Development and Use of Nitrogen Removal Coefficients for Vegetable and Berry Crops

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Outline

- N fertilizer use and groundwater quality in California
- New reporting requirements
- Applied vs removed N
- A-R example
- N removal coefficient project
- Summary

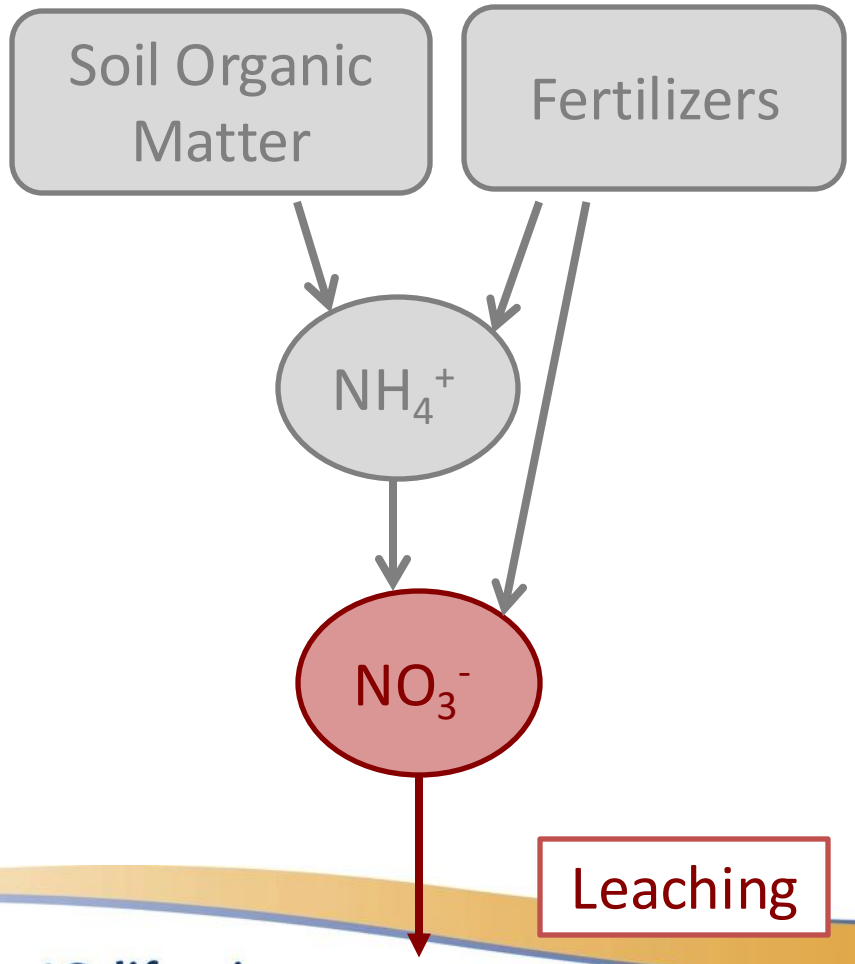
Soil Nitrogen Fluctuation

Among all essential plant nutrients, N is the most unstable in the soil, with significant fluctuation of in-season soil N levels;

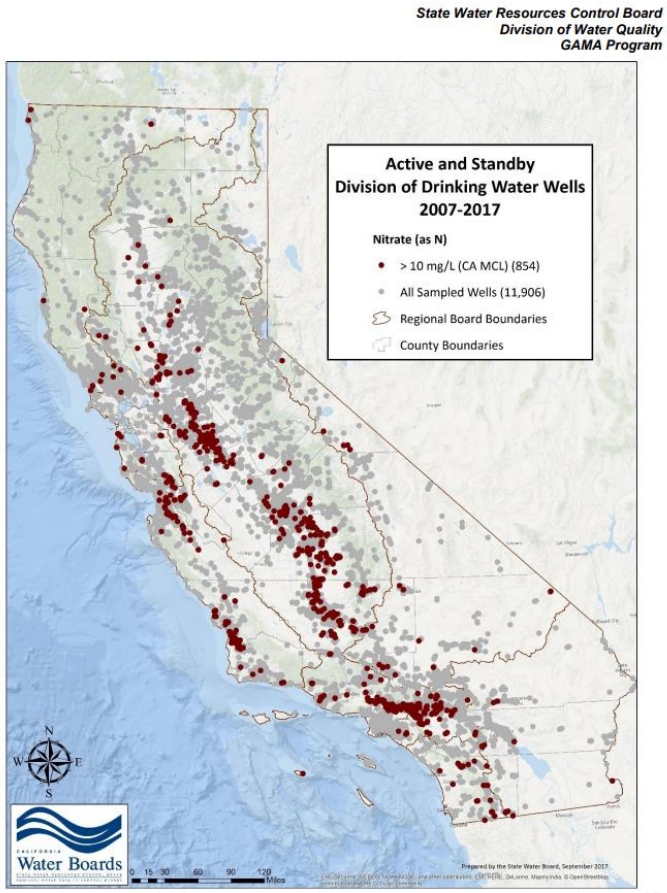
Reason: combination of factors including numerous biological and chemical processes, variable uptake rates, uneven rainfall pattern, irrigation inefficiency and soil type, among others.

