College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

ESTIMATING PLANT AVAILABLE NITROGEN (PAN) USING COVER CROP CALCULATOR DEVELOPED IN HAWAII

Sustainable Pest Management Lab
University of Hawai'i at Mānoa,
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CRATE
Center of Rural Agricultural Training &

Sustainable and Organic Agriculture Program
College of Tropical Agriculture and Human Resources - University of Hawai'i at Mānoa

LIFE Local & Immigrant Farmer Education
University of Hawai'i at Manoa
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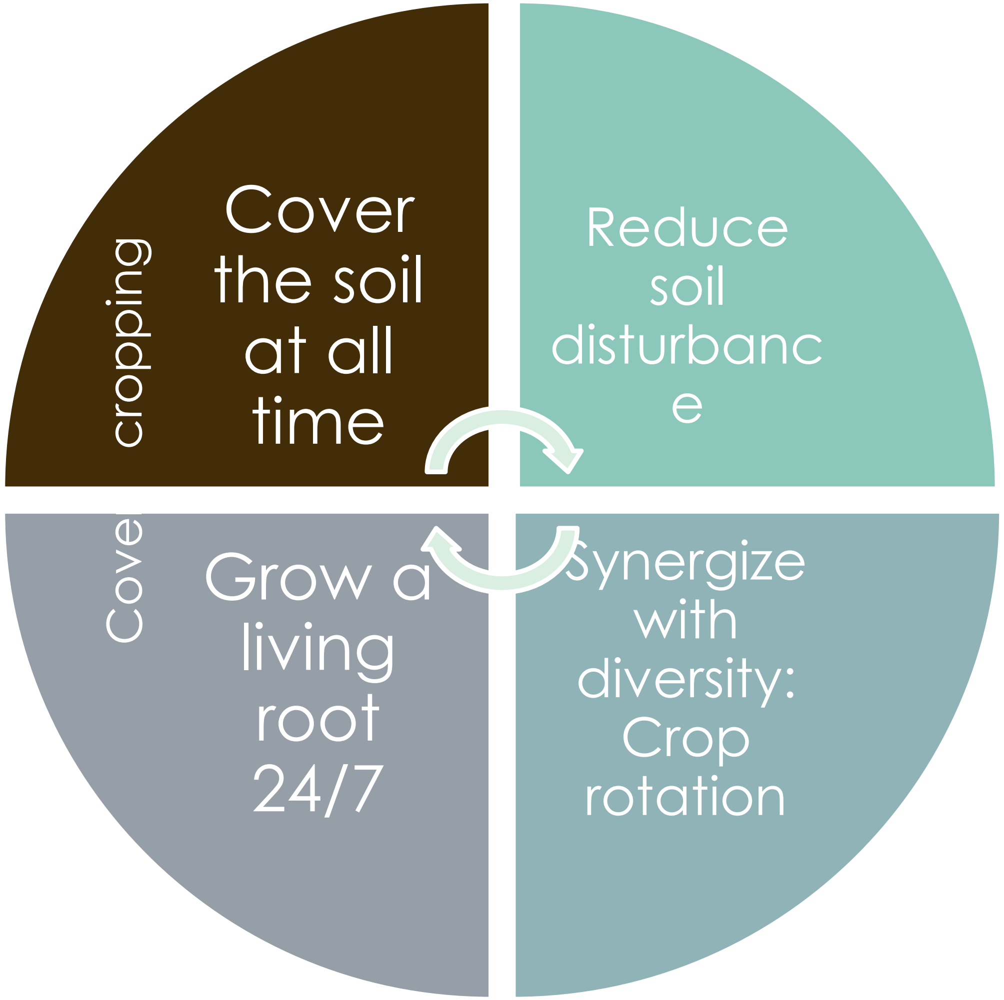
USDA

NRCS

Goal: Promote Conservation Agricul

Cover Crop Calculator
CIG 69-3A75-14-231



Water Health?

