Do nutrient management practices change nitrogen outcomes?

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Adoption of Nitrogen Management Practices

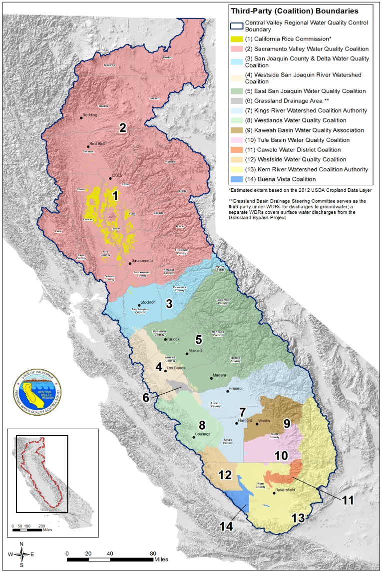
- Experimental evidence suggests that N management practices can improve Nitrogen outcomes without reducing yields:
  - **Test for N:** Soil, Water, Tissues
  - **Change application strategy:** Foliar N, Split Application, Fertigation, Variable Rate Application
  - **Erosion prevention:** Cover Crops
- Much of the literature currently looks at adoption behavior of N management practices (Prokopy et al. (2019))

Our Objectives

- How does the adoption of nutrient management practices influence nitrogen efficiency?
  - What practices are the most influential in increasing nitrogen efficiency?
  - Are there groupings of practices that have the biggest influence?

ESJWQC anonymized field-level data (2019-2021):

- Unique Member ID
- Crop
- Irrigation system (primary and secondary)
- Irrigation and nitrogen management practices adopted
- N Applied
- N efficiency (A/R, A-R)



Summary Statistics: Practices

Testing Practices	% of Fields
Irr. Water N Testing	54.1
Tissue Testing	74.3
Soil Testing	83.5
Application Practices	
Variable Rate	2.1
Cover Crop	16.6
Foliar N	52.9
Fertigation	66.4
Split N	90.3

Summary Statistics: Crops

	Field	Fruit	Nut	Row
# N Practices Adopted	2.9	4.6	4.6	3.4
	(1.8)	(1.9)	(1.6)	(1.5)
N Applied (lb/acre)	143.7	77.5	160.4	138.2
	(99.3)	(53.3)	(64.1)	(55.6)
A - R (lb/acre)	-104.1	40.8	31.5	36.9
	(203.5)	(50.7)	(62.6)	(78.0)

Note: negative A-R for Field is driven by alfalfa

Regression Analysis

We want to run a regression on nitrogen efficiency that captures as many factors as we can:

- Crop choice
- Nitrogen practices
- Juvenile crops
- Irrigation system
- Year
- **Nitrogen fertilizer application**

Challenge: Endogeneity

Nitrogen fertilizer applied has a major influence on nitrogen use efficiency.

However, we cannot directly put this into a regression, since total nitrogen in the system is a fundamental component of nitrogen efficiency (the "A" in "A - R").

Proposed Solution: Instrumental Variables

Use the "testing practices": **soil testing**, irrigation water testing, and **tissue testing**, which influence N application rates but not efficiency directly.

We run two regressions:

1. Factors that influence nitrogen application rates, including testing practices
2. Taking the results (the "residuals") and using these to estimate the impact of other practices on nitrogen efficiency.

Essentially, we use the testing practices as a proxy for nitrogen application rates in the efficiency regression.

Instrumental Variables

First stage:

$$Nfert_{it} = \beta_1 Z_{it} + \beta_2 X_{it} + \beta_3 Irr_{it} + \beta_4 Juv_{it} + \eta_c + tau_t + u_{it}$$

Second Stage:

$$A - R_{it} = \delta_1 \hat{Nfert}_{it} + \delta_2 X_{it} + \delta_3 Irr_{it} + \delta_4 Juv_{it} + \eta_c + \tau_t + \epsilon_{it}$$

Where:

- Z_{it} is the vector of N testing practices
- X_{it} is the vector of N efficiency practices
- Irr_{it} indicates a field uses a flood irrigation system
- Juv_{it} indicates a juvenile crop
- η_c are fixed effects for crop or crop category
- τ_t is a time fixed effect

