Organic Agriculture

Current Research and Perspectives on Yield Gaps

Houston Wilson and Krista Marshall

University of California - Organic Agriculture Institute

February 24, 2023 – USDA Agricultural Outlook Forum 2023

Outline for Today

Outline for Today

Current Scale/Scope of Organic Agriculture

Outline for Today

Current Scale/Scope of Organic Agriculture

What Do We Know About Organic Productivity / Yield Gaps?

Outline for Today

Current Scale/Scope of Organic Agriculture

What Do We Know About Organic Productivity / Yield Gaps?

Current Knowledge Gaps and Policy Recommendations

Outline for Today

Current Scale/Scope of Organic Agriculture

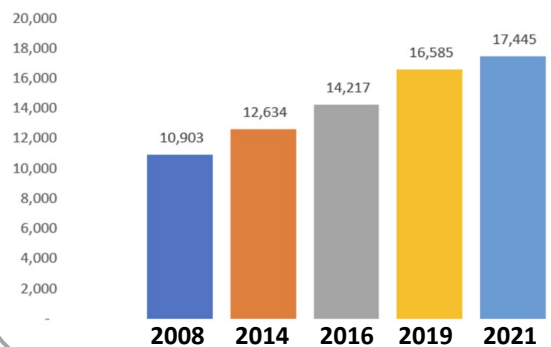
What Do We Know About Organic Productivity / Yield Gaps?

Current Knowledge Gaps and Policy Recommendations

Continued Expansion of Organic Production

Various Economic, Social and Environmental Benefits

Total Organic Farms



Top Crops (by value)

$1,633 mil	$1,509 mil	$1,221 mil	$629 mil	$424 mil
Milk	Broilers	Eggs	Apples	Grain corn

*Total sales grew 13% to $11.2 billion from 2019 to 2021

Top States: Certified Organic Acres	thousands
California	814
New York	331
Montana	320
Wisconsin	245
Texas	241

Various Marketing Activities

$2.02 Billion	$310 Million	$707 Million
Direct to Institution	Direct to Consumer	Value Added

USDA NASS Certified Organic Survey 2021 Summary
https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Organic_Production/index.php

Positive Impacts of Organic Farming

Biodiversity, Ecosystem Services, Impacts

Biodiversity Conservation

Increased species richness (~34%) and abundance (~45%) across multiple taxa

Soil Quality

Soil biology, carbon, fauna, organic matter etc.

Agroecosystem Function

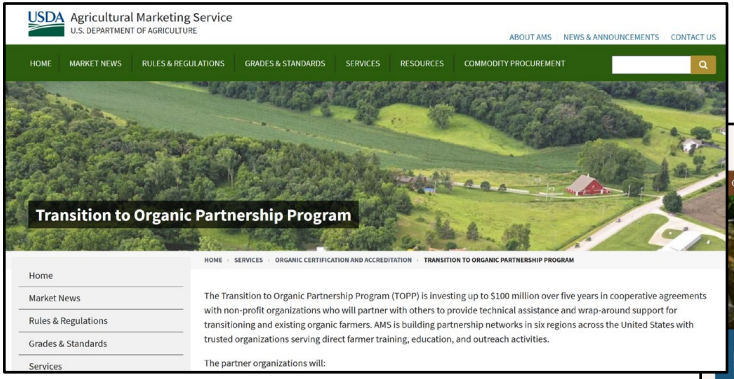
Biological Control, Nutrient Cycling, Pollination etc.

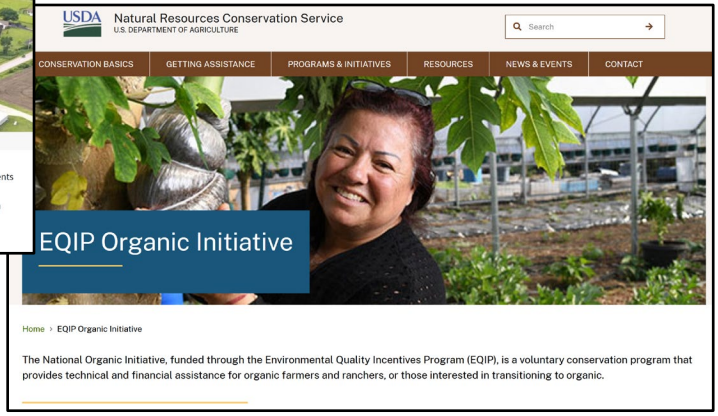
Reganold & Wachter 2016; Seufert & Ramankutty 2017; Roos et al. 2018; Smith et al. 2019; Gong et al. 2022; Tamburini et al. 2022

Photos (L-R): Matthew Tschumi, Science Breaker; Krista Marshall, UC OAI; Jennifer Hopwood, Xerces Soc.)

