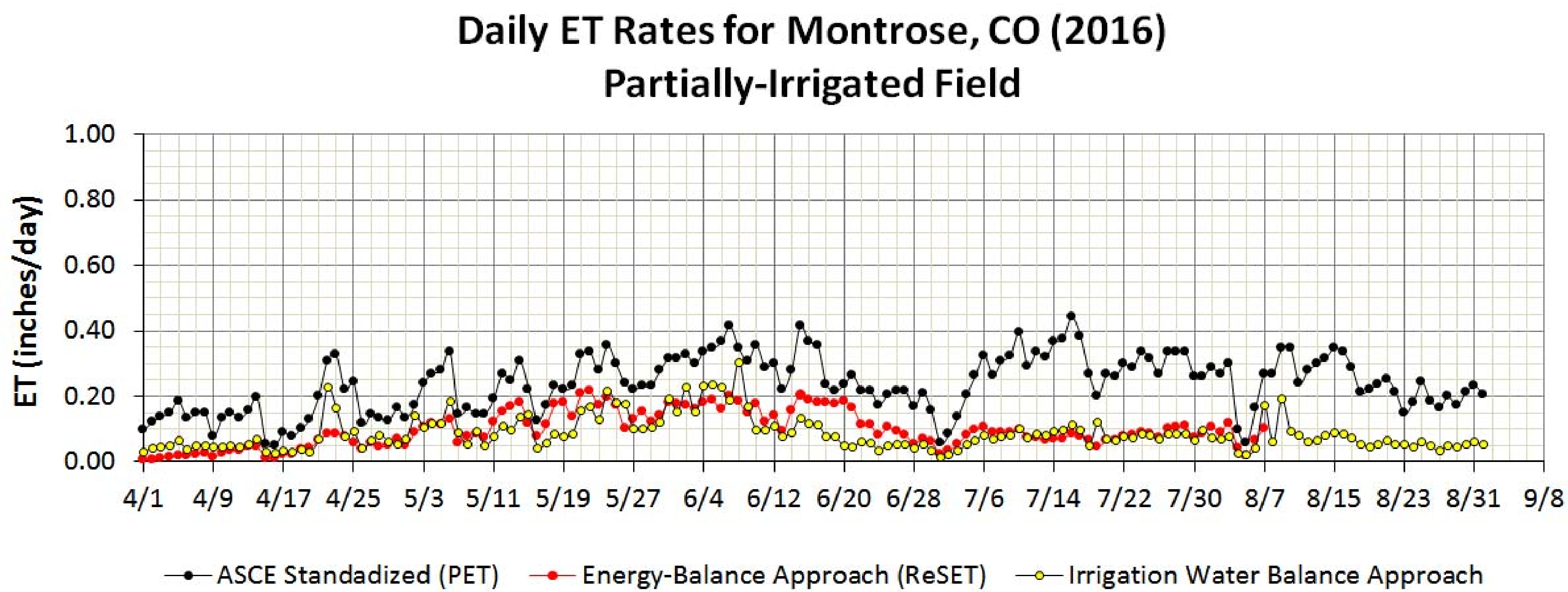
Temple et al. (2000). Consumptive Water Use in Mountain Meadows, Upper Gunnison River Basin, CO.

- Irrigated ETa for grasses
  - Carlson et al. (1991) 22.28 in. (May-Aug)
  - Temple et al. (2000) ~22.16 in. (May-Aug)

Cabot et al. (2016)

