Whole Orchard Recycling Effects on Long Term Carbon Sequestration and Soil Health in California Almond Orchards

UCDAVIS AGROECOLOGY Gaudin Lab

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Background

- Unproductive orchards are historically burned before replanting but aggressive climate change mitigation and adaption policies are calling for a change.

Whole orchard recycling (WOR), where whole trees (~60T C/ha) are ground and returned to the soil, may serve as a feasible alternative to capture carbon back into the soil while improving resilience of Almond orchards.

- California soils are historically low in organic matter and recycling biomass could provide a mean to: 1) significantly build up soil health and water conservation while 2) decreasing the cumulative GHG impacts associated with Almond production.

Woodchipping and soil incorporation

- We evaluated the long term climate smart potential of this practice:

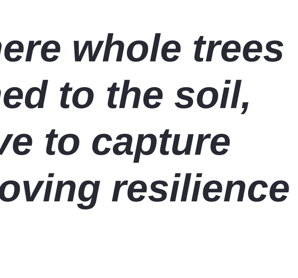
1- Can WOR significantly increase and sequester soil carbon in a Mediterranean irrigated systems over the long term?

2- What are the long term impacts on soil health parameters, including soil hydraulic properties and retention of irrigation water?

3- Does it improve orchard capacity to resist water shortages and increase water use efficiency?

4- Do these soil-driven changes significantly decrease the GHG footprint of Almond production?

Methods



- The trial was established in 2008 at the University of California Kearney Agricultural Research and Extension Center (Parlier, CA) on a sandy loam.
- Half of a 20-year old stone fruit orchard was recycled using land clearing equipment (grind treatment) and the other half was burned (burn treatment). Orchard was replanted with 3 almond varieties (Nonpareil, Butte, and Carmel) in a complete randomized block design.
- In 2017, a deficit irrigation trial was implemented for 28 days from 6/5 to hull split (7/3) on the Nonpareil variety (Fig.1)
  - **Regular irrigation (100% ET)**
  - **Deficit irrigation (80% ET)**

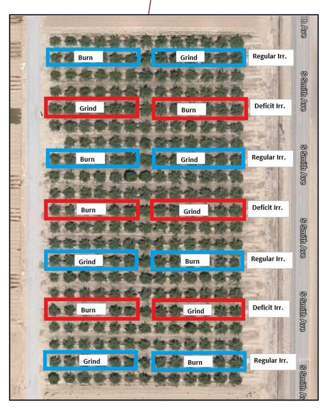
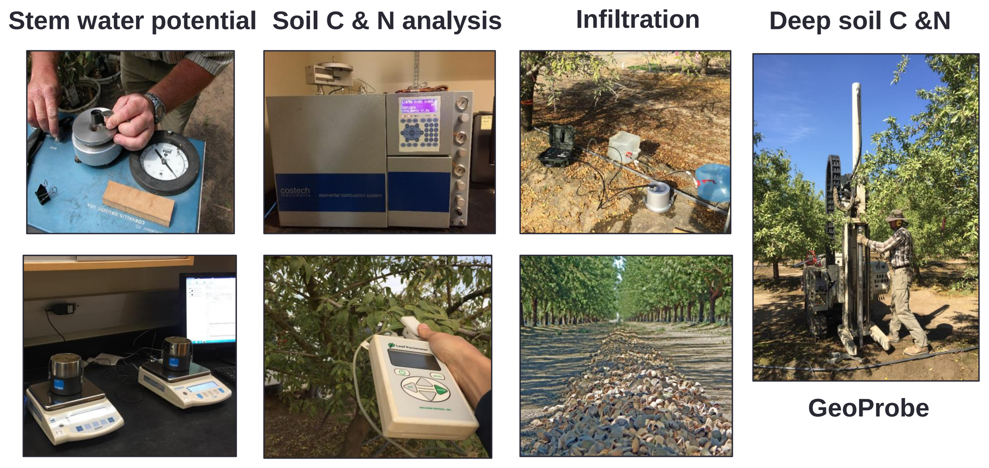


Figure 1. Plot layout and treatments.

