How do moisture patterns in subsurface drip irrigation impact soil health in organic systems?

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Background

- Subsurface drip irrigation (SDI) has become increasingly popular for many crops in California.
- In processing tomatoes, SDI is now used on 80-85% of total acreage (Fig 1) and ~67% of organic acreage.
- Though only ~5% of total acreage is organic, this is a very high value crop for organic growers in CA.
- Precision application of water into the root zone through drip emitters has improved water use efficiency.

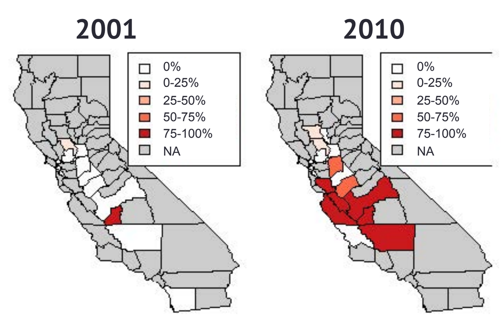


Fig 1: Percent of processing tomato acres under drip irrigation in 2001 and 2010.
(Image from Doug Parker, UC ANR. Data from CDWR Irrigation Surveys)

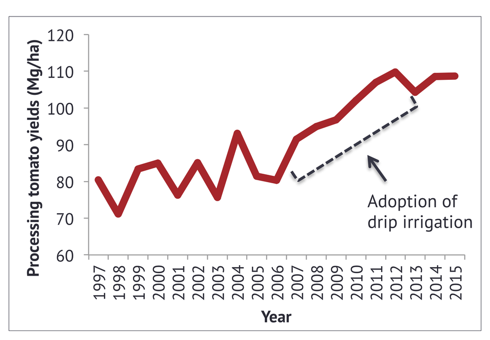


Fig 2: Annual statewide yields (Mg/ha) for processing tomatoes in California
(Data from CDFA Agricultural Statistics Reports)

- Targeted water and fertilizer use in conventionally managed systems has spurred an upward trend in annual yields statewide (Fig 2).
- Fertility sources in organic fields, however, rely on microbially-driven mineralization, making precision management with SDI difficult in these systems.
- With only a small volume of soil wetted by drip lines, limited moisture in surface soils may affect other activities performed by microbes, such as C processing and aggregate formation.

Are we reducing soil health by irrigating and fertilizing with only the plant and not the soil in mind?

Objectives

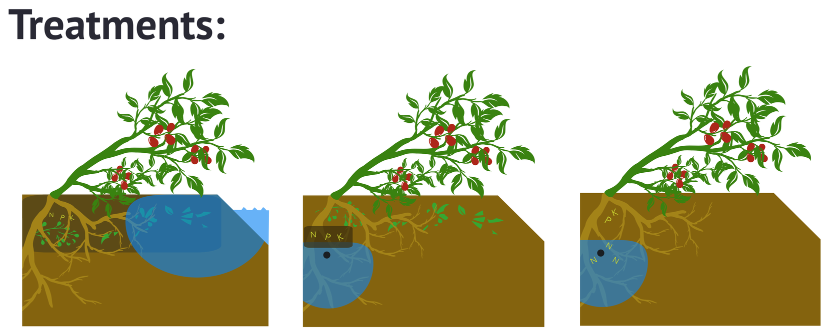
- Compare **wetting patterns** from subsurface drip and furrow irrigation
- Analyze the effects of different wetting patterns and agroecosystem management (organic vs. conventional) on **soil health parameters**:
  - Microbial biomass carbon
  - Water-stable aggregates
- Evaluate the effects of irrigation and fertility management on **crop yields**, **plant biomass production**, **water use efficiency**, and **weed pressure.**

Methods

Location:

- UC Davis's Russell Ranch Sustainable Agriculture Facility provides a unique opportunity for long-term field research with commercial-scale farming operations
- All measurements presented here are from Summer 2017.