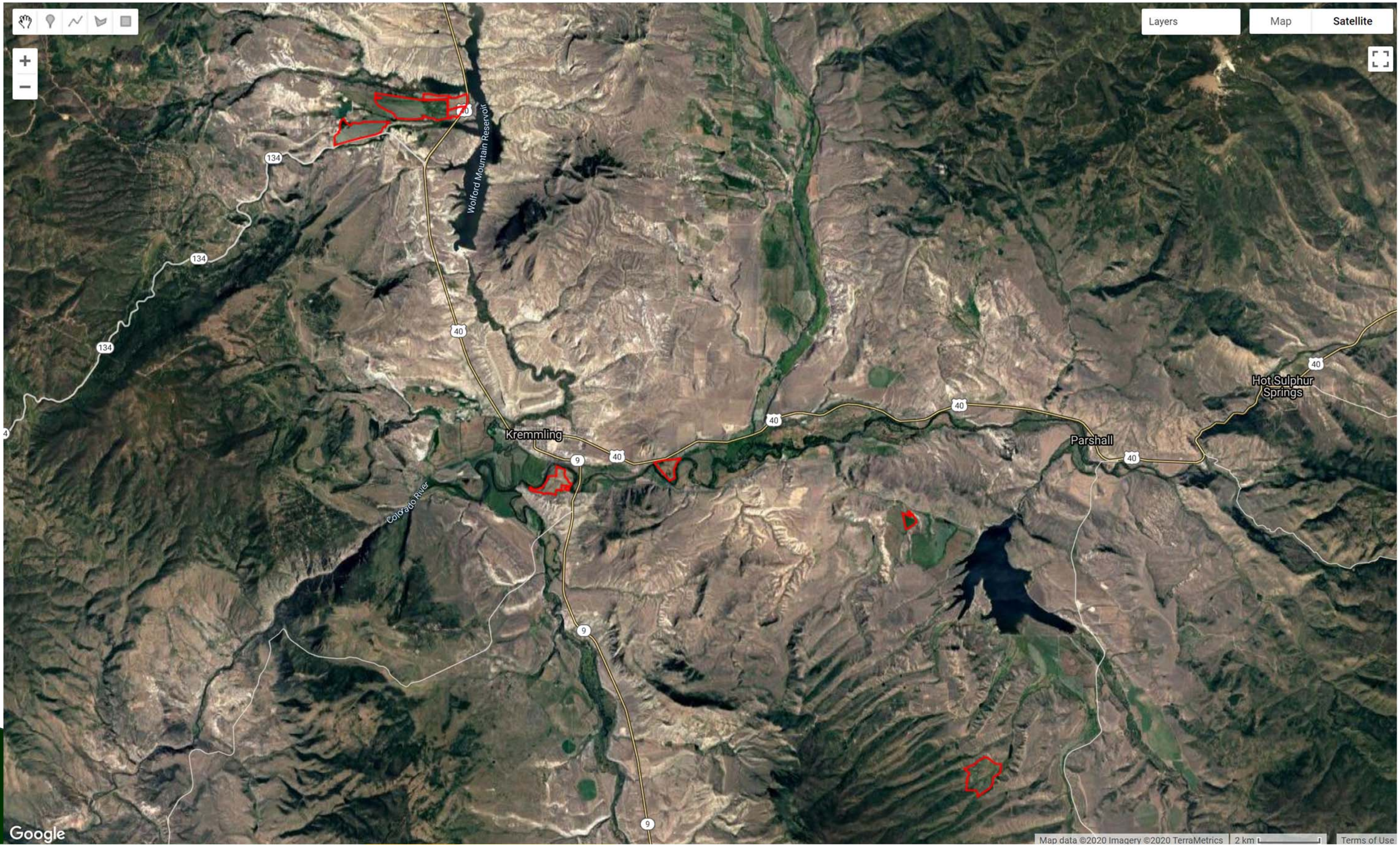


Cabot et al. (2016)



Tasks 2 and 3 – Remote Sensing

- Advantages
  - Spatial Scale is large enough to encompass diverse underlying soil and vegetative patterns that can affect consumptive use at the surface
  - GPRT1, GPRT2, RSRT1, SBRT1, SPRT1 = 210, 337, 124, 77, 213 acres
  - Able to map and estimate seasonal CU (ETa) on fields experiencing curtailment and compare with nearby reference conditions receiving full irrigation
    - Particularly useful under curtailed conditions, for which there are no Kc
- Disadvantages
  - Landsat 7 and 8 satellites image the entire Earth every 16 days in an 8-day offset
  - Mapping and estimates benefit from in-field ($$) calibration.