Removing orchard using land clearing equipment (Iron wolf)

Measurements

- Soil samples were taken in spring of 2017 to measure soil health parameters (Physical, Chemical, Biological).
- Samples were collected from the berms in between two trees to a depth of 0-15 cm. A Life Cycle Assessment model developed for Almond was used to predict GHG footprint of WOR practice (Kendall et al., 2015).
- Data were analyzed using Proc Mixed (SAS). Significant differences when $P \leq 0.05$.



Soil C pools and fractions

- As expected, grind plots had more total C and N, organic C, labile C, and organic matter content compared to the burn treatment (Table 1).

Table 1. Soil chemical properties (0-15 cm).

Soil test results								
	Total C	Org. C	OM	Total N	Labile C (mg/kg)	K (mg/L)	EC	pH
	……………%……………						ds/m	
Grind	0.79	0.88	1.52	0.07	250	11.06	0.57	6.94
Burn	0.55	0.62	1.07	0.06	153	11.68	0.58	7.02
p Value	0.001	0.001	0.001	0.05	0.04	0.39	0.45	0.39
	Mg (meq/L)	Ca (meq/L)	Na (meq/L)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	B (mg/L)
Grind	1.46	3.02	0.89	9.69	9.25	9.03	33.23	0.3
Burn	1.43	3.05	0.72	9.64	9.26	6.79	28.01	0.31
p Value	0.47	0.48	0.03	0.47	0.5	0.01	0.11	0.4

P values ≤ *0.05* indicate significant difference between the treatments

- + 14.6 T/ha C stored in the grind plots across the soil profile compared to the burn; + 58% TC (0-30 cm) in the grind, 9 years after incorporation (Fig. 2).

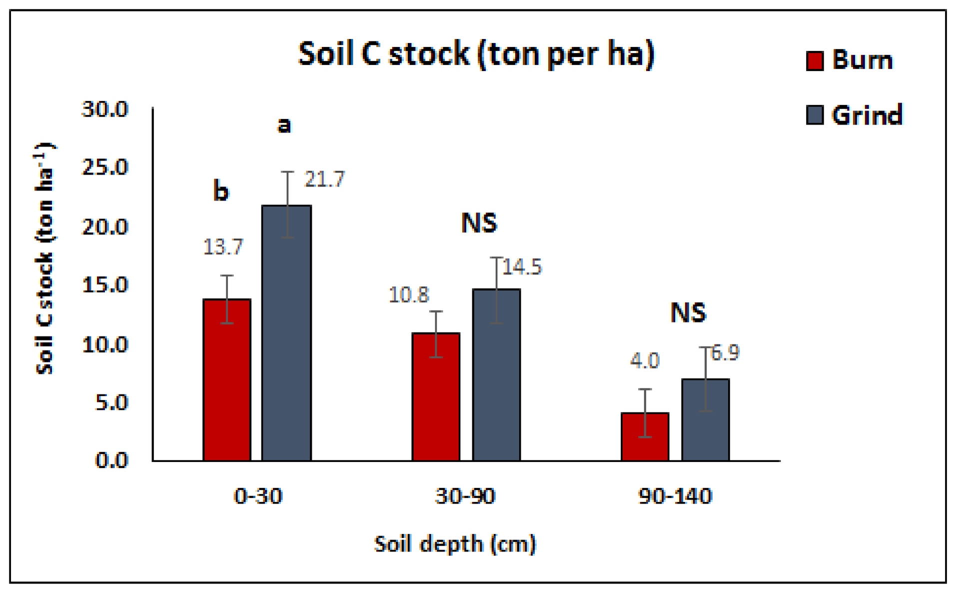


Figure 2. Total carbon stored in the grind and burn soil at different soil depths. Different letters indicate significant difference between the treatments (*P* ≤ *0.05*). NS, no significant difference.

- 14% greater C storage in large macroaggregates and 34% greater N content in the silt and clay fractions in the grind treatment (Fig. 3).