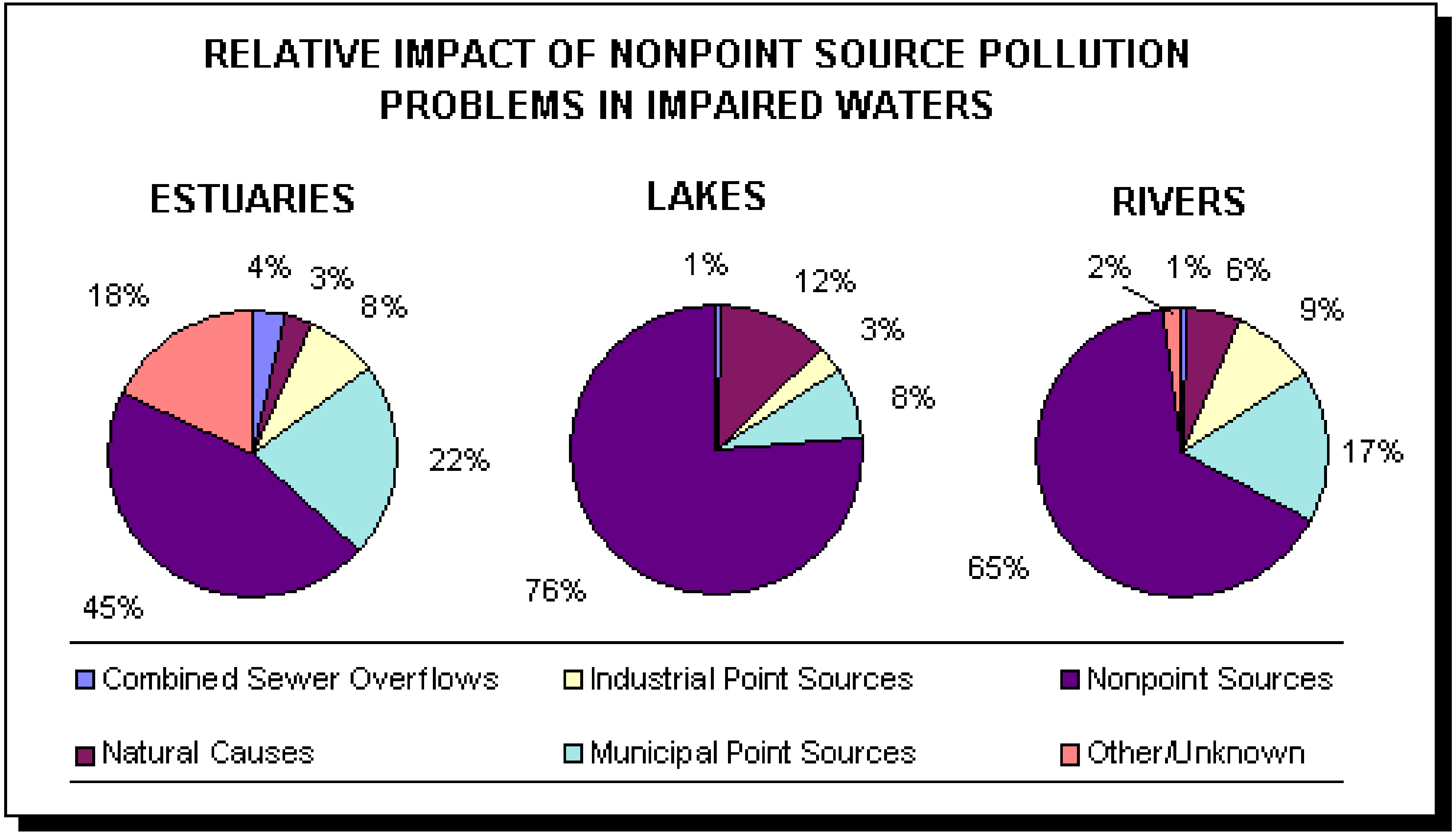
Outline

- ✓ Benefits of cover crop for soil fertility management
- Cover crop calculator
  - Factors affecting plant available N% (PAN%)

BENEFITS OF COVER CROP

1. Reduce non-point source pollution, reduce eutrophication, protect marine life.
2. Leguminous cover crop fix N
3. Cover crop can scavenge nutrients that have leached
4. Cover crop add soil organic matter, improve soil nutrient cycling, thus reduce fertilizer inputs
5. Cover crop out compete weeds, reduce herbicide application
6. Cover crop attract natural enemies, reduce pesticide application