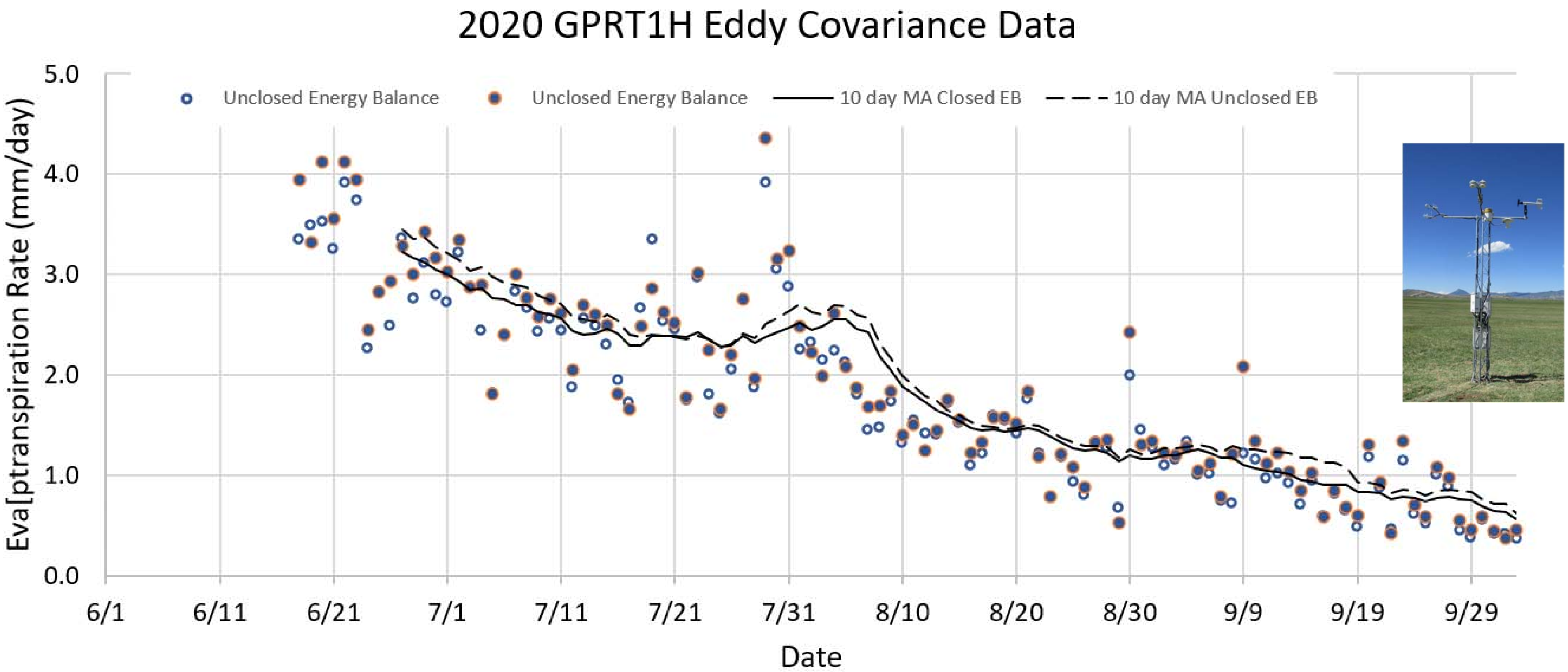
Layers
Map
Satellite
Wolford Mountain Reservoir
134
40
Kremmling
9
Colorado River
Parshall
Hot Sulphur Springs
Google
Map data ©2020 Imagery ©2020 TerraMetrics
2 km
Terms of Use

Eddy Covariance Tower at GPRT1H

Eddy Covariance evaluation is based on the theory that, as the air moves within a fetch (600 ft radius), it carries molecules of water vapor.

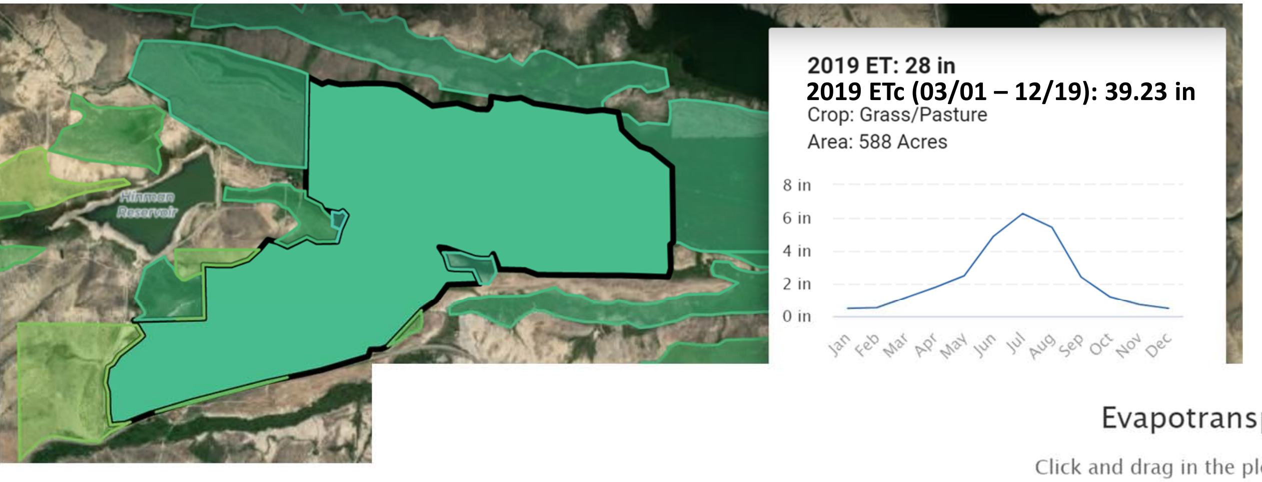
If the speed of these eddies can be measured three dimensionally, the net exchange of these molecules between the surface and the atmosphere can be determined and evapotranspiration rates can be estimated closely.