Treatments:

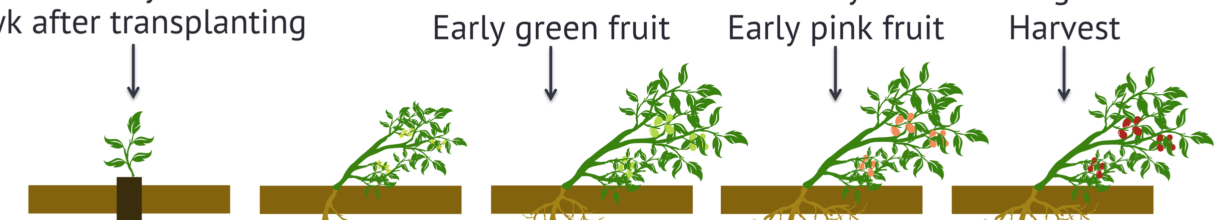


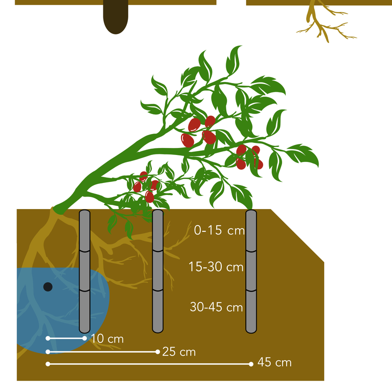
Furrow-irrigated organic | **Drip-irrigated organic** | **Drip-irrigated conventional**

- Organic: Poultry manure compost & cover crops
- Conventional: Mineral fertilizer applied at planting and through fertigation
- Treatments were replicated 3x in 1-acre plots
- Fertility treatments have been implemented for 24 years.

Sampling (2017):

May
1 wk after transplanting | June
Early green fruit | July
Early pink fruit | August
Harvest

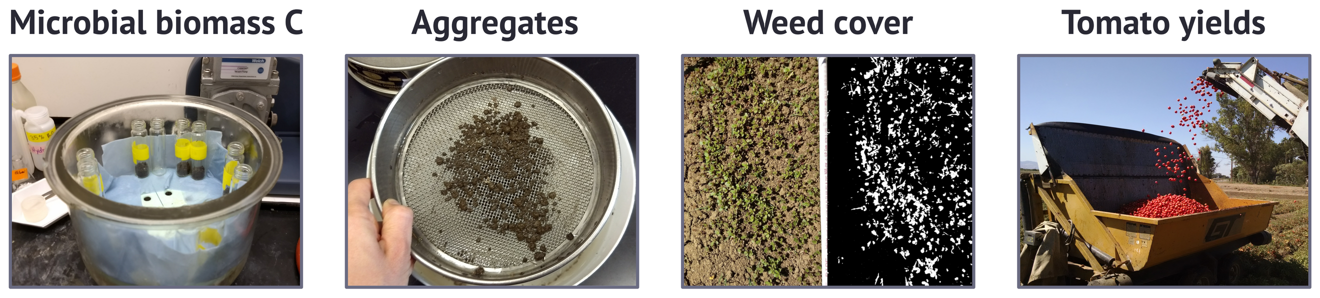




- Soil cores were taken at 3 distances from the center of the bed: 10 cm, 25 cm, and 45 cm
- Cores were then divided into 3 depths: 0-15 cm, 15-30 cm, and 30-45 cm
- Two sets of cores per plot were collected at each time point

Measurements:

Microbial biomass C | **Aggregates** | **Weed cover** | **Tomato yields**



- Chloroform fumigation
- Extracted with 0.5M K_2SO_4
- Analyzed for DOC

- Wet sieving at 50 reps min^{-1} for 2 min into 4 aggregate fractions

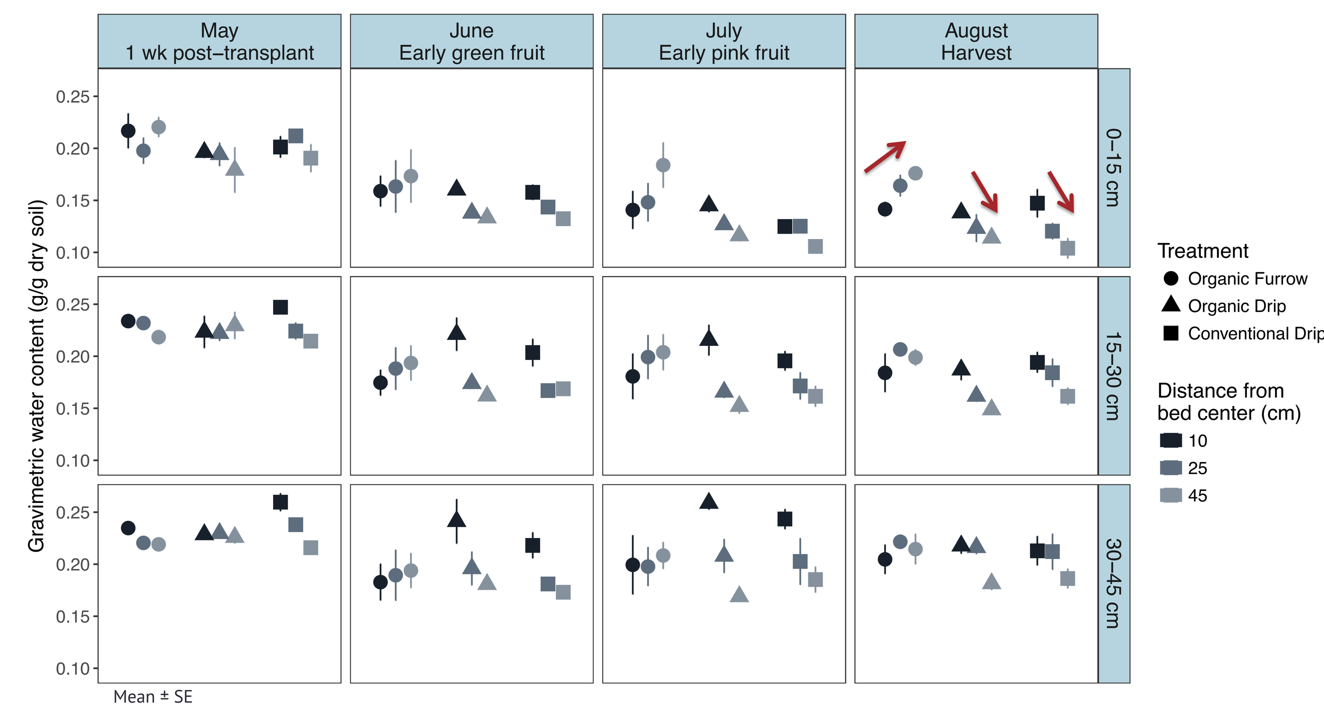
- Measured using the Canopeo app developed at Oklahoma State Univ.