NON-POINT SOURCE POLLUTION

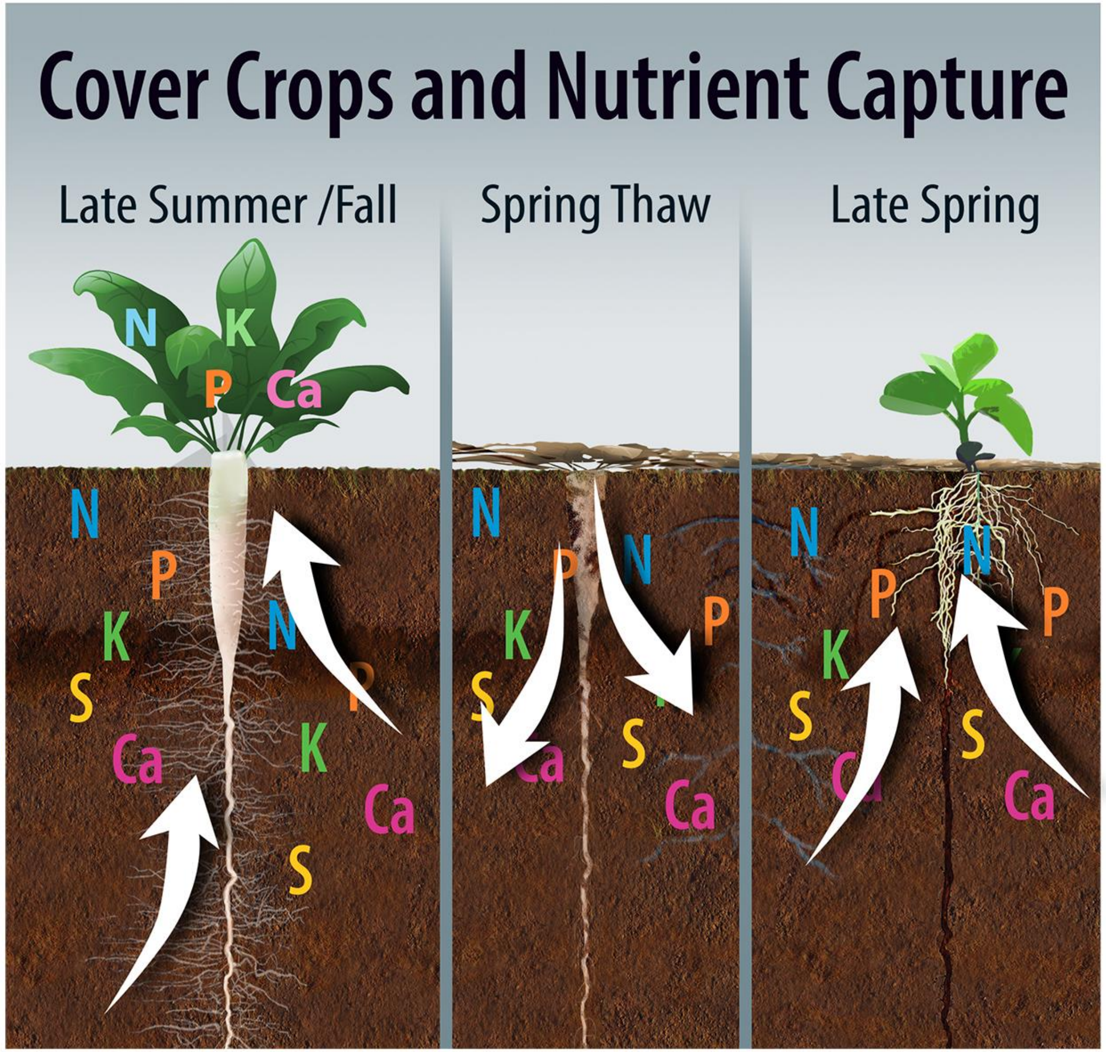


Nonpoint source pollutants, such as sediments, nutrients, pesticides, herbicides, fertilizers, animal wastes and other substances that enter our water supply as components of runoff and ground water, have increased in relative significance and accounts for > 50%

US Forest Service (NA-PR-07-91)

3. COVER CROP CAN SCAVENGE LEACHED NUTRIENTS

- Fibrous-rooted cereal grains scavenge excess N when planted soon after termination of last crop.
- Deep-rooted cover crops (such as oil radish) draw **Ca and K** that leach down the soil to upper soil surface.
- Cover crops (e.g. buckwheat and lupines) secrete acids into soil that put P into a soluble form for plant to uptake.
- Cover crops could also enhance plant P uptake by hosting mycorrhizal fungi.

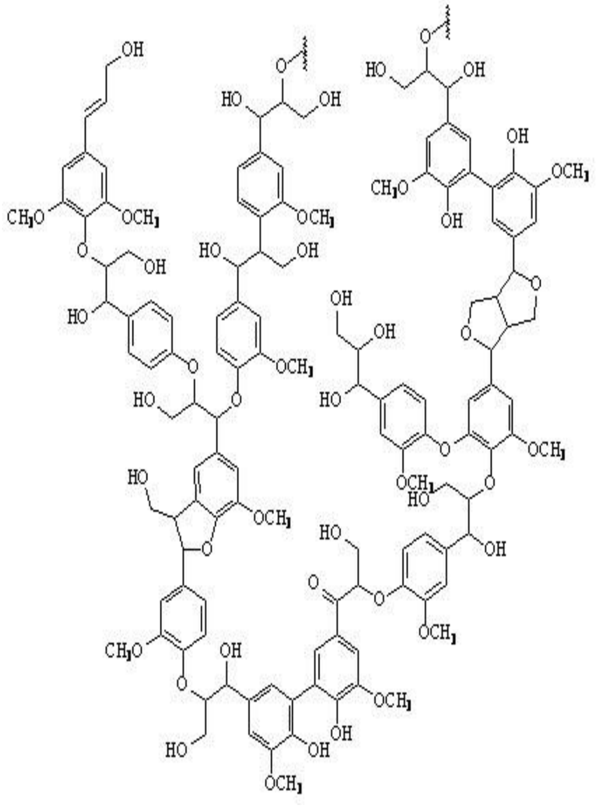


Cover crops can increase the amount of nutrients available for the next crop by taking up nutrients that remain in the soil and holding them in plant tissue until they are released the next spring, when they can be used by the following crops. *Courtesy: Cover Crop Solutions*