As Multiple Benefits Become Apparent, Increased State/Federal Support to Organic

- Organic Research and Extension Initiative (OREI)
- USDA Transition to Organic Partnership Program
- NRCS EQIP Organic Initiative

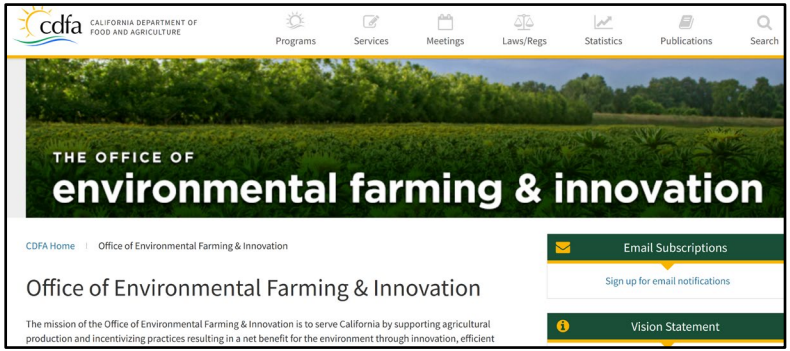


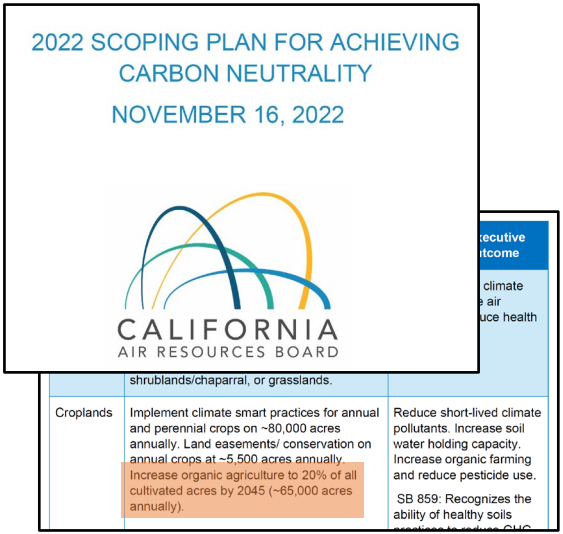


https://www.ams.usda.gov/services/organic-certification/topp
https://www.nrcs.usda.gov/eqip-organic-initiative

As Multiple Benefits Become Apparent, Increased State/Federal Support to Organic

- California Dept. Food & Agriculture (CDFA)
- CDFA Office of Environ. Farming & Innovation
- CA Air Resources Board – Scoping Plan 2022





https://www.cdfa.ca.gov/oefi/
https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents

Organic Agriculture

- Multiple Environmental, Social and Economic Benefits
- Growing Market Demand
- Increased Public Support

Outline for Today

Current Scale/Scope of Organic Agriculture

What Do We Know About Organic Productivity / Yield Gaps?

Current Knowledge Gaps and Policy Recommendations

Concerns About the Productivity of Organic Production Systems

Focus on Yield - Biodiversity Conservation, Hunger


THE WALL STREET JOURNAL.

Can Organic Food Feed the World?

Catherine Badgley says it's our best hope; Steve Savage says the yields are too low


Diversification practices reduce organic to conventional yield gap

Lauren C. Ponisio[1], Leithen K. M'Gonigle[1,2], Kevi C. Mace[1], Jenny Palomino[1], Perry de Valpine[1] and Claire Kremen[1]

[1]Department of Environmental Science, Policy, and Management, University of California, Berkeley, 130 Mulford Hall, Berkeley, CA 94720, USA
[2]Department of Biological Science, Florida State University, Tallahassee, FL 32306, USA


Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis

Olivia M. Smith[1], Abigail L. Cohen[2], Cassandra J. Rieser[3], Alexandra G. Davis[3], Joseph M. Taylor[2], Adekunle W. Adesanya[2], Matthew S. Jones[2,4], Amanda R. Meier[2,5], John P. Reganold[3], Robert J. Orpet[2,4], Tobin D. Northfield[2,4,6] and David W. Crowder[2]*

[1] School of Biological Sciences, Washington State University, Pullman, WA, United States, [2] Department of Entomology, Washington State University, Pullman, WA, United States, [3] Department of Crop and Soil Sciences, Washington State University, Pullman, WA, United States, [4] Tree Fruit Research and Extensions Center, Washington State University, Wenatchee, WA, United States, [5] Department of Entomology, University of Georgia, Athens, GA, United States, [6] Centre for Tropical Environmental Sustainability Science, James Cook University, Cairns, QLD, Australia

To promote food security and sustainability, ecologically intensive farming systems should reliably produce adequate yields of high-quality food, enhance the environment, be profitable, and promote social wellbeing. effects of ecologically intensive farming s considered variability. This represents a k on reliable provisioning of yields, profits,


Berkeley News

RESEARCH, SCIENCE & ENVIRONMENT

Can organic crops compete with industrial agriculture?

By Sarah Yang, Media Relations | DECEMBER 9, 2014

Tweet | Share 112 | Reddit | Email


The Guardian

Can we feed 10 billion people on organic farming alone?

John Reganold

What is Known About Organic Yields?