- Machine/hand harvests for fruit & biomass

Results – Soil measurements

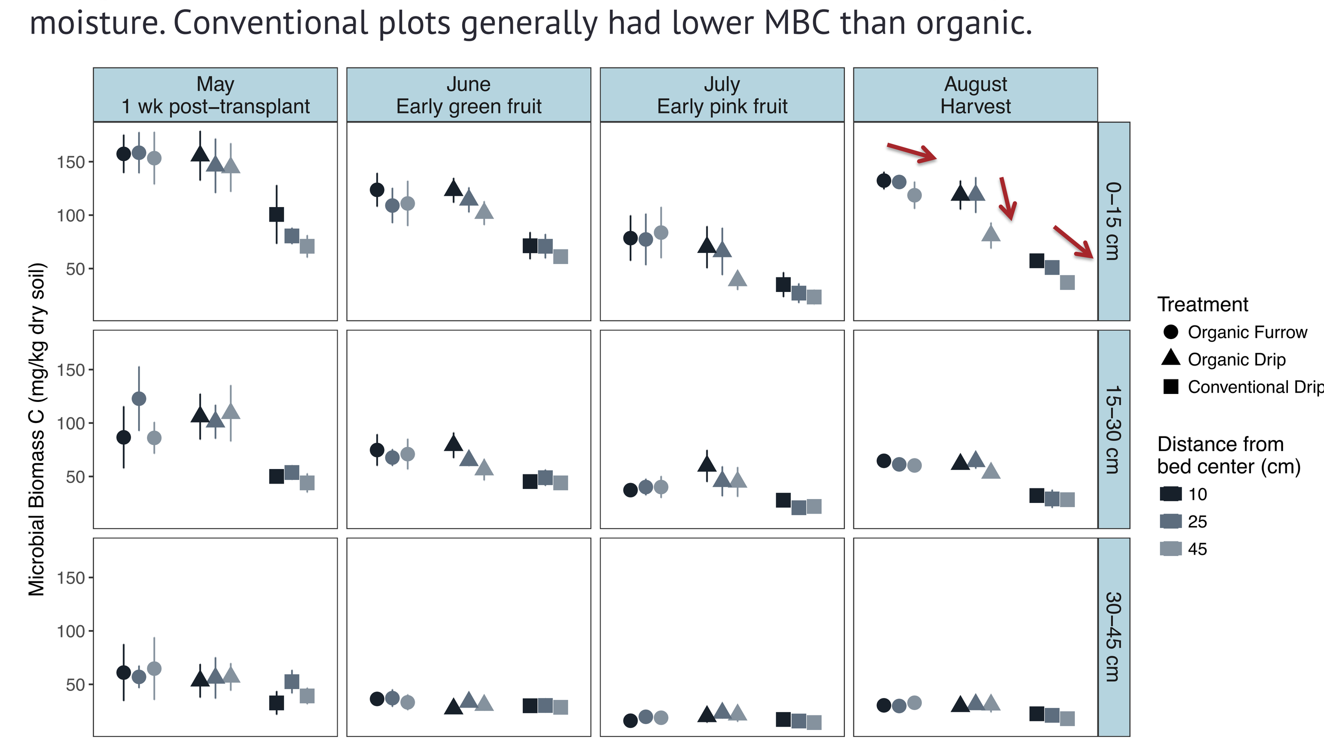
Gravimetric water content

As expected, drip-irrigated plots were much wetter near the center of the bed, particularly at depth, and were drier at the bed edge. Furrow-irrigated plots showed less of a moisture gradient and were wetter than drip plots at the surface.