2. Leguminous cover crops contribute N to cash crops

- 30-60% of N that the legume produced can be available for the subsequent cash crop (WSARE, 2007)
- Plant N available rates varies by cover crop and soil condition --- Cover crop calculator

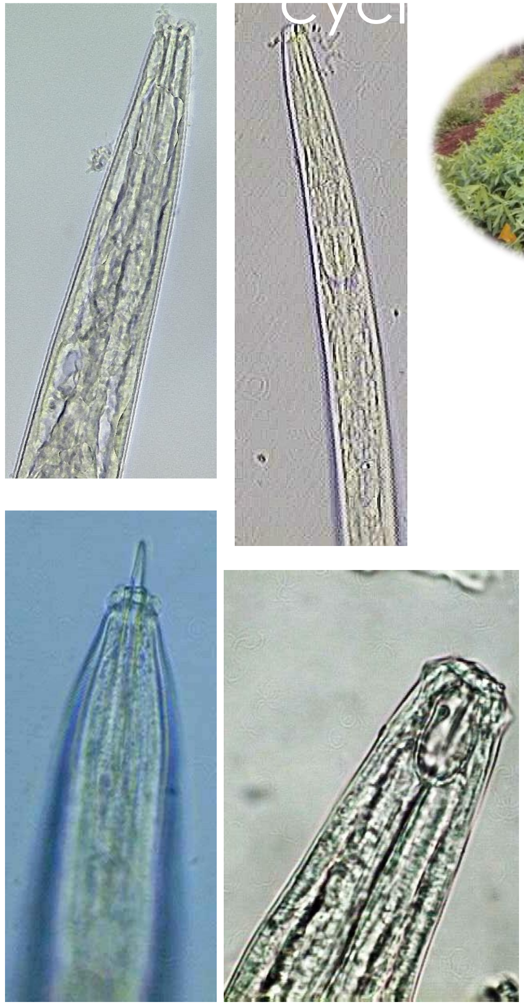
3. ADDING SOIL ORGANIC MATTER (SOM)

