Developing DayCent® for Agrivoltaic Grassland

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INTRODUCTION

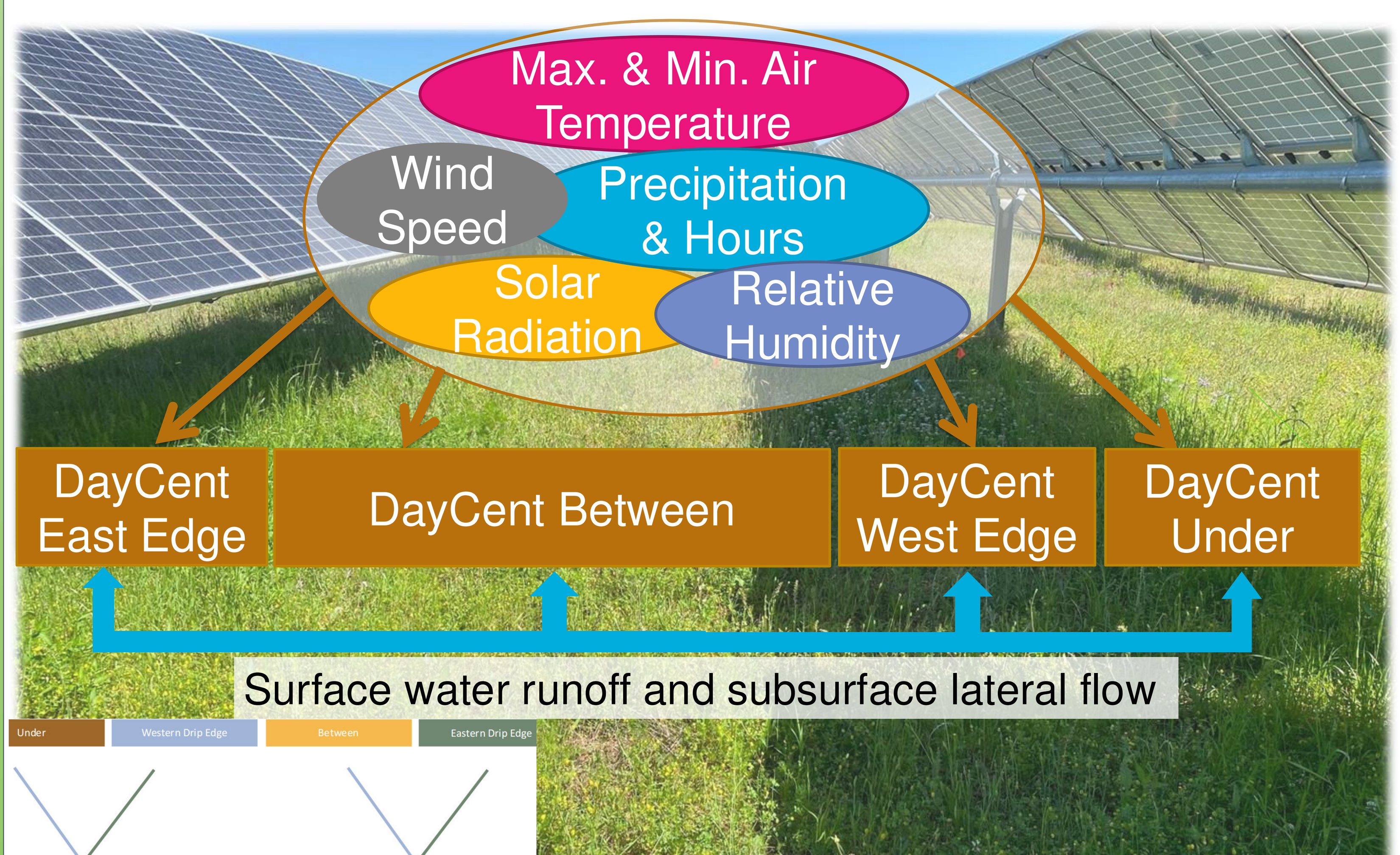
- **Global Challenges**: The increasing global demand for energy and agricultural products, combined with heightened ecosystem vulnerability due to climate change, presents critical challenges.
- **Agrivoltaics as a Solution**: Agrivoltaics offers a dual-use approach by integrating solar energy generation with agricultural production. This innovative system has the potential to enhance ecosystem services such as carbon sequestration, greenhouse gas avoidance, and soil health improvement when compared to single-use systems.

OBJECTIVES

1) This study is part of an ongoing project designed to expand the utilization of agrivoltaics, and investigate the impacts of agrivoltaics under various land management strategies, including rotational cattle/sheep grazing and conventional mowing.
2) Develop and validate methodologies based on the DayCent® model to assess agrivoltaic impacts, for future development of a solar industry-specific methodology to verify ecosystem services in utility-scale photovoltaic systems.