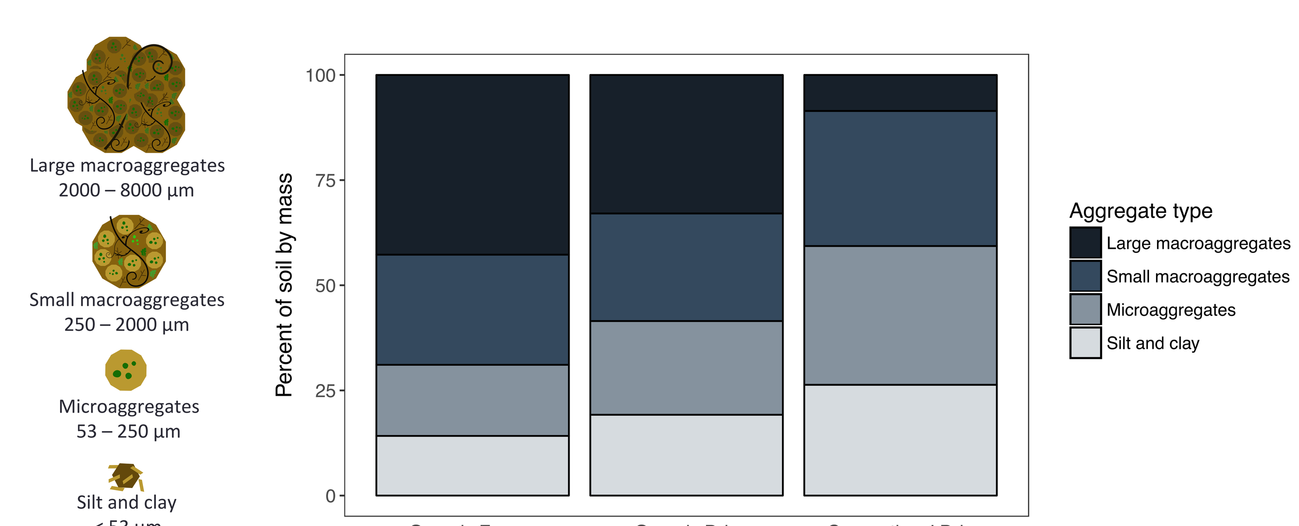
Microbial biomass carbon

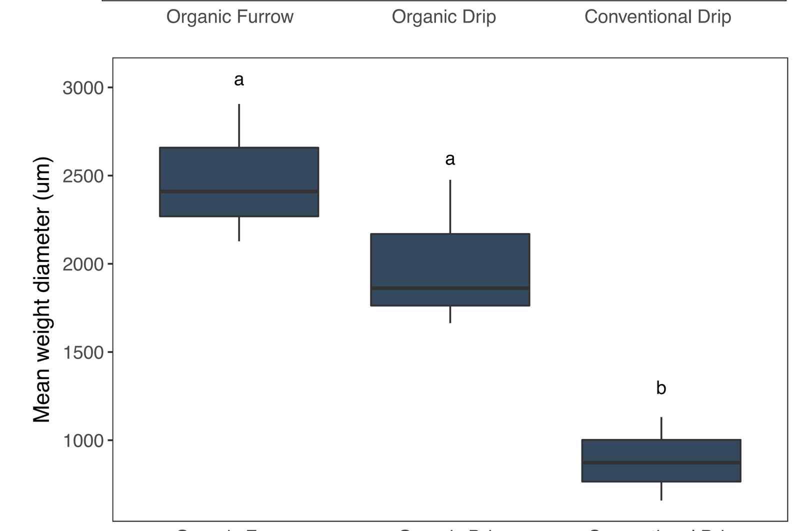
Both organic treatments began the season with similar MBC throughout the bed, but MBC in organic drip plots declined at the surface and edge of the bed, possibly due to lack of moisture. Conventional plots generally had lower MBC than organic.



Water stable aggregates

Organic plots had better aggregation than conventional. Organic drip plots had slightly lower aggregation than furrow-irrigated, but this was not significant (analyzed on July samples from 0-15 cm depth and 25 cm bed distance).

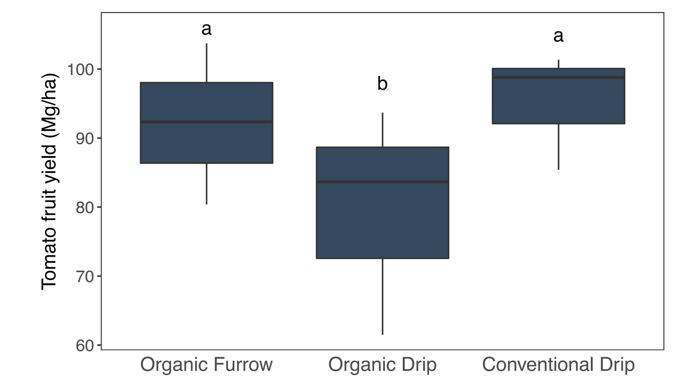




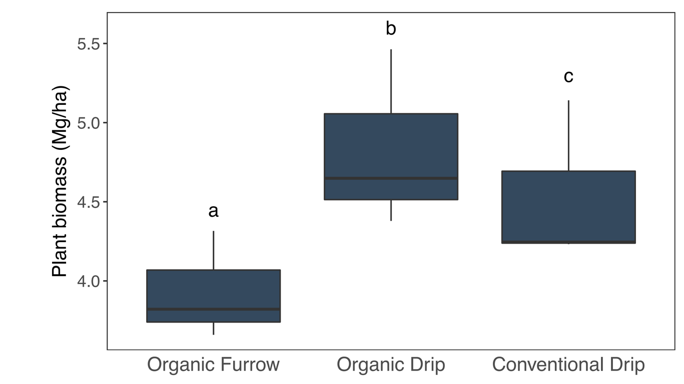
Mean weight diameter = $\sum_{i=1}^{4} P_i S_i$ where P_i is the weight percentage and S_i is the average diameter for an aggregate fraction