Various Meta-Analyses to Evaluate

Drawing Upon Hundreds of Scientific Studies

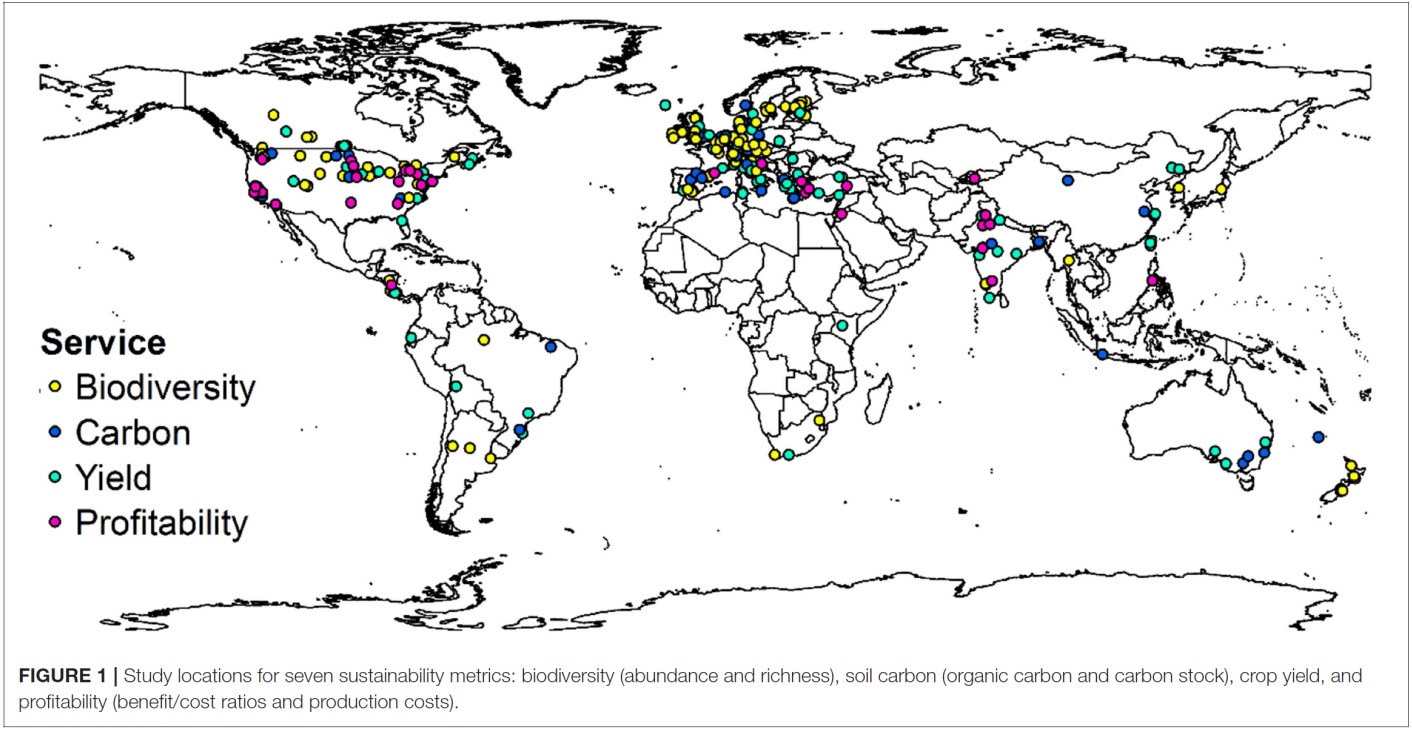


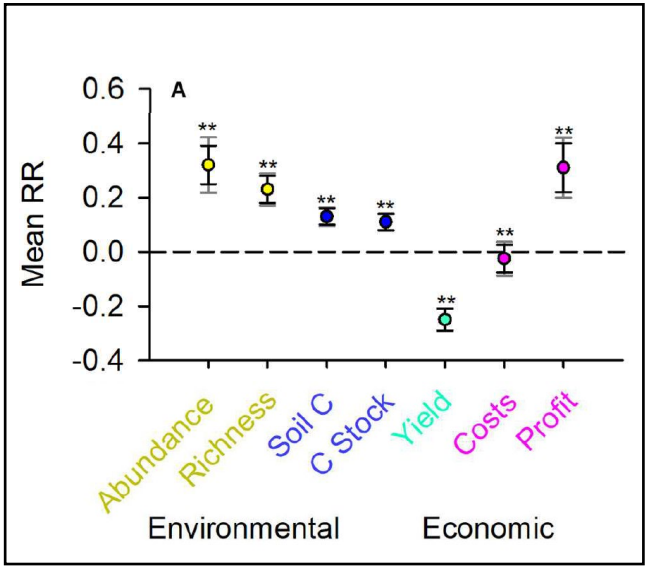
FIGURE 1 | Study locations for seven sustainability metrics: biodiversity (abundance and richness), soil carbon (organic carbon and carbon stock), crop yield, and profitability (benefit/cost ratios and production costs).