MATERIALS & METHODS

- Grassland was managed by periodical sheep grazing or mowing treatments, each with three sampling locations in Silicon Ranch® Bancroft Station (102.5 MW and ~1,200 acres) in southwest Georgia.
- Volumetric water content, soil temperature, and weather data were measured by TEROS 11 and ATMOS 41 (METER Group) per 15-45 minutes at four zones (Between, East Edge, Under, West Edge) within solar arrays of each location (Fig. 1). Soil texture, bulk density were measured at three depths.
- A process-based ecosystem model, DayCent, was modified for agrivoltaic system, connecting the four zones for water exchanges using Inter-Process Communication (Fig. 1). Soil saturated conductivity, minimum rain for counting raining hours, crop coefficient (Kc), and shading effect on max./min. surface temperature were calibrated using the mowing treatment.



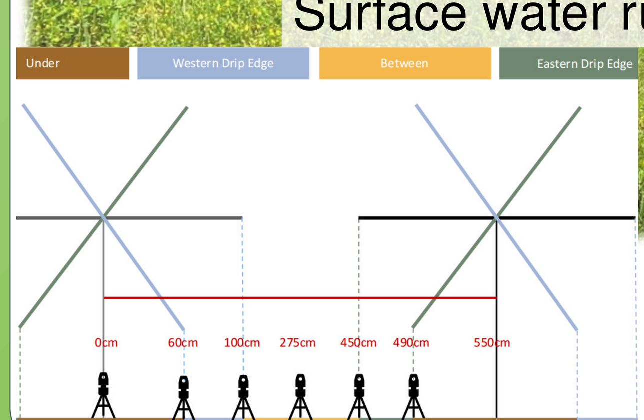


Figure 1. Agrivoltaic DayCent Concept Map.

RESULTS

Table 1. Comparison of Agrivoltaic and default DayCent (isolated zones) for simulating soil volumetric water content and temperature at 3 soil depths and 4 zones of 2 treatments over the first year. Metrics include adjusted coefficient of determination (Adj. R^2), root mean square error (RMSE), and mean daily standard deviation (SD, n=3). Color bars highlight metric comparisons.

			Volumetric Water Content					Soil Temperature				
			Agrivoltaic DayCent		Default DayCent		Measurement	Agrivoltaic DayCent		Default DayCent		Measurement
Treatment	Zone	Depth	Adj. R^2	RMSE	Adj. R^2	RMSE	SD	Adj. R^2	RMSE	Adj. R^2	RMSE	SD
Grazed	Between	10cm	0.78	0.03	0.77	0.02	0.03	0.98	1.48	0.98	1.48	0.81
Grazed	Between	20cm	0.75	0.04	0.75	0.04	0.02	0.92	2.02	0.92	2.04	0.79
Grazed	Between	30cm	0.77	0.04	0.77	0.04	0.01	0.77	3.27	0.77	3.28	0.75
Grazed	East	10cm	0.78	0.02	0.73	0.03	0.03	0.98	1.33	0.98	1.33	0.58
Grazed	East	20cm	0.75	0.04	0.72	0.04	0.02	0.94	1.70	0.94	1.70	0.55
Grazed	East	30cm	0.40	0.04	0.71	0.04	0.01	0.80	2.92	0.80	2.92	0.60
Grazed	Under	10cm	0.64	0.04	0.22	0.04	0.05	0.98	1.28	0.99	1.30	0.47
Grazed	Under	20cm	0.47	0.03	0.03	0.05	0.05	0.96	1.46	0.96	1.38	0.35
Grazed	Under	30cm	0.32	0.03	0.00	0.06	0.03	0.85	2.70	0.85	2.65	0.33
Grazed	West	10cm	0.77	0.02	0.68	0.03	0.02	0.99	1.37	0.99	1.37	0.61
Grazed	West	20cm	0.79	0.01	0.54	0.03	0.03	0.95	1.72	0.95	1.72	0.63
Grazed	West	30cm	0.54	0.02	0.34	0.03	0.02	0.82	2.95	0.82	2.95	0.52
Mown	Between	10cm	0.73	0.03	0.75	0.03	0.03	0.97	1.74	0.97	1.75	0.35
Mown	Between	20cm	0.61	0.03	0.65	0.02	0.02	0.90	2.60	0.90	2.61	0.37
Mown	Between	30cm	0.41	0.03	0.49	0.02	0.03	0.74	3.75	0.73	3.76	0.29
Mown	East	10cm	0.77	0.02	0.72	0.02	0.01	0.98	1.35	0.98	1.33	0.31
Mown	East	20cm	0.62	0.02	0.58	0.02	0.02	0.92	2.11	0.92	2.11	0.28
Mown	East	30cm	0.31	0.03	0.50	0.02	0.01	0.77	3.24	0.77	3.24	0.24
Mown	Under	10cm	0.54	0.03	0.11	0.05	0.02	0.99	1.52	0.99	1.59	0.24
Mown	Under	20cm	0.37	0.02	0.04	0.05	0.02	0.95	1.83	0.95	1.89	0.27
Mown	Under	30cm	0.19	0.02	0.00	0.05	0.03	0.82	2.96	0.82	3.00	0.23
Mown	West	10cm	0.73	0.02	0.61	0.03	0.03	0.99	1.55	0.99	1.54	0.31
Mown	West	20cm	0.70	0.02	0.49	0.03	0.01	0.93	2.16	0.93	2.15	0.33
Mown	West	30cm	0.36	0.02	0.32	0.04	0.02	0.79	3.28	0.79	3.28	0.22