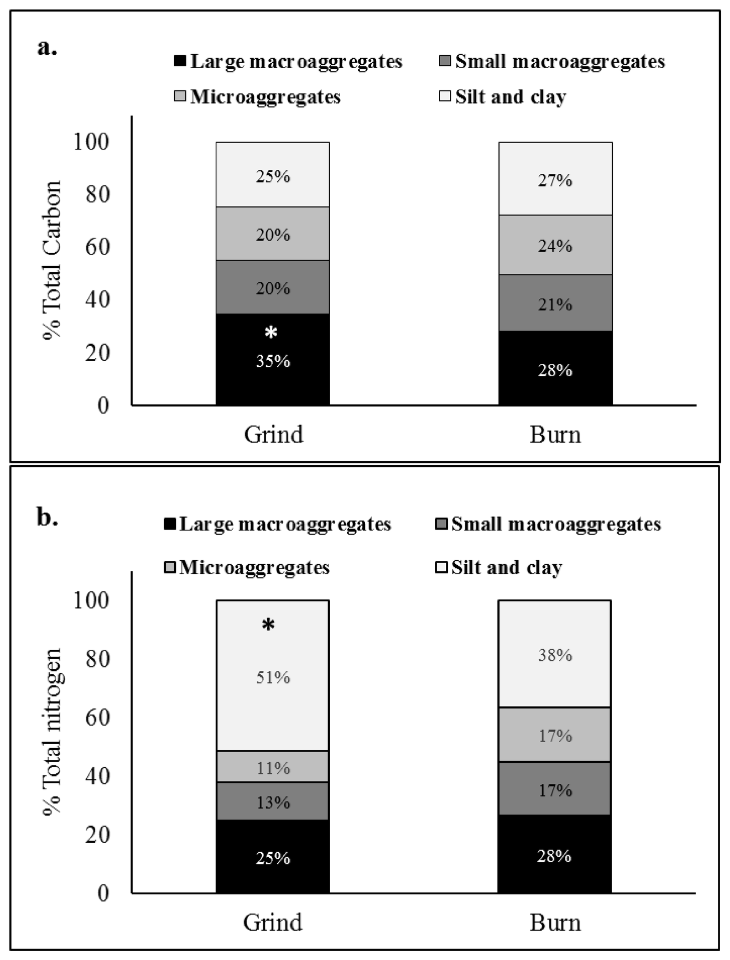


Figure 3. Total carbon and nitrogen content in different soil aggregate sizes (a and b, respectively), * Significant difference at *P* ≤ *0.05*.

- WOR increased soil microbial biomass, + 46% and + 14% (MBC and MBN, respectively) (Fig. 4).

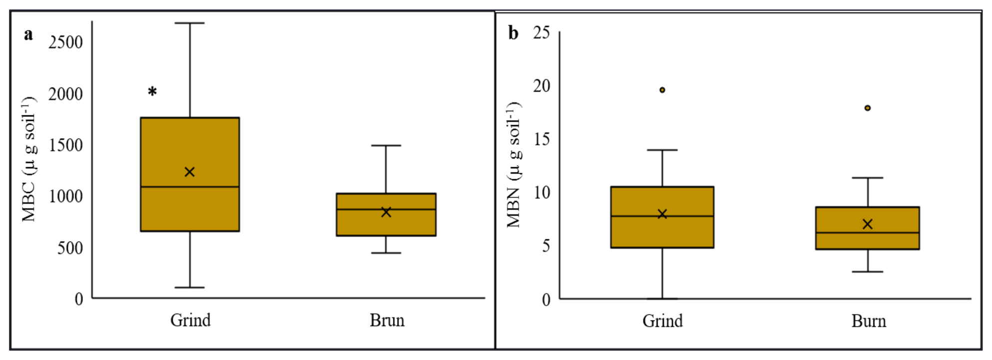


Figure 4. Microbial biomass carbon (a) and nitrogen (b) in the grind and burn treatments. *Significant difference at *P* ≤ *0.05*.

Soil biological activity

- Higher activity of carbon and nitrogen cycling enzymes in the grind plots (Fig. 5).