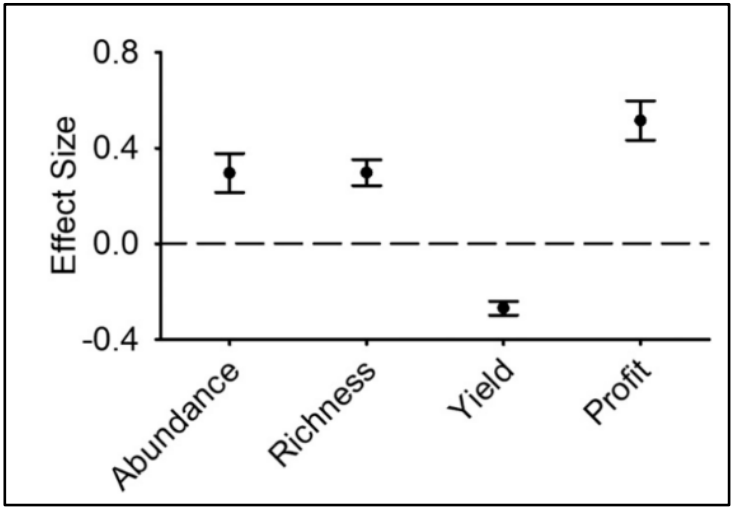
Smith et al. 2019a "Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis." *Frontiers in Sustainable Food Systems*

What is Known About Organic Yields?

Various Meta-Analyses to Evaluate

Organic yields ~20% lower than conventional





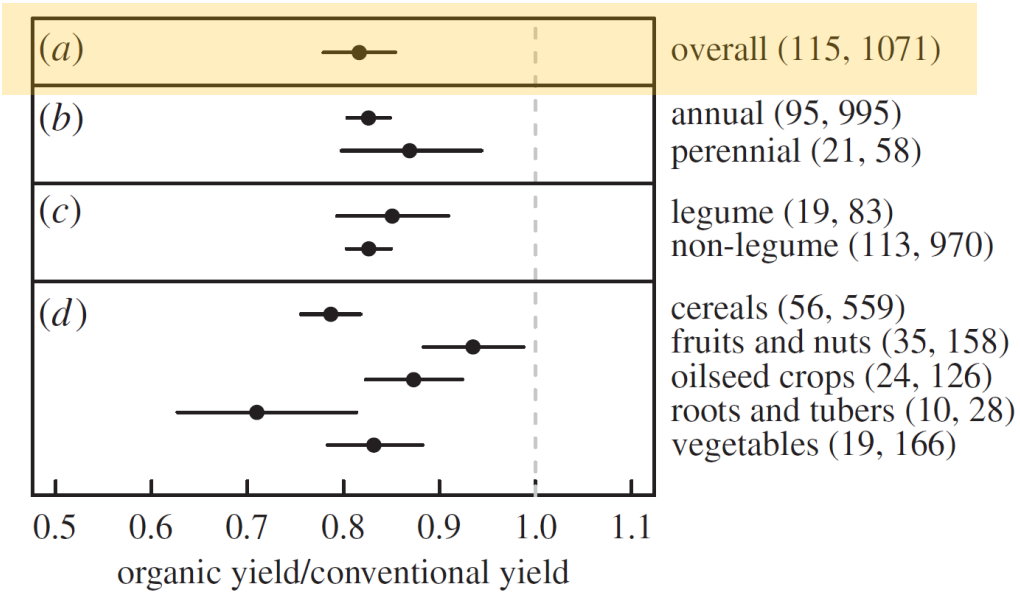
Smith et al. 2019a "Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis." *Frontiers in Sustainable Food Systems*

Smith et al. 2019b "Landscape context affects the sustainability of organic farming systems" *PNAS*

What is Known About Organic Yields?

Various Meta-Analyses to Evaluate

Organic yields ~20% lower than conventional

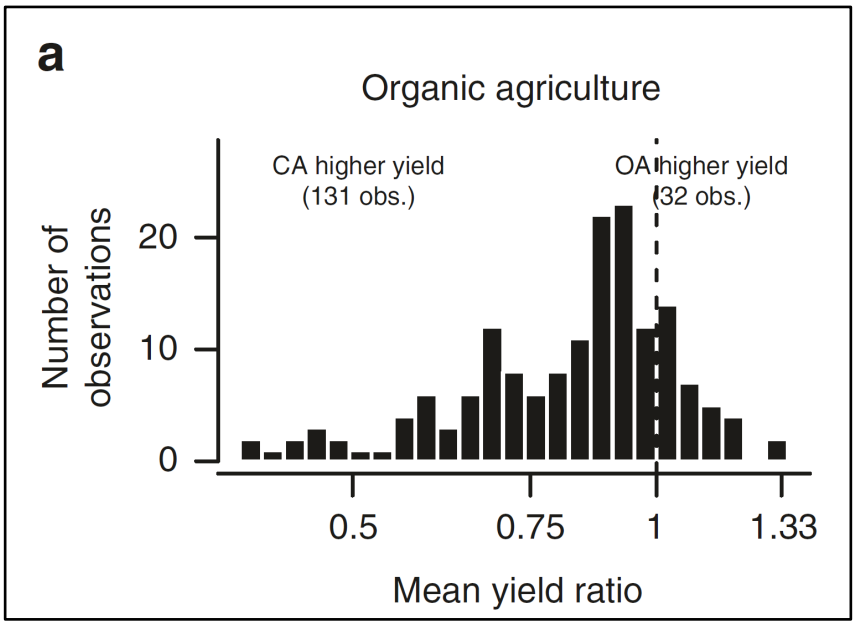


Ponisio et al. 2015 "Diversification practices reduce organic to conventional yield gap"
Proceedings Royal Society B

What is Known About Organic Yields?