Nitrate Leaching

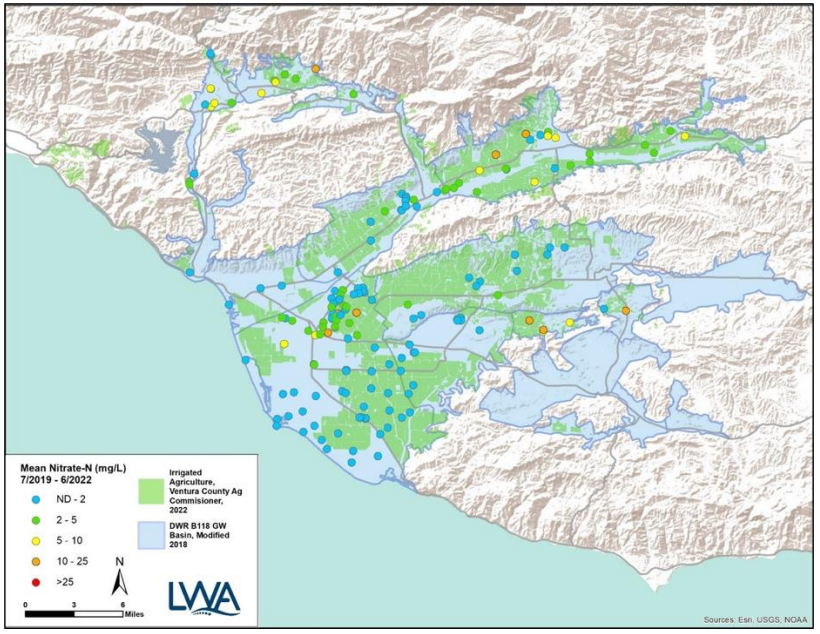
Loss of nitrate (NO_3^-) from the soil due to irrigation or rain.
Greatest loss potential of nitrogen from the soil.