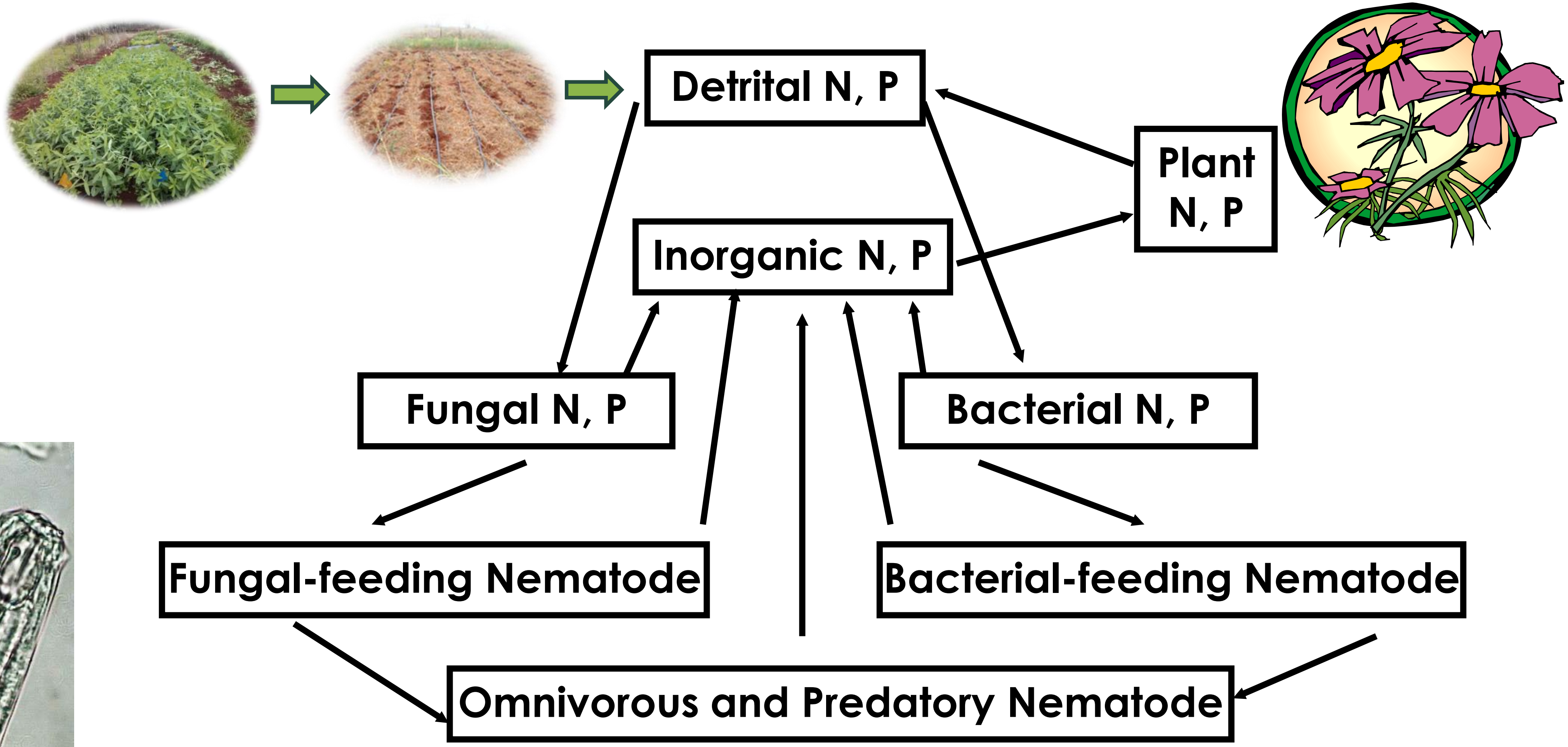


- Soil organic matter contributes to improve soil structure, increase infiltration and water holding capacity, increase cation exchange capacity (help soil to store nutrients).
- Two portions of soil organic matter:
  - Active fraction -- rich in simple sugars, proteins, fresh residues, microbial cells (release of most N, P, K from organic matter)
  - Stable fraction – rich in celluloses and lignins, contribute to humus (responsible for real soil organic matter, dark content, water holding capacity, cation exchange capacity or CEC)

4. IMPROVE SOIL NUTRIENT CYCLING

Cover crops enhance microbial activities involve in soil nutrient cycling





Outline

- Benefits of cover crop for soil fertility management
- ✓ Cover crop calculator
  - Factors affecting plant available N% (PAN%)

http://www.ctahr.hawaii.edu/WangKH/Downloads/CCChart-Hawaii-KHWang.pdf

Cover Crop Chart for Hawaii

Koon-Hui Wang and Archana Pant, CTAHR, University of Hawaii

CRATE

High Elevation ⟶ = = = = = = ⟵ Low Elevation

Grass	Broadleaf	Broadleaf	Broadleaf	Broadleaf	Broadleaf	Broadleaf	Broadleaf	Grass
Black Oat [A] 75 lb/acre		Legume	Legume	Legume	Legume	Legume	Sesame [A] [R*] 4 lb/acre	
Barley [A] 90 lb/acre							Buckwheat [A] 20-30 lb/acre	Pearl Millet [A] 15 lb/acre
Cereal Rye [A] 90 lb/acre	Canola [A] 7-10 lb/acre	Hairy vetch [A] 30-50 lb/acre	Woolly pod Vetch [A] 40-60 lb/acre	Jack bean [P] 50-60 lb/acre	('CA Blackeye 5', 'Purple knuckle', 'TS Brown', 'MS Silver') Cowpea [A] [R] 40-60 lb/acre	Mustard [A] 7-10 lb/acre	Oat [A] 90 lb/acre
Oat [A] 90 lb/acre	Mustard [A] 7-10 lb/acre	Bell Bean [A] 150 lb/acre	Yellow Sweetclover [B] 10-15 lb/acre	Velvet Bean [SP] [R*] 40 lb/acre	Soybean [A] 50-75 lb/acre	Rape Seed [A] [S] 7-10 lb/acre	Black Oat [A] 75 lb/acre
Winter Wheat [A] 120 lb/acre	Rape Seed [A] [S] 7-10 lb/acre	Red Clover [SP] 20 lb/acre	White Clover [P] 20 lb/acre	Pigeon Pea [P] 40-60 lb/acre	Lablab [P] 11-18 lb/acre	Oil Radish [A] [S] 10 lb/acre	Grain Sorghum [A] 25-30 lb/acre
Annual Ryegrass [A] 100 lb/acre	Oil Radish [A] [S] 10 lb/acre	Austrian Winter pea [A] [R] 100 lb/acre	('Moapa 69') [P] [R] Alfalfa 15 lb/acre	Perennial Peanut [R] 40 lb/acre	Sunn Hemp [A] [R*] 30-60 lb/acre	Marigold [A] [R] 3 lb/acre	Sorghum-Sudangrass [A] [R] 35-60 lb/acre

* = seedig rate

A = annual; B= Biennial; P = Perennial; SP = Short-term perennial.

R = resistant to root-knot but not reniform nematode; (note: only certain cultivars are resistant to root-knot nematodes for alfalfa and cowpea; cowpea is very susceptible to reniform nematode).