Various Meta-Analyses to Evaluate

Organic outperforms conventional ~19% of the time



Knapp and van der Heijden 2019 "A global meta-analysis of yield stability in organic and conservation agriculture" *Nature Communications*

Organic Yields

Yes They Can Be Lower, But It’s Not That Simple

Yield Outcomes - Very Context Specific

Crop Type, Rotations, Polycultures etc.

- **Relative performance of organic is highly variable**
- **Outcomes influenced by a wide variety of factors**

Variable	Low performance	High performance	References
Production per unit area	Cereals	Fodder crops	(*18, 20, 21*)
	Nonlegumes and annuals	Legumes and perennials	(*18, 21*)
	Lower N inputs in org	Higher N inputs in org	(*18, 19*)
	No rotation	More rotation in org	(*18, 19*)
	Strong acidic and alkaline soils	Neutral soils	(*18, 19*)

Seufert and Ramankutty 2017 "Many shades of gray – the context-dependent performance of organic agriculture" *Science Advances*

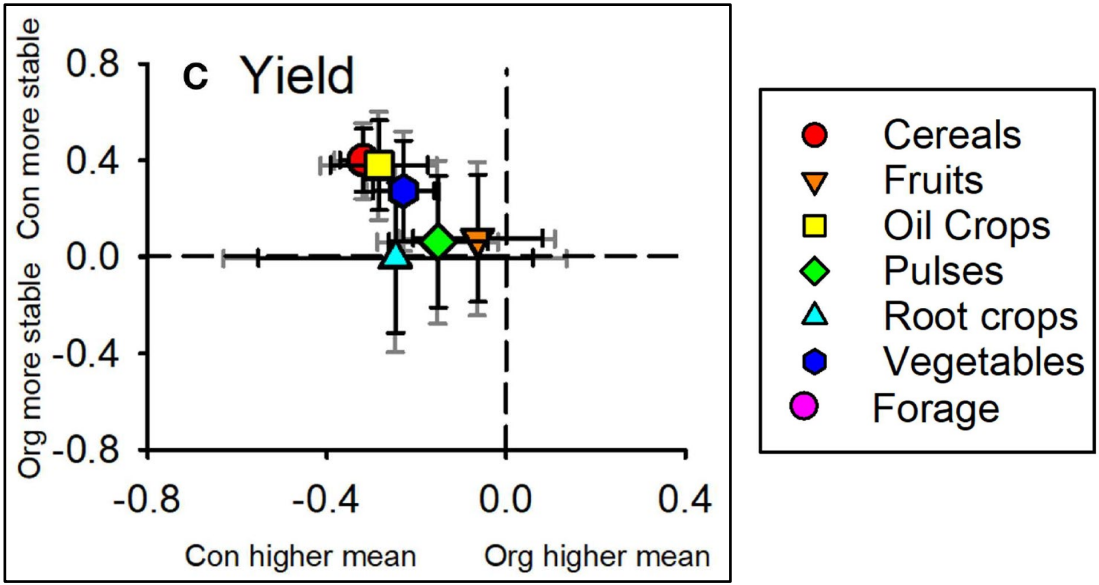
Variable	Low performance	High performance	References
 Production per unit area	Cereals	Fodder crops	(*18, 20, 21*)
	Nonlegumes and annuals	Legumes and perennials	(*18, 21*)
	Lower N inputs in org	Higher N inputs in org	(*18, 19*)
	No rotation	More rotation in org	(*18, 19*)
	Strong acidic and alkaline soils	Neutral soils	(*18, 19*)
 Species richness and abundance	Arthropods and Birds	Plants	(*32, 34*)
	Predators, herbivores, and decomposers	Pollinators and producers	(*32, 33*)
	Pastures	Cereal fields	(*32, 34*)
	Extensive agriculture in region	Intensive agriculture in region	(*34*)
	Complex landscapes	Simple landscapes	(*32, 33*)
	Outside fields/at farm level	Within fields	(*34*)
 Soil organic carbon	Same organic matter inputs in org and conv	Higher organic matter inputs in org	(*39, 40, 42*)
 Energy use	Fruits and vegetables	Other field crops	(*58*)
GHG emissions	Multicropping systems	Monocropping systems	(*58*)
 N loss	High N inputs in org	Low N inputs in org	(*60*)
P loss	Organic amendments	Legume-based systems	(*65*)
N and P loss	Horticultural systems	Arable systems	(*63*)
 Profitability	No access to premium prices	Access to premium prices	(*81*)
	Regions with high labor cost	Regions with low labor costs	(*81*)
Autonomy	Reliance on export markets	Participation in alternative food networks	(*82, 87*)
 Pesticide exposure	Crops with low pesticide use and/or regions with strong pesticide regulation and enforcement	Crops with high pesticide use and/or regions with weak pesticide regulation and enforcement	—
 Rural employment	—	Regions with high rural unemployment	—

Seufert and Ramankutty 2017 “Many shades of gray – the context-dependent performance of organic agriculture” *Science Advances*