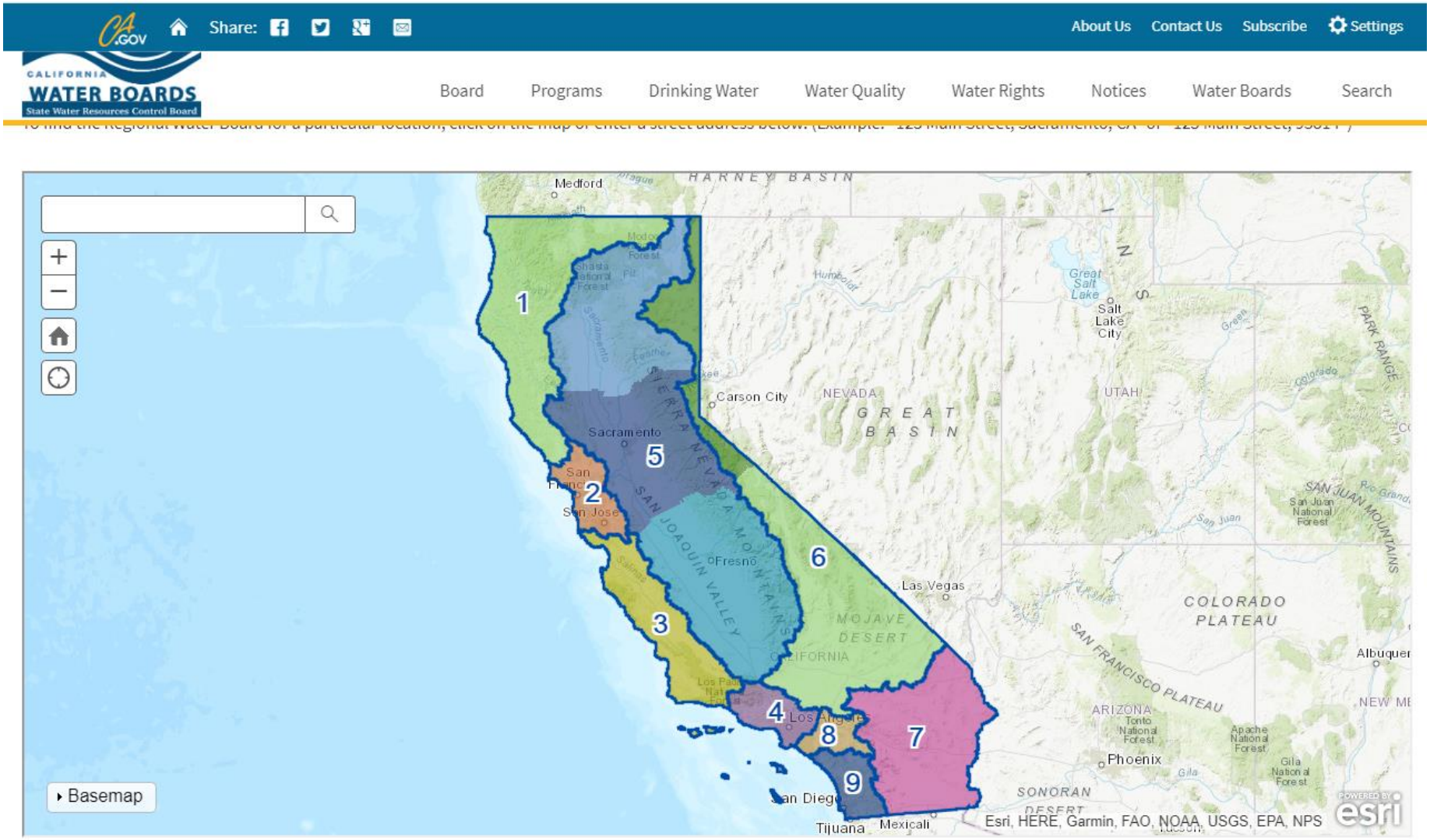
Exceeding nitrate levels in groundwater



Active and standby public drinking water wells that had at least one detection of nitrate (as N) above the MCL, 2007-2017, 854 wells. *(Source: Public Well Data using GeoTracker GAMA).*



Regional Water Quality Control Boards



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https://www.waterboards.ca.gov/waterboards_map.html

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NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit:

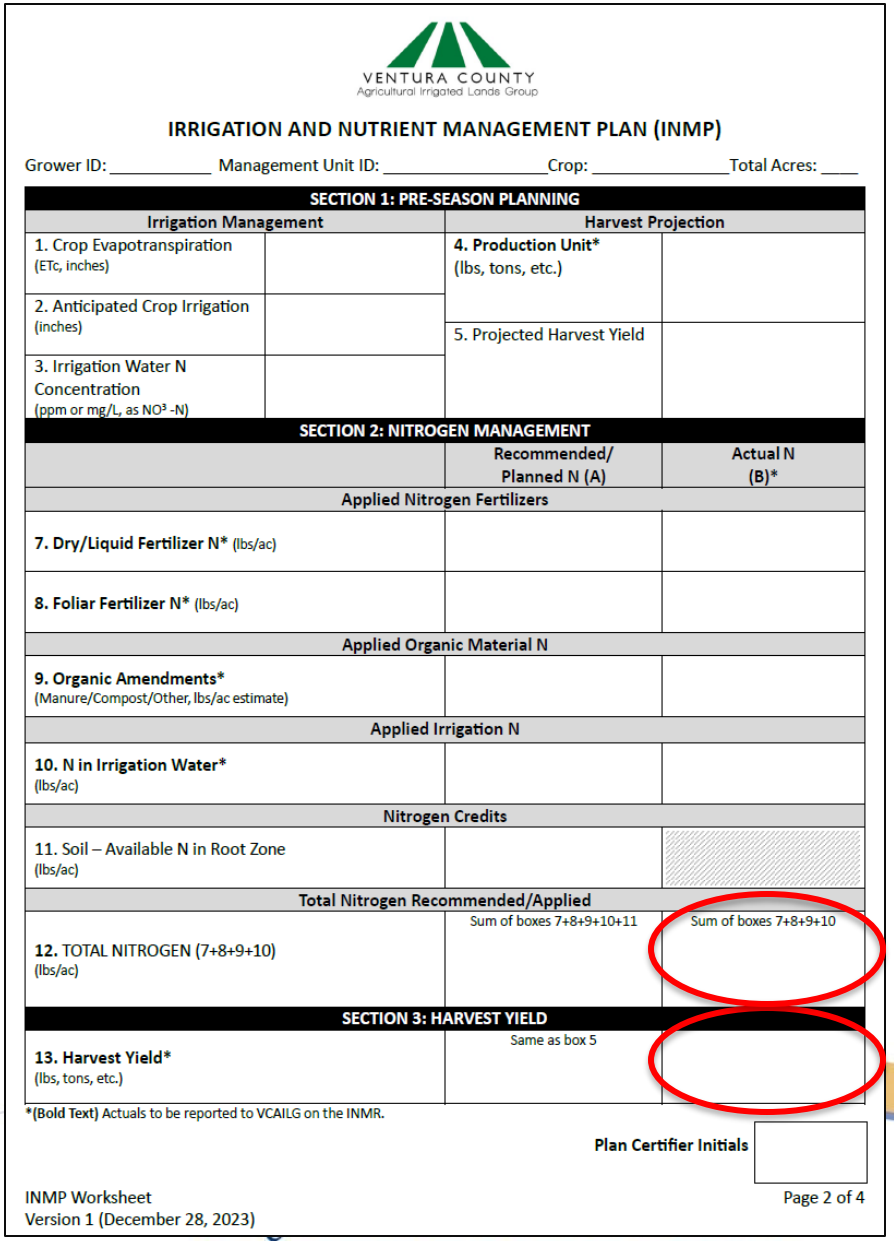
1. Crop Year (Harvested)	4. APN(s):	5. Field(s) ID	Acres
2. VCAILG ID#			
3. Name:			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended / Planned N	16. Actual N
6. Crop		17. Nitrogen Fertilizers		
7. Production Unit		18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (units/ac)		19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)		20. Organic Material N		
10. Acres		21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals		**22. Total Available N Applied** (lbs/ac) (18+19+21)		
11. Actual Yield (units/ac)		23. Nitrogen Credits(est)		
12. Total N Applied (lbs/ac) (22+26)		24. Available N carryover in soil (annualized, lbs/ac)		
13. N Removed (lbs N/ac)*		25. N in Irrigation water (annualized, lbs/ac)		
14. Notes:		**Irrigation sources**		
		Irrigation amount applied (ac/ft)		
		26. Total N Credits (lbs/ac) (24+25)		
		27. Total N Recommended & Applied (22+26)		
		Actual N Applied (12) **vs Actual N Removed** (13)		