Eddy Covariance Results (GPRT1H) – Non-Irrigated

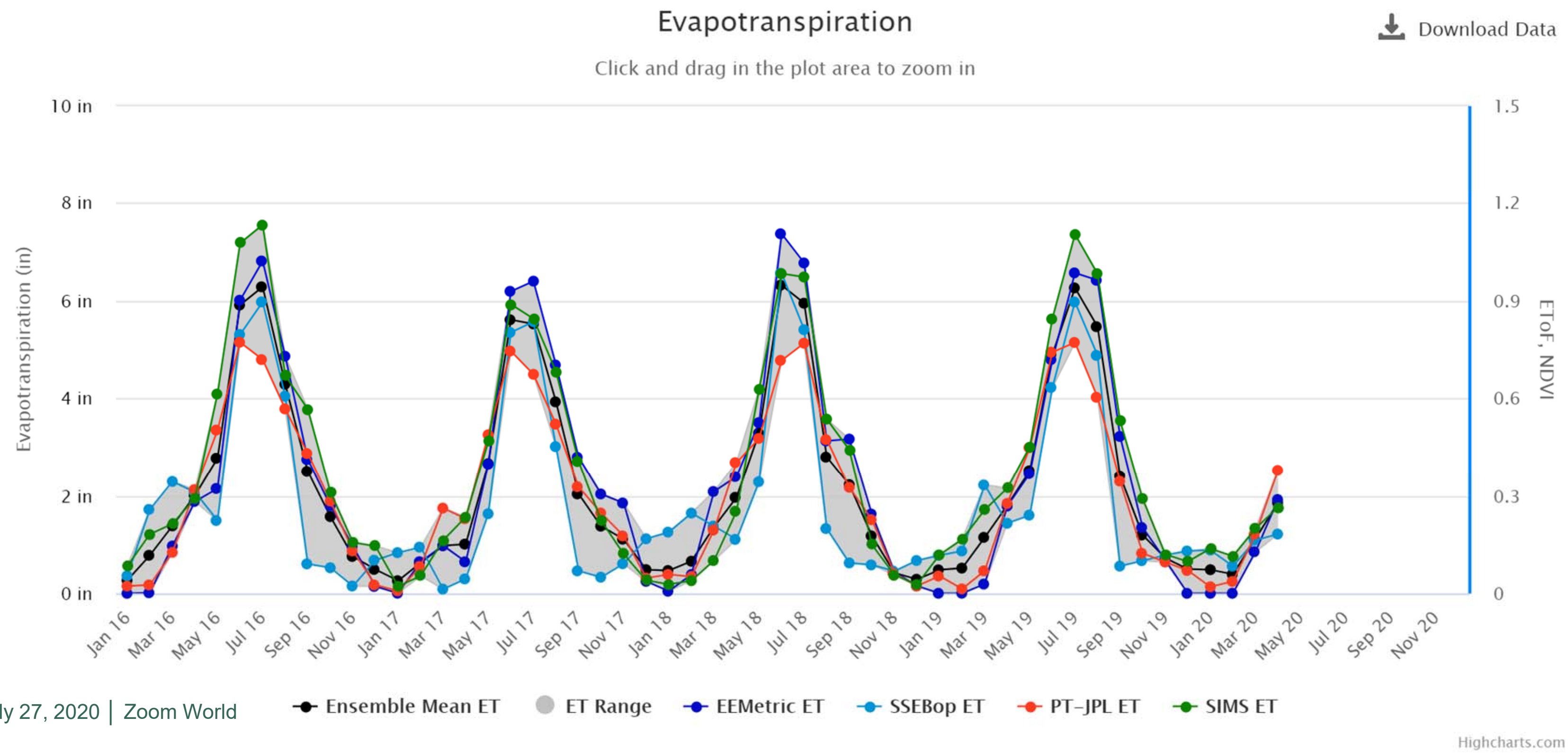


Eddy Covariance Results

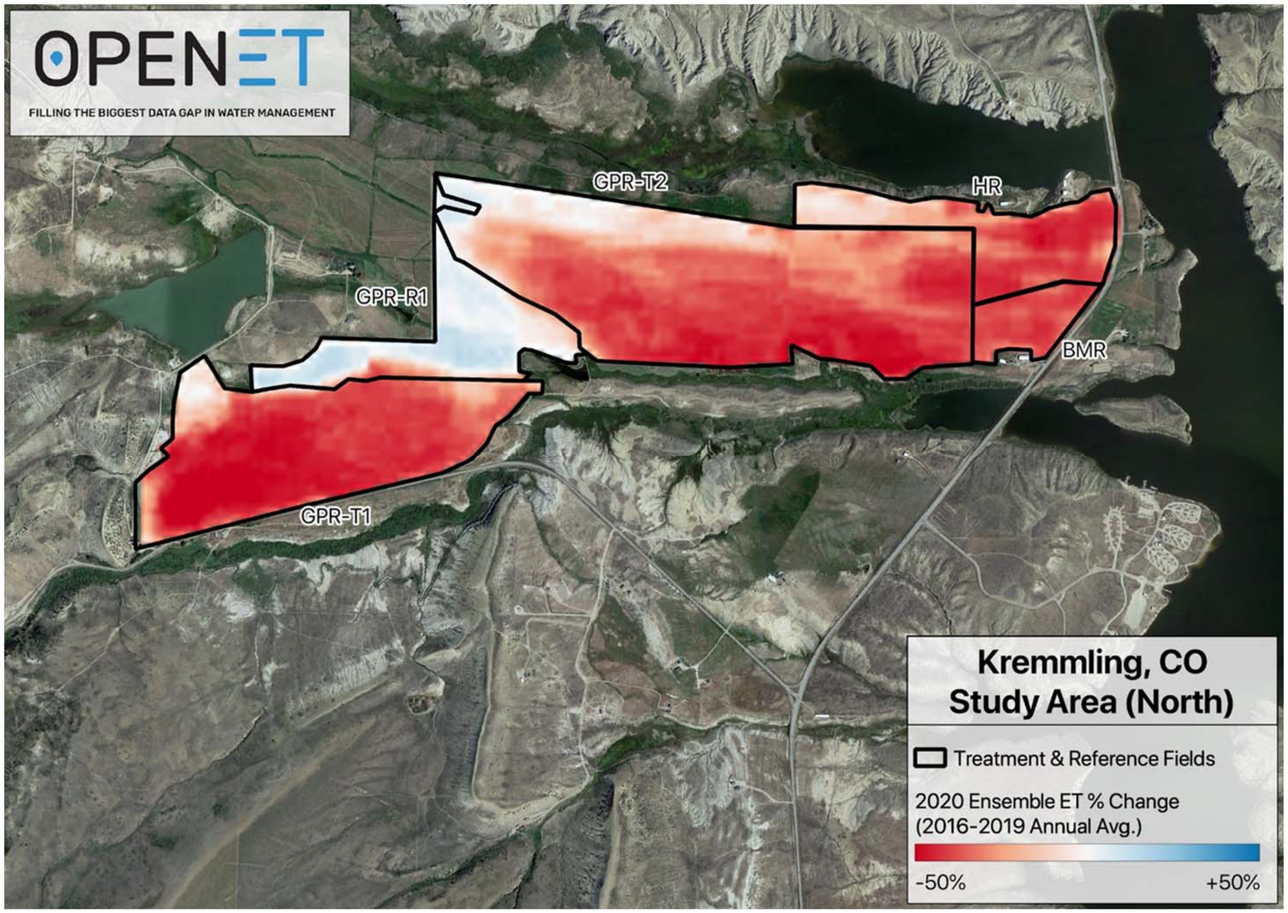
- Initial Interpretations
  - Over this area on a grass pasture field (GPRT1H) that went *un-irrigated for an entire season*, the ET rate declined from **4.0 mm/day** (06/18/20) to **0.5 mm/day** (10/22/20)
    - Some increase in ET occurred as a result of a rainfall event that happened near the end of July
    - Initial ET was likely due to stored soil moisture but no groundwater contribution was evident
  - July ET for **non-irrigated** estimated at **2.4 mm/day** using eddy covariance
  - July ET for **irrigated** grass reported by others between **4.22 – 5.24 mm/day** (Carlson et al., 1991; Temple et al., 2000)



GPR (previous years)