Yields in Organic Systems

Key Factor - Differences Across Crop Types

Higher Gaps – Cereals + Roots/Tubers
Lower Gaps – Fruit/Nut Systems + Pulses

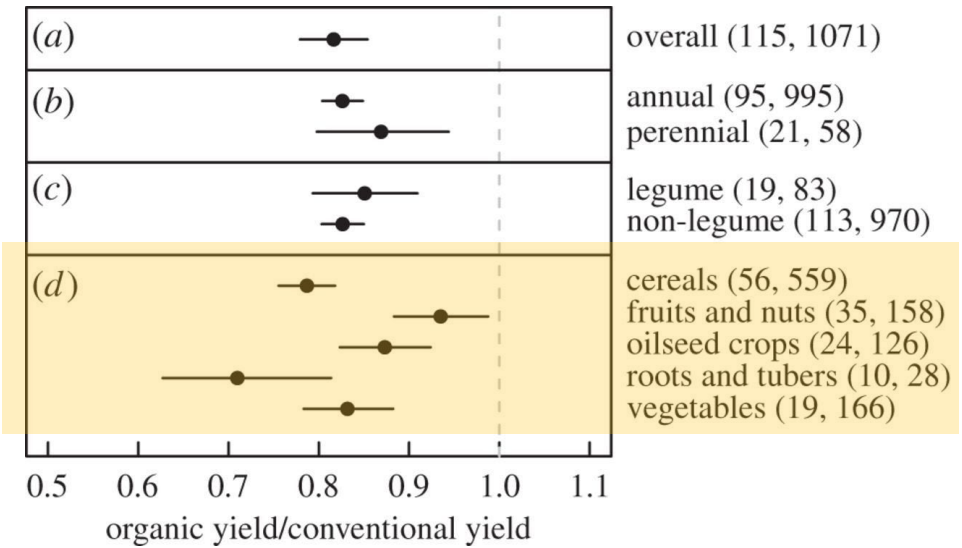


Smith et al. 2019a "Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis." *Frontiers in Sustainable Food Systems*

Yields in Organic Systems

Key Factor - Differences Across Crop Types

Higher Gaps – Cereals + Roots/Tubers
Lower Gaps – Fruit/Nut Systems + Pulses



Ponisio et al. 2015 "Diversification practices reduce organic to conventional yield gap"
Proceedings Royal Society B

Yields in Organic Systems

Key Factor - Crop Diversification Practices

Polycultures/Diversification and Rotations Tend to Minimize Yield Gaps

Input-substitution approach doesn't work well for organic

Variable	Low performance	High performance	References
 Production per unit area	Cereals	Fodder crops	(*18, 20, 21*)
	Nonlegumes and annuals	Legumes and perennials	(*18, 21*)
	Lower N inputs in org	Higher N inputs in org	(*18, 19*)
	No rotation	More rotation in org	(*18, 19*)
	Strong acidic and alkaline soils	Neutral soils	(*18, 19*)

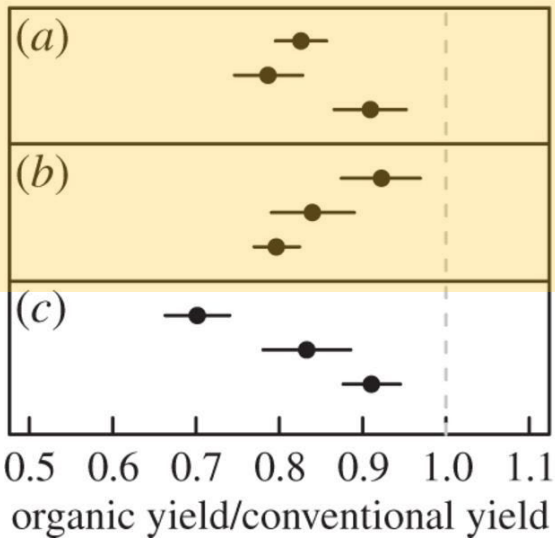
Seufert and Ramankutty 2017 "Many shades of gray – the context-dependent performance of organic agriculture" *Science Advances*

Yields in Organic Systems

Key Factor - Crop Diversification Practices

Polycultures/Diversification and Rotations Tend to Minimize Yield Gaps

Input-substitution approach doesn't work well for organic



monoculture (77, 449)
polyculture (18, 367)
organic polyculture only (17, 173)

more rotations in organic (14, 113)
no rotations (36, 178)
similar rotations (54, 670)

more conventional (33, 379)
more organic (15, 167)
similar (37, 300)

Ponisio et al. 2015 "Diversification practices reduce organic to conventional yield gap"
Proceedings Royal Society B

Optimizing Organic Production

- Organic systems are not necessarily inherently low yielding
- Input-substitution approach inadequate
- Breeding, crop rotations, polyculture etc. are fundamental

Outline for Today

Current Scale/Scope of Organic Agriculture

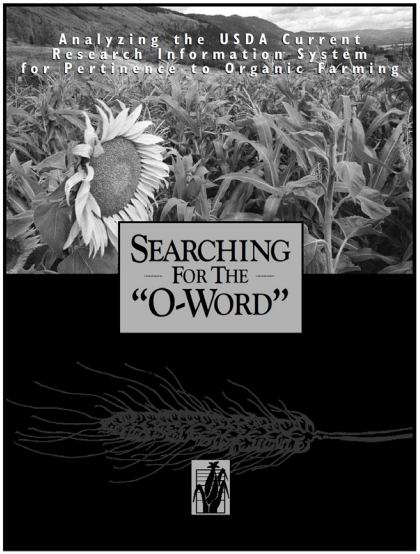
What Do We Know About Organic Productivity / Yield Gaps?