CROP NITROGEN MANAGEMENT PLANNING	
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**
	30. Self-Certified, approved training program attended
	31. Self-Certified, UC or NRCS site recommendation
DATE:	32. Certified Crop Advisor

* Note: N Removed is only required if information is available for your crop type. Check for available values at: www.ipni.net/app/calculator/home or https://plants.usda.gov/npk/main

INMP Worksheet



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IRRIGATION AND NUTRIENT MANAGEMENT PLAN (INMP)

Grower ID:_____ Management Unit ID: _____Crop: _____Total Acres: ____

SECTION 1: PRE-SEASON PLANNING			
Irrigation Management		**Harvest Projection**	
1. Crop Evapotranspiration (ETc, inches)		**4. Production Unit*** (lbs, tons, etc.)	
2. Anticipated Crop Irrigation (inches)		5. Projected Harvest Yield	
3. Irrigation Water N Concentration (ppm or mg/L, as NO^3 -N)			

SECTION 2: NITROGEN MANAGEMENT		
	Recommended/ Planned N (A)	**Actual N (B)***
Applied Nitrogen Fertilizers		
7. Dry/Liquid Fertilizer N* (lbs/ac)		
8. Foliar Fertilizer N* (lbs/ac)		
Applied Organic Material N		
9. Organic Amendments* (Manure/Compost/Other, lbs/ac estimate)		
Applied Irrigation N		
10. N in Irrigation Water* (lbs/ac)		
Nitrogen Credits		
11. Soil – Available N in Root Zone (lbs/ac)		
Total Nitrogen Recommended/Applied		
12. TOTAL NITROGEN (7+8+9+10) (lbs/ac)	Sum of boxes 7+8+9+10+11	Sum of boxes 7+8+9+10

SECTION 3: HARVEST YIELD		
13. Harvest Yield* (lbs, tons, etc.)	Same as box 5	

***(Bold Text)** Actuals to be reported to VCAILG on the INMR.

Plan Certifier Initials

INMP Worksheet
Version 1 (December 28, 2023)

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Increase Efficiency

Kept On-Farm

Certification Required

INMR

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IRRIGATION AND NUTRIENT MANAGEMENT REPORT (INMR)

Refer to your INMP Worksheet(s) for information to complete the INMR for each Management Unit (MU) ID. **Duplicate pages if additional lines are needed.**

GENERAL INFORMATION

VCAILG ID #:_____ Form Completed By:_____ Crop Year: _____ Submittal Date: _____

OUTLIER NOTIFICATION RECEIPT	ALTERNATIVE REPORTING	INMP CERTIFICATION METHOD
Were any of the below listed Management Units identified as a statistical outlier by the Coalition last year? ☐ Yes ☐ No	**Does the Member meet the alternative reporting qualifications for "A" only reporting?** *Refer to "A" Only Reporting Qualifications listed in INMP Worksheet Instructions.* ☐ Yes ☐ No	☐ Certified by Certified Crop Adviser or NRCS Technical Service Provider ☐ Self-Certified by Member who has completed the CDFA training program ☐ Self-Certified by Member who follows NRCS site-specific recommendations (documentation required) ☐ Certification not required (Member's total farming operation consist of ≤10 acres and has never been identified as an outlier)

IRRIGATION AND NUTRIENT MANAGEMENT REPORT

Complete the table below for each Management Unit (MU) for this membership. All values should be on a per acre basis.

MU ID	Crop	Crop Age	Total Irrigated Acres	Total N Applied Lbs/acre				Yield	Prod. Unit	Yield Info*
Refer to MU and Parcel Inventory		Perennial only (years)	(acres)	N in Irrigation Water (lbs/acre) INMP Box 10b	Organic Amendments (lbs/acre) INMP Box 9b	Dry/Liquid Fertilizers (lbs/acre) INMP Box 7b	Foliar Fertilizers (lbs/acre) INMP Box 8b	Harvested Yield (lbs/acre or tons/acre) INMP Box 13b	(lbs or tons) INMP Box 4	

* Use this column to provide information about yield i.e. nonbearing; crop not harvested, etc.