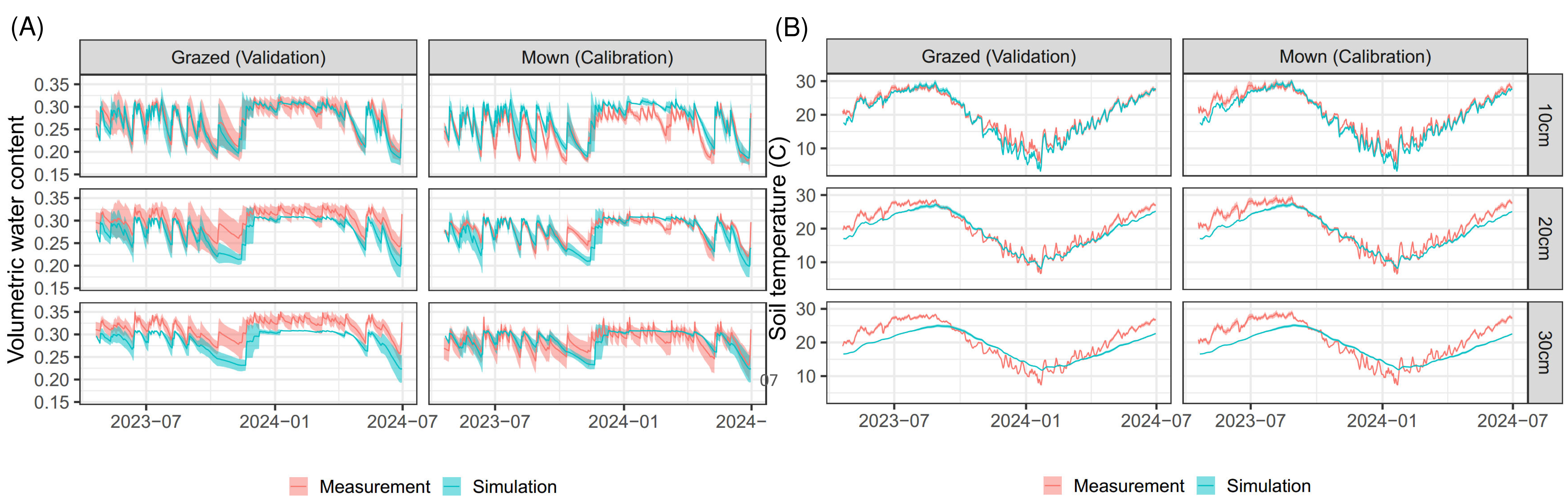


Figure 2. Agrivoltaic-DayCent simulated soil volumetric water content (A) and temperature (B) area-weighted averages over the four zones within the solar array of a grassland agrivoltaic plant. Shaded area shows standard deviation from the four zones within solar arrays.

DISCUSSION

- By connecting zones within solar arrays, Agrivoltaic DayCent had improved zonal soil water simulations in 0-10cm and 10-20cm depths (adjusted R^2 = 0.37-0.79; RMSE = 0.01-0.04 %; Table 1), especially for Under and West zones. Soil temperature of Agrivoltaic DayCent was similar to the default DayCent that simulated isolated zones (adjusted R^2 = 0.74-0.99; RMSE = 1.28-3.75 °C).
- Agrivoltaic DayCent simulations of soil water and temperature aligned well with the seasonal patterns and dynamic zonal variations within solar arrays (Fig. 2). New algorithms integrated in DayCent, which connects surface and subsurface water exchanges between zones, increased accuracy in soil water prediction.
- Challenges remain in deeper soil simulations of water and temperature. Further calibrations of the Agrivoltaic DayCent model for biomass and flux will be conducted using ongoing vegetation biomass, eddy covariance, and soil measurements.

ACKNOWLEDGEMENT

We thank the U.S. Department of Energy for the financial support.