A - R	(1)	(2)
Fert Applied	1.5**	1.1***
	(0.6)	(0.4)
Variable Rate	-34.9*	-29.9**
	(19.1)	(11.9)
Cover Crop	11.5*	8.7**
	(6.8)	(4.4)
Foliar N	-16.2*	-6.3
	(9.6)	(5.0)
Fertigation	-15.9*	-11.7***
	(8.5)	(4.3)
Split N	-29.4*	-30.0***
	(16.2)	(9.5)
Total Practices	0.2	0.5
	(1.2)	(0.9)
Juvenile	42.3***	42.1***
	(15.1)	(9.8)
FE	Crop Cat, Year	Crop Group, Year
Wald p-val	0.0518	0.0270
Wu-Hausman p-val	0	0
Sargan p-val	0.7781	0.0497
Observations	16,786	16,786
AIC	199,587	186,697

Clusters

Most producers do not adopt a single practice.

- For example, fruit producers had adopted (on average) 4.61 practices of the 8 listed in our study

It can be beneficial to know if there is a group of practices that is more effective than others

We run the same analysis, but substitute in clusters of practices (instead of individual practices)

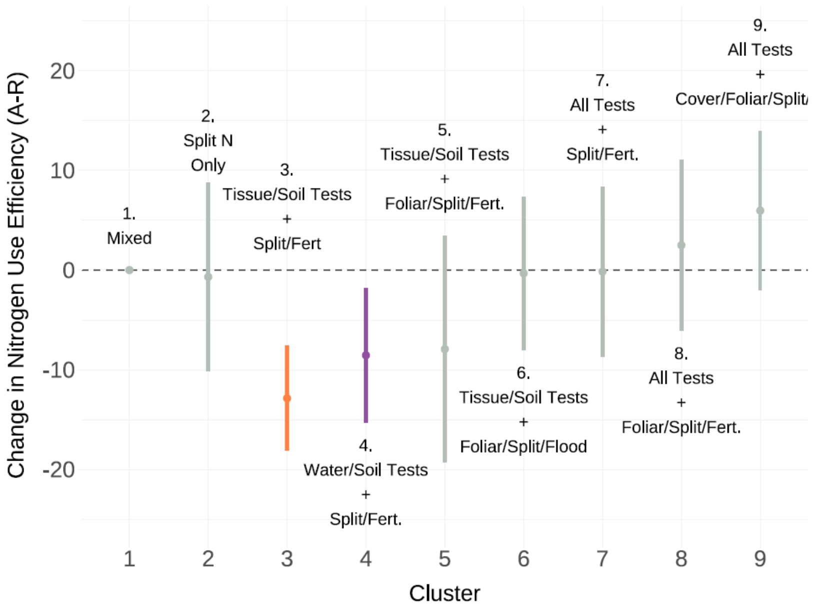
Ways to Cluster

We want to isolate groups of practices that have the largest influence on nitrogen efficiency (either higher or lower)

To do this, we use a machine learning technique that searches across all different practices to look at those with the greatest influence on nitrogen efficiency, and repeats this thousands of times (Random Forest)

Based on the results, we look for groups of practices that have a similar influence on nitrogen efficiency (k-Medoids)

Note that this does not tell us how much they influence efficiency directly! Still need same IV regressions


Change in Nitrogen Use Efficiency (A-R)
20
10
0
-10
-20
1.
Mixed
2.
Split N
Only
3.
Tissue/Soil Tests
+
Split/Fert
4.
Water/Soil Tests
+
Split/Fert.
5.
Tissue/Soil Tests
+
Foliar/Split/Fert.
6.
Tissue/Soil Tests
+
Foliar/Split/Flood
7.
All Tests
+
Split/Fert.
8.
All Tests
+
Foliar/Split/Fert.
9.
All Tests
+
Cover/Foliar/Split/
1
2
3
4
5
6
7
8
9
Cluster

Summary

- Variable rate N, Foliar application, Fertigation, and Split N significantly improve N efficiency
- Two “testing practices”, combined with Split N and Fertigation, outperform most other practice combinations in improving efficiency.

Future Work

The East San Joaquin Water Quality Coalition is a great place to start, but the results are not necessarily generalizable

- Evaluating other coalitions in the Central Valley for 2021-2022
- Examining the differences in effectiveness across regions

Also, examining the role that technical advisers play. Preliminary results suggest that plans certified by technical advisers are linked with fields that have greater nitrogen efficiency, but this is not causal.

Thank you!

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