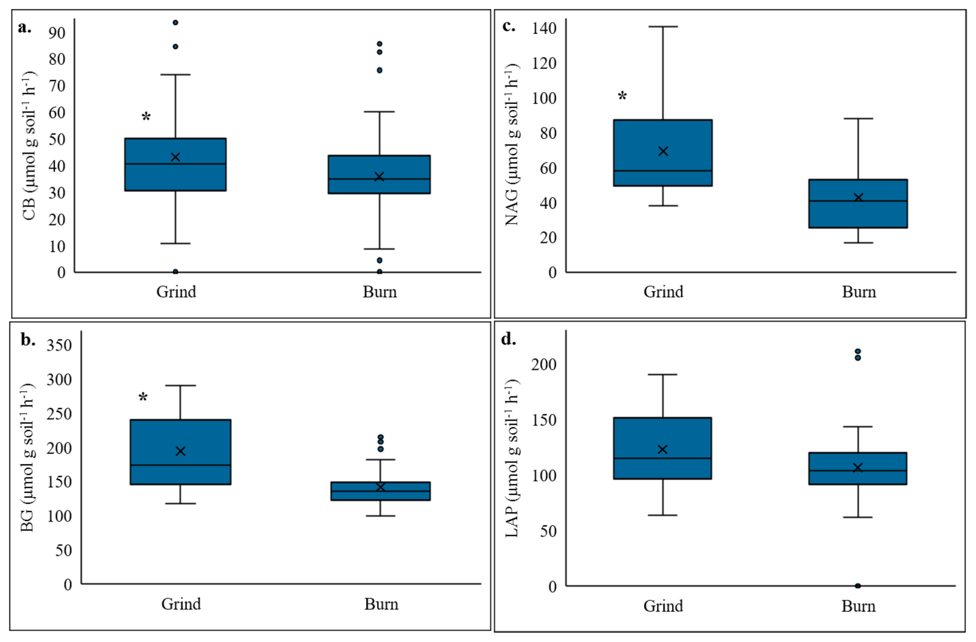


Figure 5. Soil enzyme activity in the grind and burn plots. * Significant difference at *P* ≤ *0.05*.

Soil aggregation and hydraulic properties

- WOR improved wet aggregate stability (+19%) compared to the burn treatment (Fig. 6).

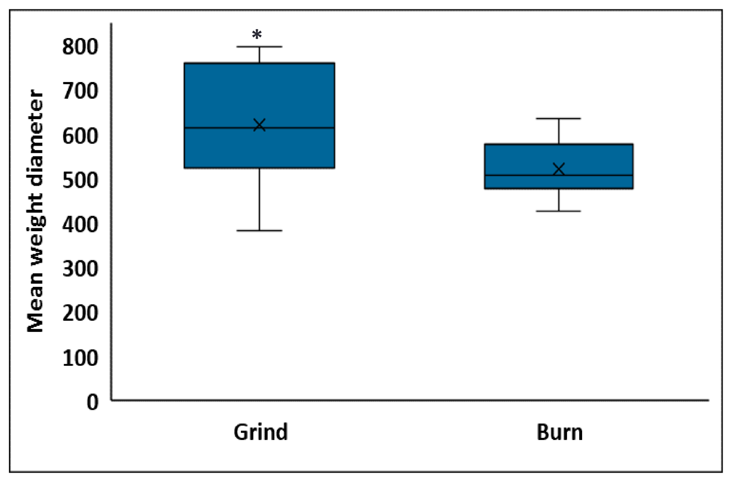


Figure 6. Mean weight diameter in the grind and burn treatments. *Significant difference at *P* ≤ *0.05*.

- Higher infiltration rate in the grind treatment compared to burn (a). 32% greater moisture retention at field capacity in the grind plots (b) (Fig.7).

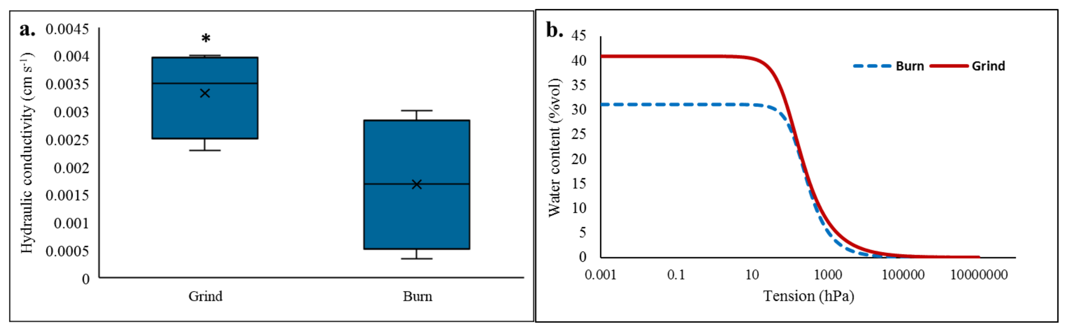


Figure 7. Infiltration rate, measured as hydraulic conductivity (a), and water retention curves (b) in the grind and burn treatments. *Significant difference at *P* ≤ *0.05*.