Remote Sensing of Water Use

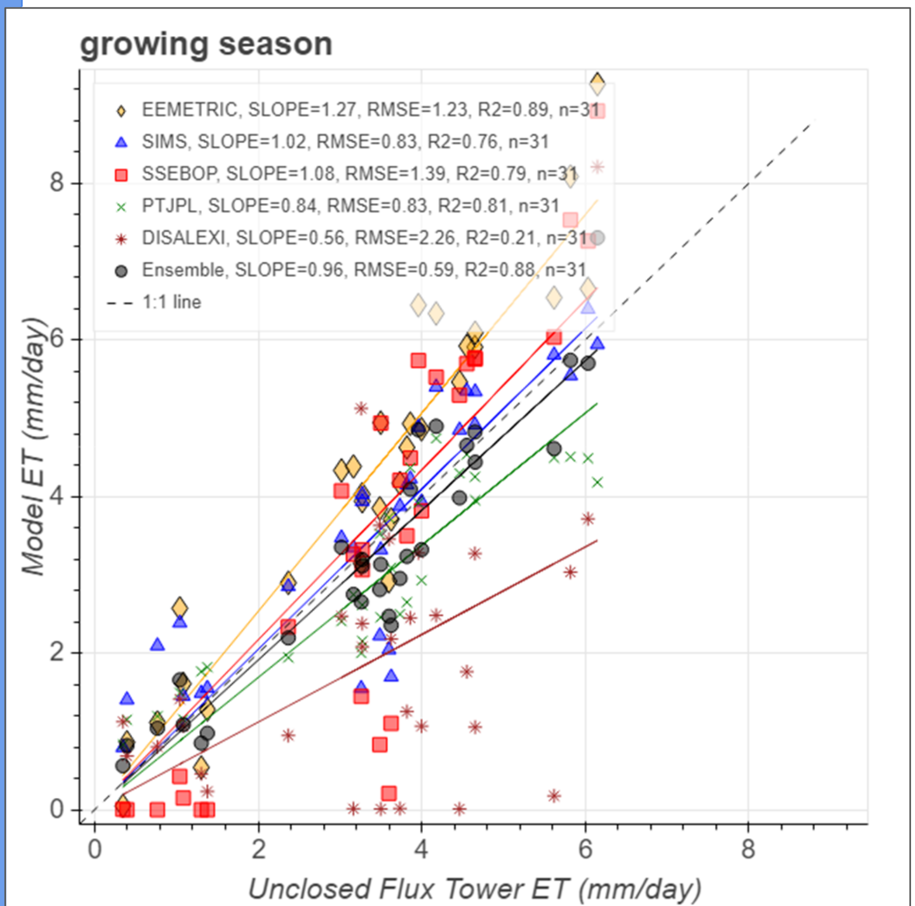


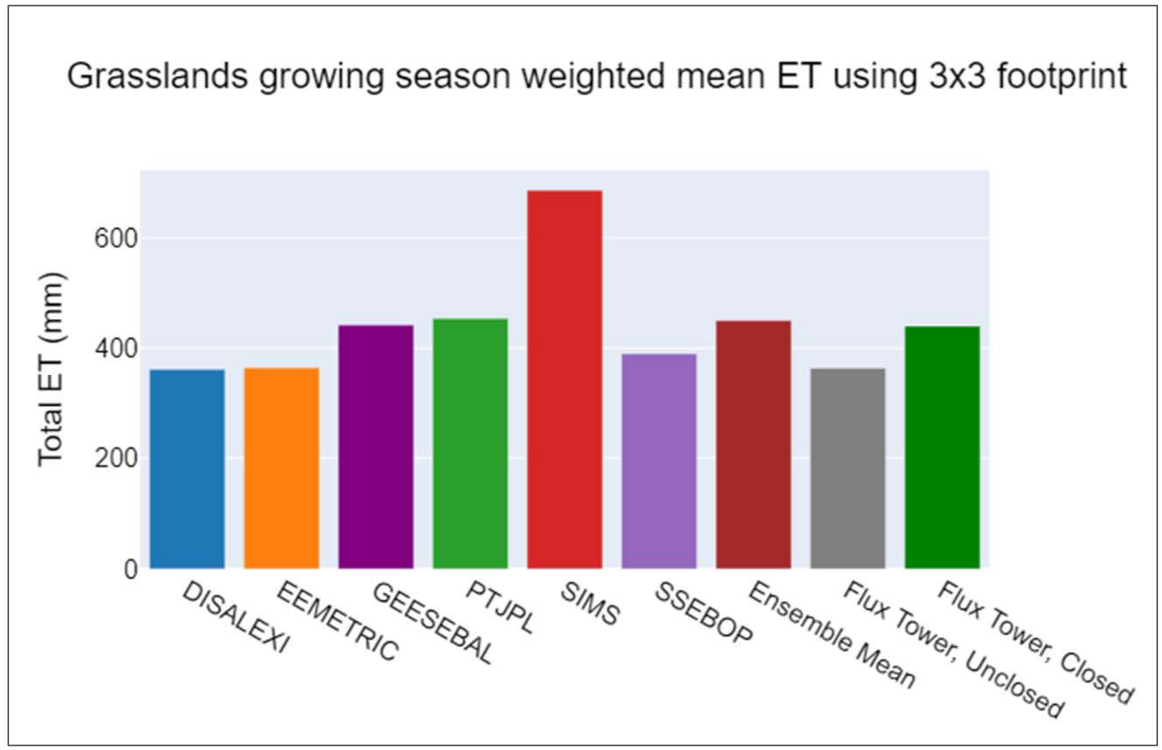
Summary of ET (May-August for 2016-2019) vs Study Year (2020)