Current Knowledge Gaps and Policy Recommendations

Optimizing Organic Production Systems

Additional Research/Extension is Required

Historically, there has been relatively little funding for organic agriculture research and extension



UNIQUE TOTALS FOR ORGANIC-PERTINENT RATING CATEGORIES 1-6

Category	1-OS+	2-OS	3-OE	4-OC+	5-OC	6-PO
Total	5	8	7	14	267	215

STRONG ORGANIC Projects (OS+, OS, OE, OC+) = 34
WEAK ORGANIC Projects (OC) = 267
POTENTIAL/TRANSITIONAL ORGANIC = 215

How can we compare organic to conventional if these systems have not been sufficiently optimized?

Lipson (1997) "Searching for the O-Word" *Organic Farming Research Foundation*

Optimizing Organic Production Systems

Additional Research/Extension is Required

USDA Organic Research and Extension Initiative (OREI) - a major step forward

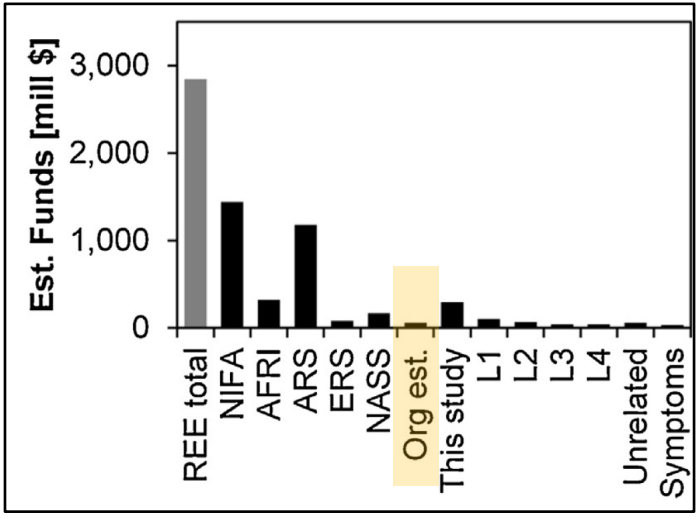


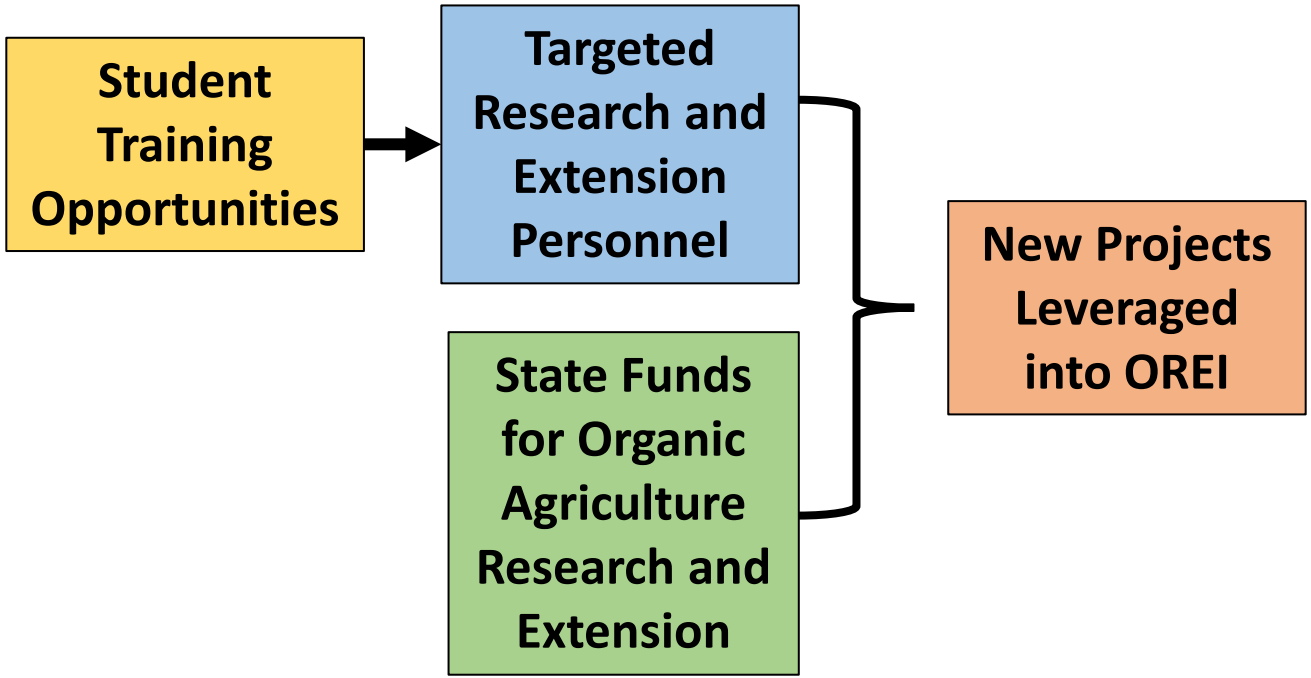
Table 2. Characteristics of select current or recent programs that could potentially support agroecology. Budgets for ongoing programs were from FY16 wherever possible. Anticipated funding for specific grant areas are from FY17 estimates when clearly available. If not available, data on actual awarded funding from the most recent available year was used.

