DeVincentis A, Solis S, Rice S, Zaccaria D, Snyder R, Maskey M, Gomes A, Gaudin A, Mitchell J. 2022. Impacts of winter cover cropping on soil moisture and evapotranspiration in California's specialty crop fields may be minimal during winter months. Calif Agr. https://doi.org/10.3733/ca.2022a0001

Experimental design

Table S1. Research site description and experimental design details for agricultural fields in California's Central Valley where soil moisture and evapotranspiration of winter cover crops was monitored.

Site	Lat	Long	Soil texture[1]	Average annual rainfall (in)[2]	Number of years growing cover crops or resident vegetation before the beginning of the study	Cover crop details			Approximate size of control area (acres)	Control design	Number of neutron probe access tubes	Evapotranspiration monitoring with surface renewal technique
						Type	Species	Density (lbs/ acre)				
Davis	38.546622	-121.872681	Rincon silty clay loam	18.0	0	Annual seeded	Triticale, Faba bean, Winter peas & Vetch	~125	2	Partial field	8	yes
Dixon	38.509719	-121.786598	Yolo loam, 0 to 4 percent slopes, MLRA 17 (Yo)	18.0	0 - 5	Annual seeded	16-species mix including: Phacelia, Balansa clover, Crimson clover, Mustard, Daikon radish, Annual ryegrass, Common vetch, Purple vetch, Cayuse oats, Triticale, Peas	65- 76	1	Adjacent field	8	
Firebaugh	36.732281	-120.608144	Cerini clay loam, 0 to 2 percent slopes (479)	7.5	15	Annual seeded	Triticale, Faba bean & Peas in years 1 and 2; Rye, Barley & Cayuse oats in year 3	40 - 80	65	Partial field	8	
Five Points	36.337122	-120.115697	Panoche clay loam, 0 to 2 percent slopes (442)	6.5	0	Annual seeded	Triticale, Faba bean & Winter peas	~125	4	Adjacent field	20	yes
Chico	39.949271	-122.126535	Kimball loam, 3 to 8 percent slopes (KpB)	22.5	0 - 5	Annual seeded	White mustard, Yellow mustard, Daikon radish, & Crimson clover	50 - 75	2	Partial orchard block	8	
Merced	37.372128	-120.506192	San Joaquin sandy loam, 0 to 3 percent slopes, MLRA 17 (ScA)	13.0	0	Annual seeded	2 cover crop mixes were used. Mix A: Bracco white mustard, Daikon radish, Merced ryegrass, Berseem clover, Common vetch; Mix B: Bracco white mustard, Daikon radish, Nemix yellow mustard, Common yellow mustard, Canola	Mix A: 8; Mix B: 50	10	Partial orchard block	8	
Arvin	35.201800	-118.791607	Whitewolf loamy sand, 2 to 5 percent slopes (203)	9.0	0	Annual seeded	Bracco white, Daikon radish, Merced ryegrass, Berseem clover, Common vetch	50	8	Partial orchard block	8	
Orland	39.671139	-122.195683	Tehama silt loam, 0 to 3 percent slopes, MLRA 17 (Tm)	18.0	0 - 5	Resident vegetation	Grasses	NA	3	Partial orchard block	8	

Durham	39.611781	-121.820783	Conejo clay loam, 0 to 1 percent slopes (420)	22.5	0 - 5	Resident vegetation	Filaree, Chickweed, & Malva (Cheeseweed)	NA	7	Partial orchard block	8	
Shafter	35.525953	-119.319850	Wasco sandy loam (243)	5.5	over 20	Resident vegetation	Grasses & Filarees	NA	3	Partial orchard block	8	

[1] Data source: https://casoilresource.lawr.ucdavis.edu/gmap/

[2] Data source: https://databasin.org/maps/new/#datasets=3fac6542263d4972af2f55dc13737f3

Data collection

Soil moisture

Neutron hydroprobes measure soil moisture based on emissions of 'fast' neutrons by a radioactive source through radioactive decay. The neutrons collide with atoms in the surrounding soil and a detector measures the quantity of low-energy neutrons that is lost energy through collision with hydrogen. The result is a count rate of slowed neutrons that is proportional to the density of hydrogen atoms near the radioactive source, which provides a proxy for soil moisture.

Gravimetric sampling events were collected at 0.15, 0.30, 0.60, 0.90, and 1.2 m using a 75 mm auger when site conditions permitted. Gravimetric water content (GWC, g water/ g soil), describes the mass of water per mass of dry soil and was calculated using a soil sample's wet and dry weights based on Equation 1. The samples' wet weights were measured on-site after samples were packaged in metal tins. The samples' dry weights were measured in the laboratory after drying at 110 degrees Celsius for a minimum of 72 hours or until the soil samples reached a constant weight.

$$Equation\ \ 1: GWC = \frac{\text{wet weight of soil (g)} - \text{dry weight of soil (g)}}{\text{dry weight of soil (g)}}$$

Evapotranspiration

The REB method calculates the latent heat flux (LE) as the residual from data collected with research-scale micro-meteorological measurements of net radiation, sensible heat flux and ground heat flux, which are main parameters of the surface energy balance. Micro-meteorological measurements are among the most direct and viable approaches to obtain information on actual water use by an area of interest. They are also more beneficial over point measurements (i.e. lysimeters, soil moisture, plant water status, etc.) because they provide information over a larger observed study area.