S = suppressive to plant-parasitic nematodes

R*= sunn hemp and velvetbean are resistant to root-knot and reniform nematodes; marigold, Tagetes patula, is resistant to root-knot and reniform, *T. erecta* is only resistant to root-knot; sesame is resistant to southern and peanut root-knot nematode (*Meloidogyne incognita* and *M. arenaria*) but not Javanica root-knot (*M. javanica*).

Sunn hemp · Oil radish · Wolly pod vetch · Sudangrass + lablab · Buckwheat · Cowpea + marigold

PLANT AVAILABLE NITROGEN (PAN)

- Although cover crops can fix or accumulate nitrogen (N) in plant tissues, not all the N in the tissue will be released into a plant available form

At 28 days after cover crop incorporation
At 70 days after cover crop incorporation

[NO_3^-]

[NO_3^-]

Plant Available Nitrogen (PAN %) = [Soil nitrate with cover crop (mg/kg) - soil nitrate without cover crop] / Total N added by cover crop (mg/kg) X 100

% N in tissue × cover crop biomass = Total N

Amount of N fertilizer input that farmers can cut back

Actual PAN = cover crop dry biomass × % N × PAN%

How to use Cover Crop Calculator?

2. Subsample 1-2 lb biomass sample and send it to a Lab:
   - for tissue N analysis (%)
   - estimate cover crop dry biomass (%)

1. Sample above ground cover crop biomass from at least four 1-sq ft quadrants, measure in lbs/sq ft.

Agricultural Diagnostic Service Center
1910 East-West Road
Sherman Laboratory 134
Honolulu, Hawaii 96822
Tel: (808)956-6706

3. Download Cover Crop Calculator for Hawaii at https://www.ctahr.hawaii.edu/WangKH/cover-crop.html
Find the location closest to your site.

Actual PAN = % N × cover crop dry biomass × PAN%

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Cover Crop Calculator for Plant Available N

Follow instruction in Sheet #1 to fill in cells in **Step 2**. Best time to terminate an annual cover crop in Hawaii is about 2-3 months after planting.

Date: 3/13/2017 1. Use row with your location and soil order			2. Enter your information in white cells				3. Results are in the orange cells						
Location and soil			Your sample info.				Dry wt. & total N			28 Day PAN		70 Day PAN	
Island	Location	Soil Order	Area sampled (ft^2)	Fresh wt of field sample (x.xlbs)	Total % N from lab (x.x%)	% dry matter from lab (xx.x%)	Fraction of acre sampled	Dry Weight (lb/Acre)	Total N (lb/A)	PAN (%)	Actual PAN (lb/A)	PAN (%)2	Actual PAN (lb/A)
Oahu	Poamoho	Oxisols	1	1.2	2	23	0.00000	0	0	0.0	0	0.0	0
Oahu	Waimanalo	Mollisols					0.00000	0	0	0.0	0	0.0	0
Oahu	Kunia	Oxisols					0.00000	0	0	0.0	0	0.0	0
Hawaii	Waimea	Andisols	1	1.2	2	23	0.00000	0	0	0.0	0	0.0	0
Maui	Alae	Andisols					0.00000	0	0	0.0	0	0.0	0
Maui	Kula	Andisols					0.00000	0	0	0.0	0	0.0	0
Maui	Waiakoa	Mollisols					0.00000	0	0	0.0	0	0.0	0
Molokai	Hoolehua	Inceptisols					0.00000	0	0	0.0	0	0.0	0

Instructions | Cover crop PAN calculator | Typical Poamoho results | Typical Lalamilo results | Model graphs

4. Enter area sampled (column D), fresh weight of field sample (column E), total %N (column F) and % dry matter (column G).

5	Follow instruction in Sheet #1 to fill in cells in **Step 2**. Best time to terminate an annual cover crop in Hawaii is about 2-3 months after planting.													
6	Date: 3/13/2017													
7	1. Use row with your location and soil order			2. Enter your information in white cells				3. Results are in the orange cells						
8	Location and soil			Your sample info.				Dry wt. & total N			28 Day PAN		70 Day PAN	
9	Island	Location	Soil Order	Area sampled (ft^2)	Fresh wt of field sample (x.xlbs)	Total % N from lab (x.x%)	% dry matter from lab (xx.x%)	Fraction of acre sampled	Dry Weight (lb/Acre)	Total N (lb/A)	PAN (%)	Actual PAN (lb/A)	PAN (%)2	Actual PAN (lb/A)
10	Oahu	Poamoho	Oxisols	1	1.20	2.00	23.00	0.00002	12023	240	58.2	140	70.1	168
11	Oahu	Waimanalo	Mollisols					0.00000	0	0	0.0	0	0.0	0
12	Oahu	Kunia	Oxisols					0.00000	0	0	0.0	0	0.0	0
13	Hawaii	Waimea	Andisols	1	1.20	2.00	23.00	0.00002	12023	240	34.3	82	41.7	100
14	Maui	Alae	Andisols					0.00000	0	0	0.0	0	0.0	0
15	Maui	Kula	Andisols					0.00000	0	0	0.0	0	0.0	0
16	Maui	Waiakoa	Mollisols					0.00000	0	0	0.0	0	0.0	0
17	Molokai	Hoolehua	Inceptisols					0.00000	0	0	0.0	0	0.0	0

5. Enter total crop N requirement (cell G18), soil N analysis from Step 1 (cell G19).

ell G20).