Site	2016	2017	2018	2019	2020	% RED
BMR	17.95	16.92	16.42	17.39	7.84	54%
BSR	13.67	13.78	16.20	16.32	13.53	10%
GPR_R1	18.02	18.23	18.69	18.36	16.62	9%
GPR_T1	17.28	17.19	17.32	17.27	7.64	56%
GPR_T2	18.85	18.46	19.30	18.68	10.01	47%
HR	18.47	18.00	17.33	18.19	10.40	42%
RSR_R1	18.68	18.93	19.07	18.01	19.02	-2%
RSR_T1	18.46	18.01	18.67	16.98	15.41	15%
SBR_R1	16.95	17.93	17.85	16.80	19.30	-11%
SBR_T1	17.08	17.06	15.83	15.68	10.31	37%
SPR_R1	13.71	13.83	11.52	16.00	13.48	2%
SPR_T1	14.98	15.68	11.80	15.74	9.95	32%

July ET for non-irrigated estimated at 1.4 mm/day using ensemble RS method on GPRT1 (other T fields are at 2.10, 2.38, 2.41)

Intercomparison and Accuracy Assessment





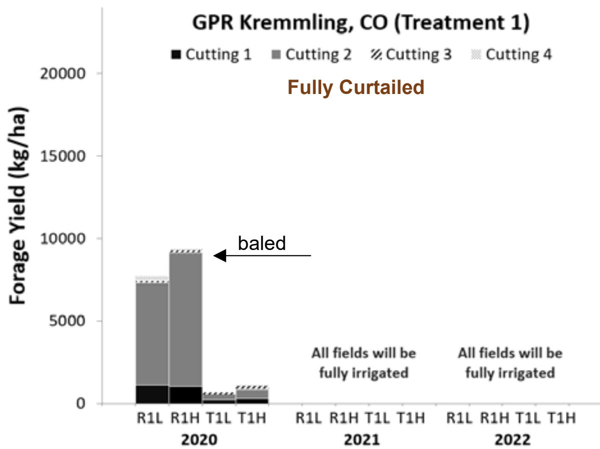
Tasks 4 – Forage Evaluations

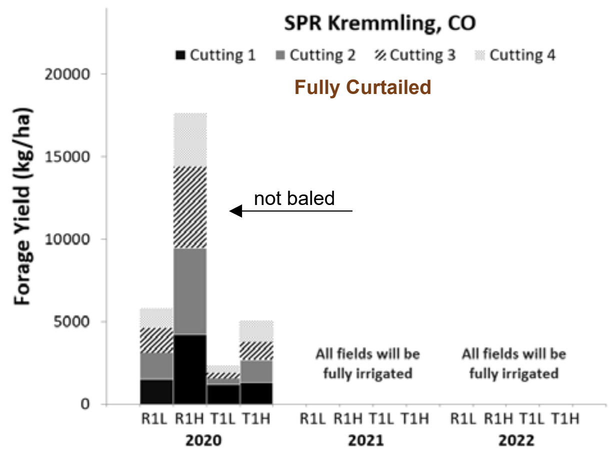
- Task 4 – Construct water production functions for different grass, forb and sedge forages under varying soil and groundwater conditions in order to understand yields as a function of CU rates.

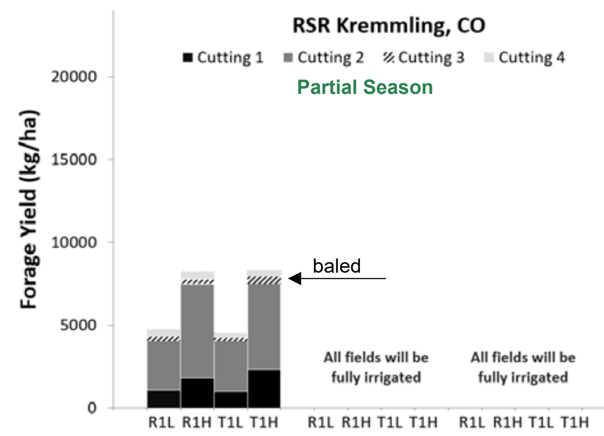
Brummer et al. (2015)