ET_a of the cover cropped and clean-cultivated plots were determined according to Equation 2 where LE is the latent heat flux (MJ d^{-1} m^{-2}), R_n is net radiation (MJ d^{-1} m^{-2}), G is soil heat flux density (MJ d^{-1} m^{-2}) and H is sensible heat flux (MJ d^{-1} m^{-2}). Once LE was determined, ET_a was then calculated using Equation 3 where the coefficient λ = 2.45 MG kg^{-1} and corresponds to the amount of energy necessary to vaporize 1 mm of water from a 1.0 m^2 surface area (Allen et al. 1998). ET_a rates obtained from Equation 3 in kg d^{-1} m^{-2} are equivalent to mm d^{-1}.

$$Equation\ 2{:}\ LE = R_n - G - H$$

$$Equation\ 3{:}\ ET_a = \frac{LE}{\lambda}$$

In the present field study, measurements of the surface energy balance parameters were collected using Medium Lite Flux stations consisting of: (a) a net radiometer (NRLite2, Kipp & Zonen Inc., Delft, The Netherlands) to measure R_n approximately 2 m above the maximum cover crop's canopy height; (b) two 76.2-μm diameter Chromel-Constantan thermocouples (model FW3 from Campbell Scientific, Logan, UT, USA), both mounted approximately 1.3 m above the cover crop's canopy to measure H at 10 Hz frequency with the SR methodology; (c) two soil sensor packages to calculate G, each consisting of a soil heat flux plate (HFT3, REBS, Bellevue, WA, USA) and two averaging soil temperature thermocouple probes (Tcav, Campbell Scientific Inc., Logan, UT, USA).

For each soil sensor package, the ground heat flux plate sensors were installed horizontally at 0.05 m below the surface, whereas the probes of the Tcav sensors were installed at an angle from 0.04 to 0.01 m depth below the ground surface and were distributed on both sides of the HFT3 sensor in a line perpendicular to the inter-rows of the future tomato plants' rows. One of the G packages was installed in the row and the second G package was located half a way between the plant row and the first soil package. The ground heat flux at the soil surface was estimated using a continuity equation using the mean HFT3 measurements and the change in temperature from 0.04 to 0.01 m (De Vries 1963).

All of the above-ground individual sensors were mounted on a structure consisting of two metal fencing posts, driven approximately 1 m into the ground, connected with a metal cross arm. The height of the mounting structure was approximately 1 m above the ground. Power for all sensors was provided by a 40-w solar collector panel connected with a 100 A battery for storage. The micro-meteorological data were collected, stored, and processed with a CR1000 data logger (Campbell Scientific, Logan, UT, USA). During the last two weeks of data collection, prior to termination of the winter cover crop, the research team installed three-dimensional (3-d) sonic anemometers (RE, RM Young Inc., Traverse City, MI, USA) at both the cover cropped and clean-cultivated plots to collect parallel measurements of the sensible heat flux density (H) with the eddy covariance (EC) and SR methodologies.

Data processing

Soil moisture

To determine how winter cover crops affected soil moisture during the winter season, researchers first digitized all soil water content datasets by transferring data field notebooks to .csv files.

Data were entered manually, and quality controlled by having every neutron probe count and soil sample weight input and later verified against the paper copy by separate individuals. Data was further cleaned by removing any values that missed human detection and were clearly inaccurate, such as neutron probe counts with 6 or 3 digits.

Due to the diversity of geographic and managerial characteristics between sites, the analysis focused on individual sampling events and treated all data collection from a study site, at a specific depth, and on a particular day as a unique event. Data was subset into unique depth-date combinations for separate statistical analysis.

Evapotranspiration

First, data control was conducted for quality check to filter for expected and/or reasonable values, and exclude data corresponding to periods of power/voltage issue and rainfall. Gap-filling was also performed, which entailed linear interpolation for short periods of missing data and a lookup table for intermediate gaps. For more than 8 to 12 hours of missing data or when the missing data could not be reasonably gap-filled with the two previous methods, the corresponding daily values were removed from the series or flagged as not available.

The sensible heat flux values were calculated using the SR technique, which entails high frequency temperature readings, and with the EC technique for the periods when 3-d sonic anemometers were used to measure H in parallel with fine-wire thermocouples. As mentioned above, the researchers used Medium Lite Flux ET stations to measure surface energy balance parameters (R_n, G, H) over the course of the winter cover crop periods in 2017 and 2018. During the last two weeks of data collection in 2018, 3-d sonic anemometers were deployed to measure

H. Specifically, the data collected with the 3-d sonic anemometers were used to compute H using the EC methodology, while the data collected with the fine-wire thermocouples were used to determine uncalibrated H (H') using the SR technique. The sonic anemometer data was corrected by increasing the magnitude of the H estimate from the RM Young sonic anemometer by 12%, according to Kochendorfer et al. (2012).

The two sets of measurements enabled the calculation of a calibration factor (α) for H' measured with the fine-wire thermocouples using the SR methodology. The H' is highly correlated with H, and the α calibration factor was determined by computing the slope of the least-squares regression of H versus H' separately for positive and negative H'. Then, the product of α x H' provided an acceptable estimate of the half-hourly 3-d sonic H values. In this way, the research team could use Medium Lite Flux stations over the entire course of the cover crop growth season utilizing only thermocouples and the SR methodology to calculate half-hourly H' values. The H' values were then multiplied by the α factor to back-calculate the calibrated values of H for the entire duration of the data collection periods on both cover-cropped and clean-cultivated plots in 2017 and 2018.

For the periods when the 3-d sonic anemometers were used, the half-hourly LE was computed using Equation 2. The daily LE was then determined by summing the 48 half-hourly values of LE (MJ m^{-2}). For the periods when only Medium Lite Flux stations were used, the daily LE was determined by summing the 48 half-hourly values of LE computed using Equation 2 and replacing H with α H'. Finally, the daily ET_a (mm d^{-1}) were computed using Equation 3.

References

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