Report Nitrogen Applied and Yield

Submitted to VCAILG Annually

Applied vs Removed N

Goal: calculate the load of N that is left in the field following crop production

Applied:
- Fertilizers
- Organic amendments
- Irrigation water N

Removed:
all N that leaves the field with produce (boxes)

Other N sources:
- Residual soil N
- SOM mineralization

Calculating Removed N

Strawberry Removal Coefficient:

- 2.8 (yield in ton/acre)
- 0.0014 (yield in lb/acre)

Yield (lb/acre) x 0.0014 = lb N removed/acre
50,000 lb/acre x 0.0014 = 70 lb N/acre

Example: Applied 250 lb N/acre; removed 70 lb N/acre; A-R = 180 lb N/acre

Need for developing these coefficients

While coefficients of several crops have already been created over the years, many are outdated and not representative of regional and current production systems.

It is important that these coefficients accurately reflect the range of vegetable and berry cultivars, growing conditions and production practices used by the industry.

Literature Review Assessing Available Removal Coefficients

Crop	VC Acreage[1]	N Coefficient	Units	Source
				Fruit and Nuts
Apples		1.08	lbs/ton of fruits	Geisseler Report (2016)
		1.23	lbs/ton of fruits	NRCS Crop Nutrient Tool
		1	lbs/ton	Ag Order 4.0 Approved Coefficient
		6.0	lbs/ton	IPNI Calculator
Apricots		5.56	lbs/ton of fruits	Geisseler Report (2016)
		5.6	lbs/ton	Ag Order 4.0 Approved Coefficient
		4.48	lbs/ton of fruits	NRCS Crop Nutrient Tool
Asian Pears				
Asparagus		5.86	lbs/ton	Ag Order 4.0 Approved Coefficient
Avocado				
		4.4	lbs/ton	Ag Order 4.0 Approved Coefficient
(all varieties)	16,435	6.336	lbs/ton of fruits	NRCS Crop Nutrient Tool
(Florida)		5.088	lbs/ton of fruits	NRCS Crop Nutrient Tool
(California)		6.752	lbs/ton of fruits	NRCS Crop Nutrient Tool
Blackberry	656	2.304	lbs/ton of fruits	NRCS Crop Nutrient Tool
Blueberries	636	2.144	lbs/ton of fruits	NRCS Crop Nutrient Tool
Cherimoya	100*	4.16	lbs/ton of fruits	NRCS Crop Nutrient Tool
Figs		2.54	lbs/ton	Ag Order 4.0 Approved Coefficient
Grapefruit		2.96	lbs/ton of fruits	Geisseler Report (2016)
		3.00	lbs/ton of fruits	Ag Order 4.0 Approved Coefficient
Grapefruit- Pink & Red		1.6	lbs/ton of fruits	NRCS Crop Nutrient Tool
Grapefruit- White		2.816	lbs/ton of fruits	NRCS Crop Nutrient Tool
Grapes - Table		2.26	lbs/ton of grapes	Ag Order 4.0 Approved Coefficient
Grapes- wine	200*	3.6	lbs/ton of grapes	Geisseler Report (2016)
		2.62	lbs/ton of grapes	Ag Order 4.0 Approved Coefficient
Guavas - Common	5*	2.624	lbs/ton of fruits	NRCS Crop Nutrient Tool
Guavas - Strawberry	1*	1.856	lbs/ton of fruits	NRCS Crop Nutrient Tool
Kiwi		3.168	lbs/ton of fruits	NRCS Crop Nutrient Tool
Lemons	17,015	3.08	lbs/ton	Ag Order 4.0 Approved Coefficient
		2.58	lbs/ton of fruits	Geisseler Report (2016)
Limes	10*	2.24	lbs/ton of fruits	NRCS Crop Nutrient Tool
Macadamia Nuts	25*	26.56	lbs/ton (dry)	NRCS Crop Nutrient Tool
Mandarins & Tangelos	1,609	2.54	lbs/ton of fruits	Geisseler Report (2016)/Ag Order 4.0 Approved Coefficient
		2.016	lbs/ton	NRCS Crop Nutrient Tool
Nectarines		3.64	lbs/ton of fruits	Geisseler Report (2016)
		3.008	lbs/ton	NRCS Crop Nutrient Tool
Olives	100*	6.28	lbs/ton of olives	Geisseler Report (2016)/Ag Order 4.0 Approved Coefficient
Oranges		2.96	lbs/ton of fruits	Geisseler Report (2016)
		3	lbs/ton	Ag Order 4.0 Approved Coefficient
		3.7373	lbs/ton	NRCS Crop Nutrient Tool
Oranges (Navel)	498	3.296	lbs/ton	NRCS Crop Nutrient Tool
Oranges (Valencia)	2,167	3.328	lbs/ton	NRCS Crop Nutrient Tool
Peaches		2.26	lbs/ton	Ag Order 4.0 Approved Coefficient
Pears		1.3	lbs/ton	Ag Order 4.0 Approved Coefficient
Persimmons - Japanese		1.856	lbs/ton	NRCS Crop Nutrient Tool
Persimmons - Native		2.56	lbs/ton	NRCS Crop Nutrient Tool

Development of Nitrogen Removal Coefficients for Vegetable and Berry Crops

Richard Smith, Michael Cahn, Aparna Gazula, Andre Biscaro

Goal: establish crop coefficients for crops lacking this information

55 crops and crop products were sampled in commercial production fields between 2020 and 2023

Fields sampled for each commodity represented different soil types and production seasons at the time of harvest

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Procedures (cont.)