	A	B	C	D	E	F	G
4							
5	Follow instruction in Sheet #1 to fill in cells in **Step 2**. Best time to terminate ar						
6	**Date:**	**3/13/2017**					
7	**1. Use row with your location and soil order**			**2. Enter your information in white cells**			
8	**Location and soil**			**Your sample info.**			
9	**Island**	**Location**	**Soil Order**	**Area sampled (ft^2)**	**Fresh wt of field sample (x.xlbs)**	**Total % N from lab (x.x%)**	**% dry matter from lab (xx.x%)**
10	**Oahu**	**Poamoho**	**Oxisols**	**1**	**1.20**	**2.00**	**23.00**
11	**Oahu**	**Waimanalo**	**Mollisols**				
12	**Oahu**	**Kunia**	**Oxisols**				
13	**Hawaii**	**Waimea**	**Andisols**	**1**	**1.20**	**2.00**	**23.00**
14	**Maui**	**Alae**	**Andisols**				
15	**Maui**	**Kula**	**Andisols**				
16	**Maui**	**Waiakoa**	**Mollisols**				
17	**Molokai**	**Hoolehua**	**Inceptisols**				
18	**Total N requirement for your crop (lb/acre):**						**180.0**
19	**Enter PAN available from your cover crop (column L or N):**						**168.0**
20	**Estimated N fertilizer for next crop (lb/acre):**						**12.0**

Day PAN
Actual PAN (lb/A)
168
0
0
100
0
0
0
0

Come with recommendation from ADSC report

=

Amount of N fertilizer input that Poamoho farmers can cut back

5. Enter total crop N requirement (cell G18), soil N analysis from Step 1 (cell G19).

(cell G20).

	A	B	C	D	E	F	G
4							
5	Follow instruction in Sheet #1 to fill in cells in **Step 2**. Best time to terminate a						
6	**Date:**	**3/13/2017**		**2. Enter your information in white cells**			
7	**1. Use row with your location and soil order**						
8	**Location and soil**			**Your sample info.**			
9	**Island**	**Location**	**Soil Order**	**Area sampled (ft^2)**	**Fresh wt of field sample (x.xlbs)**	**Total % N from lab (x.x%)**	**% dry matter from lab (xx.x%)**
10	**Oahu**	**Poamoho**	**Oxisols**	**1**	**1.20**	**2.00**	**23.00**
11	**Oahu**	**Waimanalo**	**Mollisols**				
12	**Oahu**	**Kunia**	**Oxisols**				
13	**Hawaii**	**Waimea**	**Andisols**	**1**	**1.20**	**2.00**	**23.00**
14	**Maui**	**Alae**	**Andisols**				
15	**Maui**	**Kula**	**Andisols**				
16	**Maui**	**Waiakoa**	**Mollisols**				
17	**Molokai**	**Hoolehua**	**Inceptisols**				
18					**Total N requirement for your crop (lb/acre):**		**180.0**
19					**Enter PAN available from your cover crop (column L or N):**		**100.0**
20					**Estimated N fertilizer for next crop (lb/acre):**		**80.0**

Day PAN
Actual PAN (lb/A)
168
0
0
100
0
0
0
0

This does not account for additional N for soil organic matter

Amount of N fertilizer input that Waimea farmers can cut back

Note: Majority of the PANs were released during the first 28 days after cover crop termination.

3. Results are in the orange cells						
Dry wt. & total N			28 Day PAN		70 Day PAN	
Fraction of acre sampled	Dry Weight (lb/Acre)	Total N (lb/A)	PAN (%)	Actual PAN (lb/A)	PAN (%)2	Actual PAN (lb/A)
0.00002	12023	240	58.2	140	70.1	168
0.00000	0	0	0.0	0	0.0	0
0.00000	0	0	0.0	0	0.0	0
0.00002	12023	240	34.3	82	41.7	100
0.00000	0	0	0.0	0	0.0	0
0.00000	0	0	0.0	0	0.0	0
0.00000	0	0	0.0	0	0.0	0
0.00000	0	0	0.0	0	0.0	0

- Cash crops should be planted within 2 weeks after cover crop termination for maximum recycling of PAN.
- Pending on your cropping cycle, additional fertilizer needed probably should be added around 4-week after cover crop termination (not at crop planting).