WOR improves tree water status

- Higher stomatal conductance (+ 9.7%) in the grind treatment under both irrigation scenarios (Fig. 8).

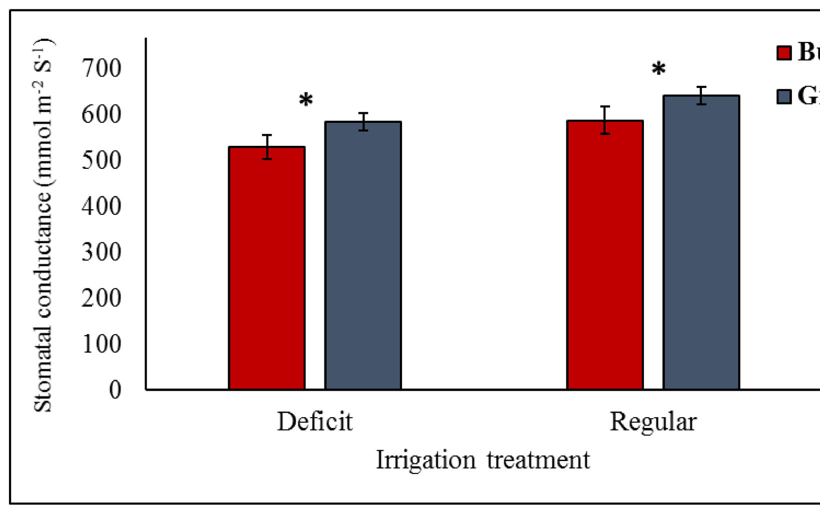


Figure 8. Effect of WOR and irrigation treatments on stomatal conductance. *Significant difference at *P* ≤ *0.05*.

- Less negative stem water potential in the grind plots on the most stressed day and a week after regular irrigation was resumed (Fig. 9).

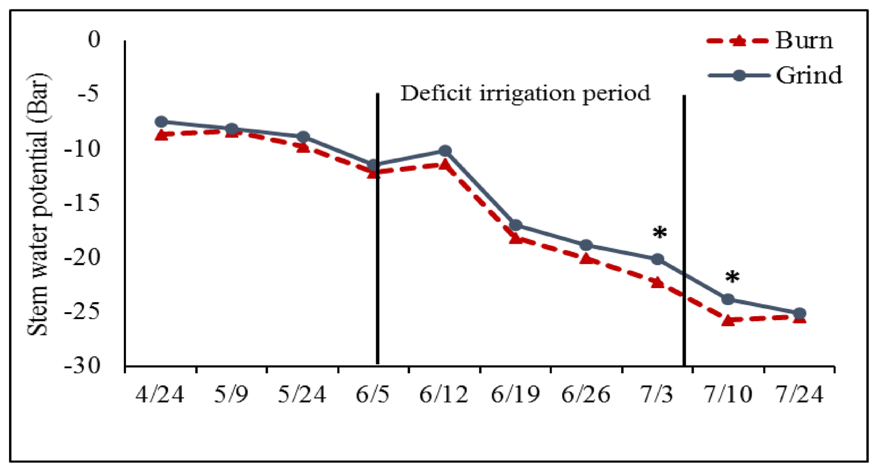


Figure 9. Stomatal conductance in the grind and burn treatments. *Significant difference at *P* ≤ *0.05*.

WOR increases yield and water use efficiency

Yield

- Yield benefits of the grind treatment under both regular and deficit irrigation treatments. Benefits were up to 20% in regular irrigation (Fig. 10).