An average of 15 fields were sampled per commodity and commodity type, with four samples collected per field at different locations throughout the field to account for site variability

Each sample consisted of six to eight subsamples collected from the harvested produce.

In cases of certain crops of relatively large unit size such as cabbage and celery, between 1/6 and 1/8 of each head was used to compose a sample, along with other subsamples.

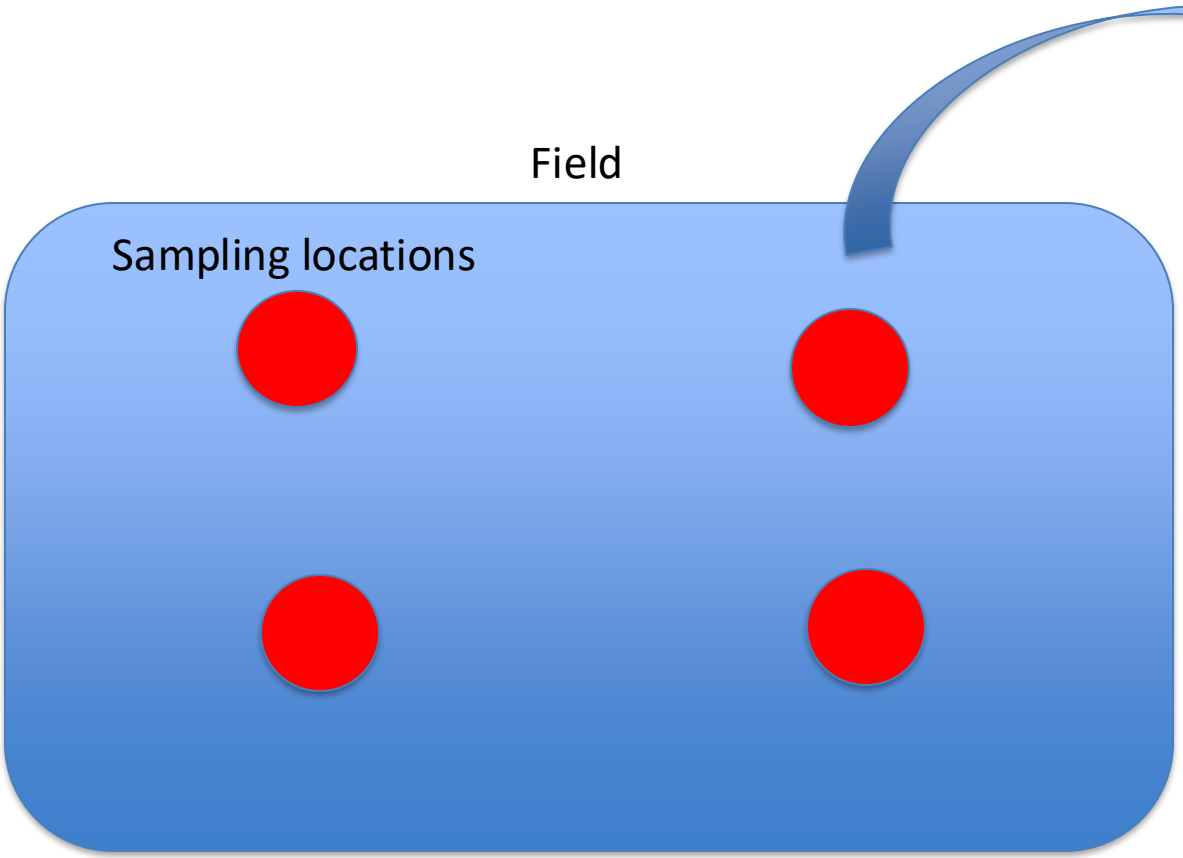
Procedures (cont.)

Each subsample included proportional parts of the sampled produce (e.g., leaves and petioles in the case of celery).

The fresh weight of each sample was taken in the field, and each sample oven dried and sent to the UC Davis Analytical Lab for total nitrogen analysis.

Dry matter content and total nitrogen for each sample were used to calculate the removal coefficient.

Illustration of celery sampling:



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Results

commodity	product	pack type	mean coeff	min coeff	max coeff	mean %DM	min %DM	max %DM	mean %N	min %N	max %N
A choy											
Amaranth											
Annual Artichoke	Fresh Market	Carton	0.00382	0.00344	0.00448	16.26	12.71	20.25	2.40	1.86	3.17
Arugula	Bulk	Bulk	0.00580	0.00507	0.00685	9.43	7.30	11.86	6.22	4.83	6.96
Beans, Green (Snap)	Fresh Market	Carton	0.00328	0.00285	0.00394	10.33	7.56	13.68	3.24	2.55	3.77
Beet	Fresh Market	Carton	0.00305	0.00269	0.00344	11.06	8.51	12.48	2.79	2.28	3.91
Berries, black	Fresh Market	Carton	0.00223	0.00140	0.00294	15.16	12.57	17.55	1.48	0.98	2.05
Berries, blue	Fresh Market	Carton	0.00078	0.00020	0.00119	15.32	13.08	17.09	0.51	0.14	0.81
Berries, raspberry	Fresh Market	Carton	0.00180	0.00160	0.00208	13.64	11.60	16.21	1.33	1.02	1.55
Bok Choy, baby	Fresh Market	Carton	0.00209	0.00085	0.00344	3.57	1.88	5.33	5.73	4.24	6.58
Bok Choy, Full size	Fresh Market	Carton	0.00178	0.00148	0.00188	4.75	3.90	5.39	3.78	2.76	4.36
Broccoli	Fresh Market	Carton	0.00463	0.00390	0.00579	9.11	8.05	11.04	5.09	4.22	6.01
Broccolini	Fresh Market	Carton	0.00520	0.00433	0.00690	11.16	9.44	13.49	4.67	3.44	5.51
Brussels Sprout	Bulk/Fresh Market	Bulk/RPC/Carton	0.00628	0.00540	0.00790	14.08	13.11	15.75	4.47	3.71	5.44
Cabbage, Green	Bulk Cored	Bulk	0.00183	0.00125	0.00229	7.26	6.38	8.04	2.51	1.80	3.02
Cabbage, Green	Bulk Whole	Bulk	0.00173	0.00107	0.00225	7.34	6.48	8.36	2.37	1.38	3.01
Cabbage, Green	Fresh Market	Carton	0.00221	0.00161	0.00357	7.86	5.74	10.95	2.82	2.06	3.26
Cabbage, Red	Bulk Cored	Bulk	0.00205	0.00138	0.00257	8.92	8.25	9.62	2.30	1.47	2.70
Cabbage, Red	Fresh Market	Carton	0.00201	0.00155	0.00239	8.10	7.16	9.46	2.50	1.73	3.05
Cauliflower	Fresh Market	Carton	0.00283	0.00234	0.00339	7.06	6.07	8.01	4.02	3.49	4.93
Celery	Fresh Market	Carton	0.00106	0.00052	0.00144	4.99	3.57	6.64	2.19	0.99	3.03
Celery	Processing	Bulk	0.00100	0.00064	0.00128	4.51	3.49	6.74	2.34	0.95	3.13
Chinese Celery	Fresh Market	Carton	0.00301	0.00161	0.00418	7.12	6.16	8.59	4.24	2.48	5.65
Chayote tips											
Cilantro	Clip	Bulk	0.00595	0.00449	0.00810	11.13	8.22	14.06	5.35	4.83	6.24
Cilantro	Bunch	Carton	0.00413	0.00250	0.00488	8.44	7.37	9.91	4.94	2.81	6.05
Cucumber	Fresh Market	Carton	0.00114	0.00088	0.00144	4.86	4.40	5.66	2.33	1.88	2.57
Endive	Fresh Market	Carton	0.00274	0.00216	0.00346	7.63	6.34	9.20	3.60	2.85	4.59
Escarole	Fresh Market	Carton	0.00242	0.00191	0.00292	6.67	5.65	7.61	3.64	3.15	4.41
Fennel	Fresh Market	Carton	0.00202	0.00132	0.00238	7.43	6.75	8.25	2.72	1.96	3.16
Flower, Gerbera	Fresh Market	Bunches	0.00325	0.00276	0.00478	13.24	11.05	14.80	2.46	2.05	3.62
Flower, Snapdragon	Fresh Market	Bunches	0.00239	0.00183	0.00314	10.76	8.61	15.45	2.27	1.52	2.97
Flower, Status	Fresh Market	Bunches	0.00327	0.00315	0.00341	27.64	25.48	29.75	1.20	1.10	1.26
Gai Choy	Fresh Market	Carton	0.00360	0.00294	0.00523	6.34	5.15	8.37	5.66	4.81	6.25
Gailan											
Jalapeno	Fresh Market	Carton									
Kale, Baby Lacinato	Bulk	Bulk	0.00705	0.00588	0.00878	11.30	9.40	14.06	6.24	5.57	6.68
Kale, Baby Curled Leaf	Bulk	Bulk	0.00631	0.00631	0.00631	10.82	10.82	10.82	5.84	5.84	5.84
Kale, Multi Pick	Retail	RPC	0.00548	0.00405	0.00700	13.27	11.87	15.36	4.16	2.64	4.98

Results (cont.)