Agency/Org	Research program ID	Available funding/funding granted (mill $)	Grants **(mill $/grant)**, max or range
USDA	AFRI (total budget)	$350.0[a] –	–
	AFRI-BNRE	***$15.0***[b]	**$0.5**
	AFRI-CCS	*$27.6* [b]	$0.2–$1.0
	AFRI-ANRS	*$8.4* [b]	–
	AFRI-Exploratory	*$2.0* [b]	–
	OREI	$17.6 [b]	$2.0
	ORG	$3.8 [b]	$0.5
	SCRI	$48.1 [b]	–
	SARE (total budget)	$24.7[a] –	–
	NE-SARE, R&E	***$1.3***[c]	$0.2
	W-SARE, R&E	***$1.7***[c]	$0.2
	NC-SARE, R&E	***$1.7***[c]	$0.2
	S-SARE, R&E	***$1.1***[c]	$0.2
	CIG	$26.6[d]	$2
NSF	INFEWS	$28.4[e]	$1.0–$3.0
	BREAD	$12.0[f]	$2.1
DOE	ARPA-E ROOTS	$35.0[g]	$1.0–7.0
FFAR	New Innovator	$2.4[h]	$0.3
	Seeding Solutions	Not yet known	$1[i]

Delonge et al. 2016 "Investing in the transition to sustainable agriculture" *Environmental Science and Policy*
Miles et al. 2017 "Triggering a positive research and policy feedback cycle to support a transition to agroecology and sustainable food systems" *Agroecology and Sustainable Food Systems*

Optimizing Organic Production Systems
Additional Research/Extension is Required

That said, complimentary resources are still needed at the state level



Research and Policy Recommendations

Research to Achieve Full Potential of Organic

- Tailored to unique ecological conditions
- Diversified farming, crop rotations etc.
- Crops and animals bred for organic context
- More appropriate technology for organic systems

Support for Farmers to Transition to Organic

- Both practices and production models

Research and Policy Recommendations

New Approaches and Metrics

- Emphasis on transdisciplinary approaches

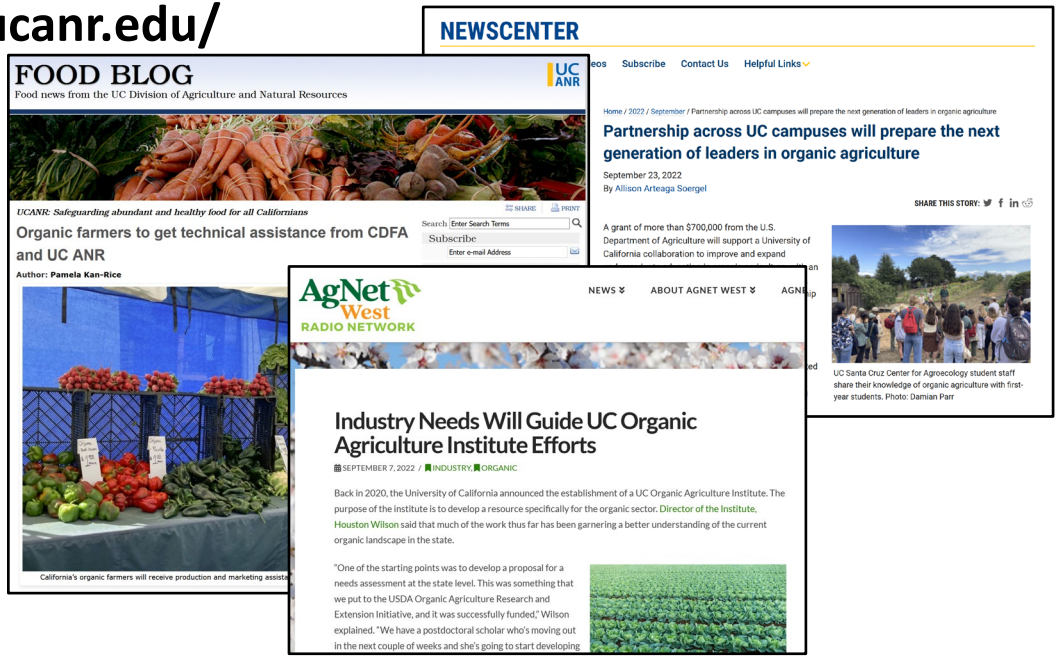
New Systems of Evaluating Outcomes

- Ecological, social and economic dimensions
- Both within and beyond the farm

UC Organic Agriculture Institute

Building Institutional Infrastructure to Support Organic Agriculture in California

http://organic.ucanr.edu/



https://news.ucsc.edu/2022/09/usda-organic-agriculture-grant.html
https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=53611
https://agnetwest.com/industry-needs-will-guide-uc-organic-agriculture-institute-efforts/

THANK YOU!

Houston Wilson
hwilson@ucanr.edu
http://organic.ucanr.edu/

UC CE | University of California Agriculture and Natural Resources

UC RIVERSIDE UNIVERSITY OF CALIFORNIA