Results – Plant measurements

Crop yield



Crop biomass

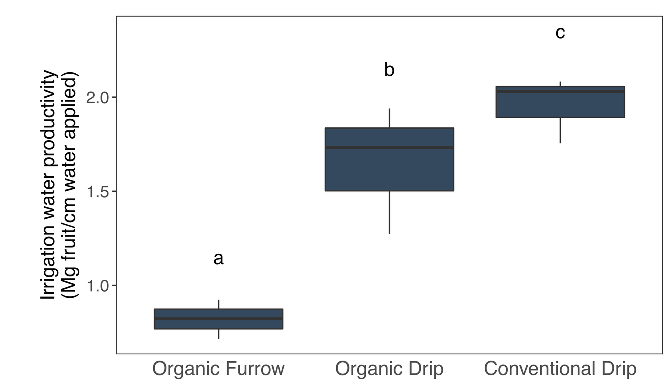


Water use efficiency

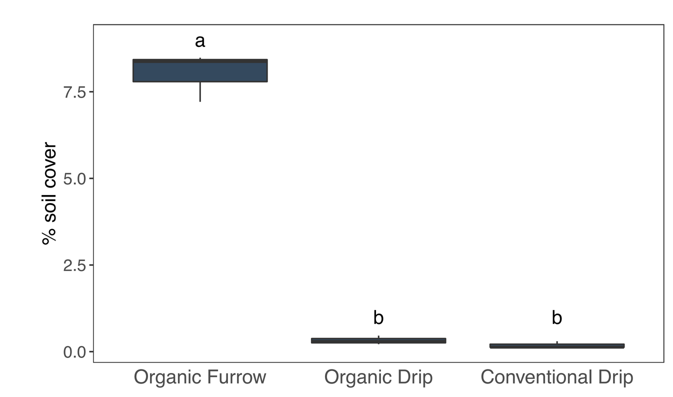
Furrow-irrigated plots had more than 2x the amount of water applied than drip-irrigated plots

Furrow: 114 cm | **Drip:** 48 cm

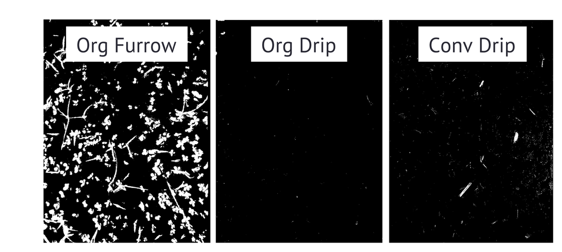
Therefore the productivity per drop of water is lower with furrow irrigation



Weeds



Measurements were taken in early June



Summary

- A steep moisture gradient and **drier surface soils** with drip irrigation likely contributed to **declines in microbial biomass C** in the latter part of the season.
- Dry soils and reduced microbial activity may also cause a trend towards **poorer aggregation in drip plots**, though both organic treatments had more stable aggregates than the conventional treatment.
- Despite greater weed cover, **organic furrow out-yielded organic drip**, though **yield per drop of water was lower**. Greater biomass production in organic drip potentially indicates mistiming of nutrient availability.
- Conventional drip had the highest yields but the lowest aggregation and MBC.

Drip irrigation improves water use efficiency but can have negative impacts on soil health and microbes that are essential to organic systems.

Next Steps...

Follow up questions:

- Is microbial community composition affected by irrigation management?
- Do N mineralization and N availability differ between these systems?
- Are microbes in surface soil able to decompose C residues in fall after being without water for 4 months?

We will continue to investigate effects on soil microbial communities through:

- 16S rRNA and ITS sequencing
- Phospholipid fatty acid analysis (PLFA)

We are also measuring other soil properties including:

- EC and pH
- Total soil C and N
- Soil nitrate and ammonium
- Permanganate-oxidizable carbon (POXC)

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