commodity	product	pack type	mean coeff	min coeff	max coeff	mean %DM	min %DM	max %DM	mean %N	min %N	max %N
Lettuce, Baby Green	Bulk	Bulk	0.00338	0.00236	0.00469	6.80	4.98	9.17	4.98	3.60	5.87
Lettuce, Baby Red	Bulk	Bulk	0.00356	0.00260	0.00546	6.97	5.20	9.13	5.11	4.36	6.12
Lettuce, Butter	Fresh Market	Carton	0.00199	0.00155	0.00266	5.70	4.53	6.72	3.50	2.87	4.05
Lettuce, Green Leaf	Fresh Market	Carton	0.00207	0.00148	0.00283	6.80	5.73	7.96	3.06	2.25	3.71
Lettuce, Iceberg	Bulk Cored	Bulk	0.00120	0.00099	0.00160	4.02	3.58	4.89	2.99	2.62	3.55
Lettuce, Iceberg	Fresh Market	Film Wrap	0.00127	0.00108	0.00168	4.31	3.73	5.13	2.95	2.52	3.80
Lettuce, Iceberg	Fresh Market	Naked (Liner)	0.00129	0.00102	0.00161	4.32	3.77	5.02	2.98	2.46	3.38
Lettuce, Iceberg	**Fresh Market**	**All**	**0.00128**	**0.00102**	**0.00168**	**4.32**	**3.73**	**5.13**	**2.97**	**2.46**	**3.80**
Lettuce, Red Leaf	Fresh Market	Carton	0.00224	0.00191	0.00307	5.81	5.03	6.99	3.85	3.32	4.41
Lettuce, Romaine	Bulk Tops & Tails	Bulk & RPC	0.00152	0.00135	0.00189	4.97	4.53	5.52	3.06	2.78	3.43
Lettuce, Romaine	Bulk Whole	Bulk & RPC	0.00149	0.00136	0.00166	4.91	4.21	5.84	3.06	2.70	3.50
Lettuce, Romaine	**All bulk**	**All bulk**	**0.00150**	**0.00135**	**0.00189**	**4.93**	**4.21**	**5.84**	**3.06**	**2.70**	**3.50**
Lettuce, Romaine	Fresh Market	Carton	0.00184	0.00137	0.00247	5.92	5.02	7.59	3.11	2.39	3.71
Lettuce, Romaine	Hearts	Bag/Carton	0.00188	0.00114	0.00239	5.71	4.29	7.50	3.33	1.64	3.87
Malabar spinach											
Mizuna	Bulk	Bulk	0.00548	0.00454	0.00646	8.97	6.83	10.25	6.19	4.57	7.24
Napa Cabbage	Fresh Market	Carton	0.00181	0.00148	0.00212	5.00	4.49	5.90	3.67	2.51	4.73
Onion, Dry Red	Bulk	Bulk	0.00126	0.00090	0.00222	11.61	10.62	12.67	1.07	0.80	1.75
Onion, Dry Yellow	Bulk	Bulk	0.00164	0.00125	0.00207	11.10	9.81	13.26	1.47	1.21	1.65
Parsley, Curly	Fresh Market	Carton	0.00440	0.00325	0.00529	13.88	10.35	16.97	3.28	1.92	4.22
Parsley, Italian	Fresh Market	Carton	0.00436	0.00382	0.00499	13.23	9.24	16.26	3.39	2.63	4.38
Parsley, All	**Fresh Market**	**All carton**	**0.00438**	**0.00325**	**0.00529**	**13.56**	**9.24**	**16.97**	**3.33**	**1.92**	**4.38**
Pea, Edible Pod	Fresh Market	RPC	0.00472	0.00415	0.00526	12.74	11.57	13.76	3.70	3.52	3.88
Pea tips											
Pepper, Red Bell	Fresh Market	Carton	0.00194	0.00181	0.00203	8.99	8.87	9.14	2.15	2.04	2.21
Radicchio	Bulk	Bulk	0.00216	0.00214	0.00219	6.55	6.52	6.58	3.31	3.28	3.33
Radicchio	Fresh Market	Carton	0.00235	0.00211	0.00295	6.96	6.41	7.68	3.40	2.81	4.47
Radicchio	**All**	**All**	**0.00233**	**0.00211**	**0.00295**	**6.91**	**6.41**	**7.68**	**3.39**	**2.81**	**4.47**
Radish, Daikcon											
Radish, Red	Bulk	Bulk	0.00167	0.00126	0.00213	5.83	5.01	7.17	2.86	2.29	3.23
Radish, Red	Fresh Market	Carton & RPC	0.00248	0.00215	0.00262	6.34	5.73	7.46	3.93	3.30	4.41
Rapini	Fresh Market	Carton	0.00605	0.00544	0.00695	9.97	8.86	10.85	6.08	5.45	6.81
Shallot	Bulk	Bulk	0.00241	0.00159	0.00339	19.99	19.17	21.20	1.20	0.76	1.66
Spinach, Clip	Bulk	Bulk	0.00484	0.00388	0.00702	8.12	6.63	11.18	5.97	5.30	6.40
S. Squash Crookneck	Fresh Market	Carton	0.00182	0.00182	0.00182	7.01	7.01	7.01	2.59	2.59	2.59
S. squash Zucchini	Fresh Market	Carton	0.00191	0.00163	0.00251	5.80	5.09	6.57	3.31	2.70	4.02
Tong Ho	Fresh Market	Carton	0.00344	0.00194	0.00553	6.94	5.50	9.26	4.97	3.53	6.46

Summary

- ✓ N removal coefficients were developed for over 55 vegetable and berry crops and crop products
- ✓ Coefficients are under review by the State Water Resources Control Board
- ✓ The parameters for determining A-R outliers haven't been defined yet
- ✓ Start reviewing your N removal and fertilization plans today
- ✓ Please reach out with any questions about these coefficients and related calculations

Thank you!

Questions/comments?

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