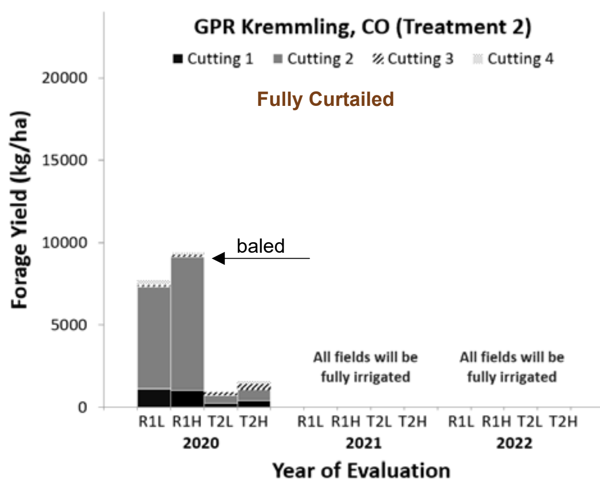
- Yield Effects
  - Reductions averaged 70% (range 24% - 93%) during the year of shutoff
  - Yields at 48% (range 13% - 83%) below control after 1 year recovery
  - Yields at 7% (range 0% - 13%) below control after 2 years recovery
- Forage Quality
  - Shutoff year - neutral detergent fiber (NDF) in curtailed plots was 5.5% lower (54.9 vs 51.9%) while crude protein (CP) content was 42% greater (7.6 vs 10.8%) than the control, both indicating higher quality
  - Recovery Year 1, NDF in fallowed plots was 8% lower (58.0 vs 53.3%) while CP did not differ significantly (8.6 vs 8.0%) from the control

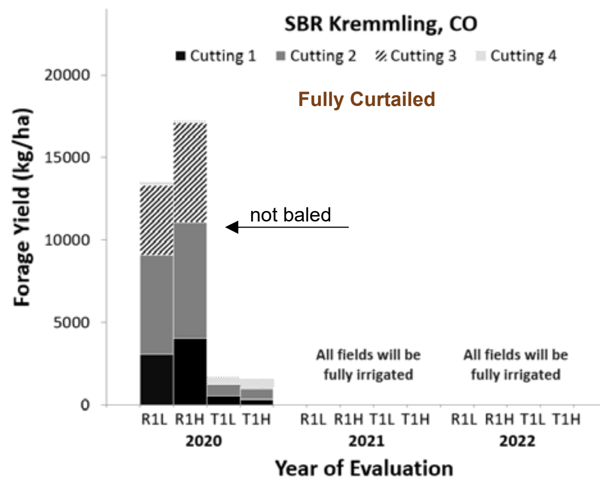
2020 Forage Yield Impacts (Kremmling, CO)

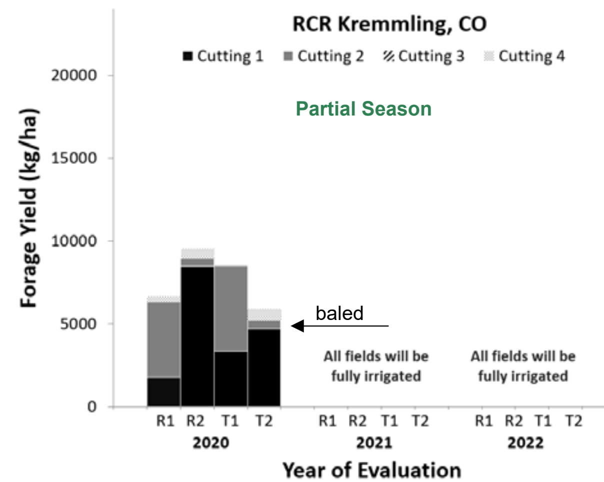












Forage Data Results

- Initial Interpretations for Forage Data on Fully Curtailed Fields
  - Dry Matter Biomass reductions averaged 73% ($\sigma = 12\%$) for first sample (June 2020)
    - assistance from stored soil moisture
  - Dry Matter Biomass reductions averaged 87% ($\sigma = 8\%$) for second sample (July 2020)
  - Dry Matter Biomass reductions averaged 88% ($\sigma = 16\%$) for third sample* (August 2020)

    * only on SBR and SPR (others were baled)
- Next Steps
  - Gear up for 2021 season and begin to evaluate recovery patterns (quality, quantity, energy)
  - Associate yield results with ET data to compare with existing data
    - *hypothesize agreement between crop ET and biomass production to identify monetary impact vs CCU*
  - Consider overlaying (grass species) or underlying conditions (soil and groundwater) explanations for heterogeneity
    - Possible heuristic for targeted curtailment based on known conditions

Last Slide