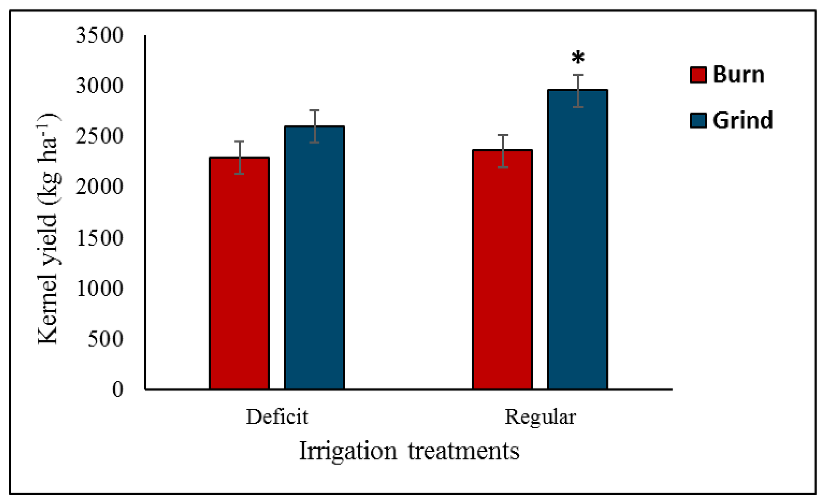
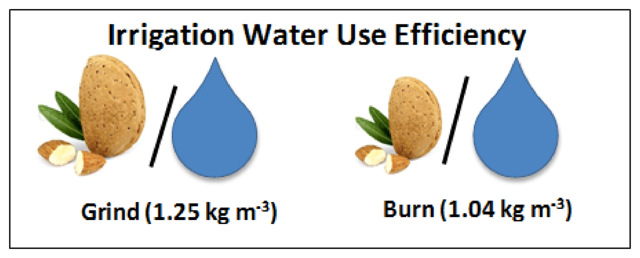


Figure 10. Kernel yield at WOR and irrigation treatments. *Significant difference at *P* ≤ *0.05* between grind and burn within irrigation treatments.

Irrigation water use efficiency (IWUE)



- 20% higher IWUE in the grind plots

Greenhouse gas footprint of almond production

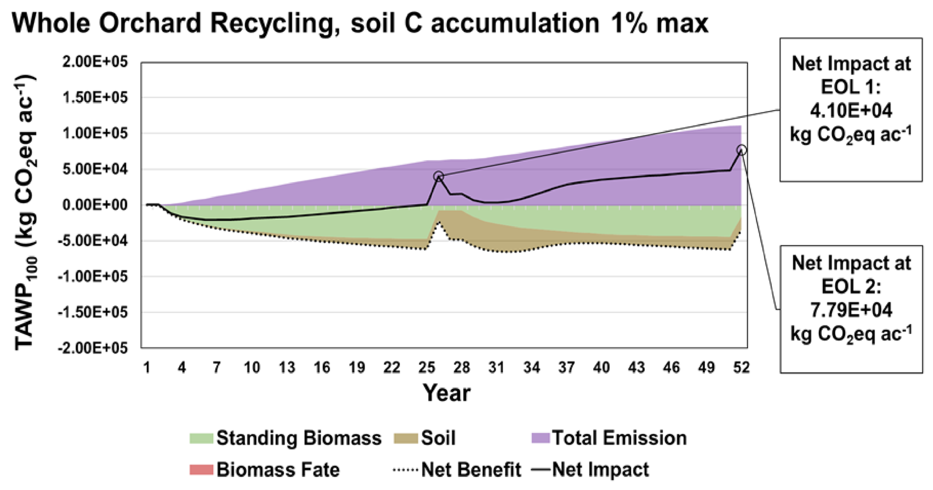


Figure 11. GHG footprint of almond production over two consecutive 25-year life cycles.

- Cumulative GHG impact (warming potential over a 100-year timeframe) of a recycled orchard was estimated as 77.9 T CO_2 eq per acre, compared to 52.3 T CO_2 eq per acre for biomass to energy and 145 T CO_2 eq per acre for open burning

Conclusions and next steps…

- Soil carbon content and labile pools remained significantly higher 9 years after biomass incorporation compared to open field burning.
- WOR provides an opportunity to improve soil health and its potentials to both conserve water and increase yields.
- Overall, Cumulative GHG impact is reduced by 46%.
- Studying long term and short term effects of whole orchard recycling on soil nitrogen retention is ongoing.
- In a soil column experiment using 15N labeled fertilizer, we will measure shifts in processes involved in soil N availability and retention such as gross N mineralization, immobilization, and leaching.

Acknowledgements

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california almonds AlmondBoard.com

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Reference:
Kendall et. al (2015). J. Ind. Ecol.

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