6. Compare your cover crop results with UH ranges (found in:

'Typical Poamoho/Lalamilo Results') for specific cover crop species. Use caution if your estimates are unusual.

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Plant Available N of Typical Cover Crops Used in Lower Elevation in Hawaii (e.g. Poamoho)

Cover Cropping Practice			Cover Crop Tissue			28 Days		70 Days	
Cover Crop	Fresh Weight (lb/ft^2)	Dry Content (%)	Dry Weight (lb/Acre)	Tissue N (%)	Total N(lb/A)	PAN (%)	Actual PAN (lb/A)	PAN (%)2	Actual PAN(lb/A)
	0.99	17.16%		2.25		58.404		67.234	104.06
Sunn hemp	0.72	21.34%	6692.91	2.72	182.05	60.54	110.21	75.14	136.79
Cowpea	1.54	14.24%	9552.53	2.83	270.34	67.57	182.67	74.43	201.21
Lablab	0.34	13.31%	1971.26	3.13	61.70	78.05	48.16	81.91	50.54
Sudex	0.96	16.02%	6699.18	1.33	89.10	43.48	38.74	54.95	48.96
Oat (TAM406)	0.51	14.72%	3270.14	1.84	60.17	46.25	27.83	62.55	37.64
Oil Radish	0.55	6.40%	1533.31	2.49	38.18	70.8	27.03	77	29.40
	0.78	14.34%		2.39		61.12		71.00	84.09
		15.83%		2.55		61.07	86.95	71.64	102.30

ons | Cover crop PAN calculator | Typical Poamoho results | Typical Lalamilo results | Model graphs

7. Look for crop N deficiencies. Supplement with additional fertilizer PAN if needed.

VERIFICATION

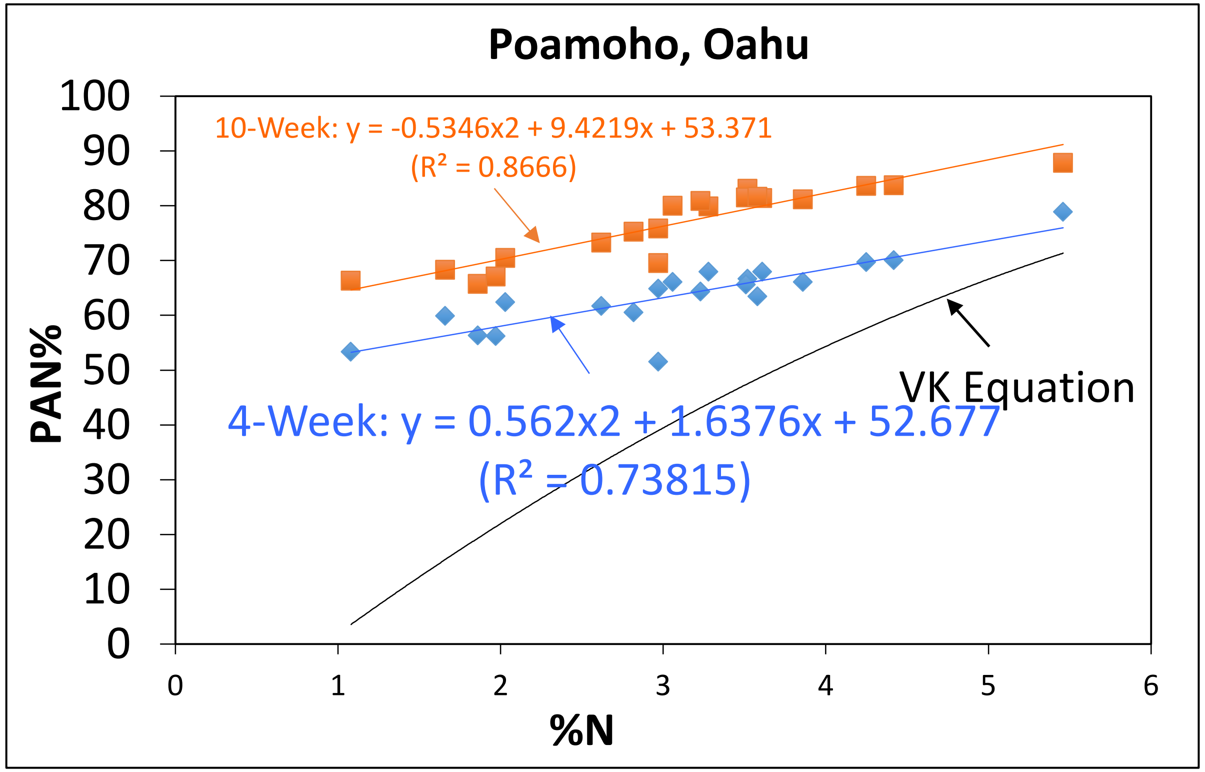
Farmers' sample through direct PAN estimation

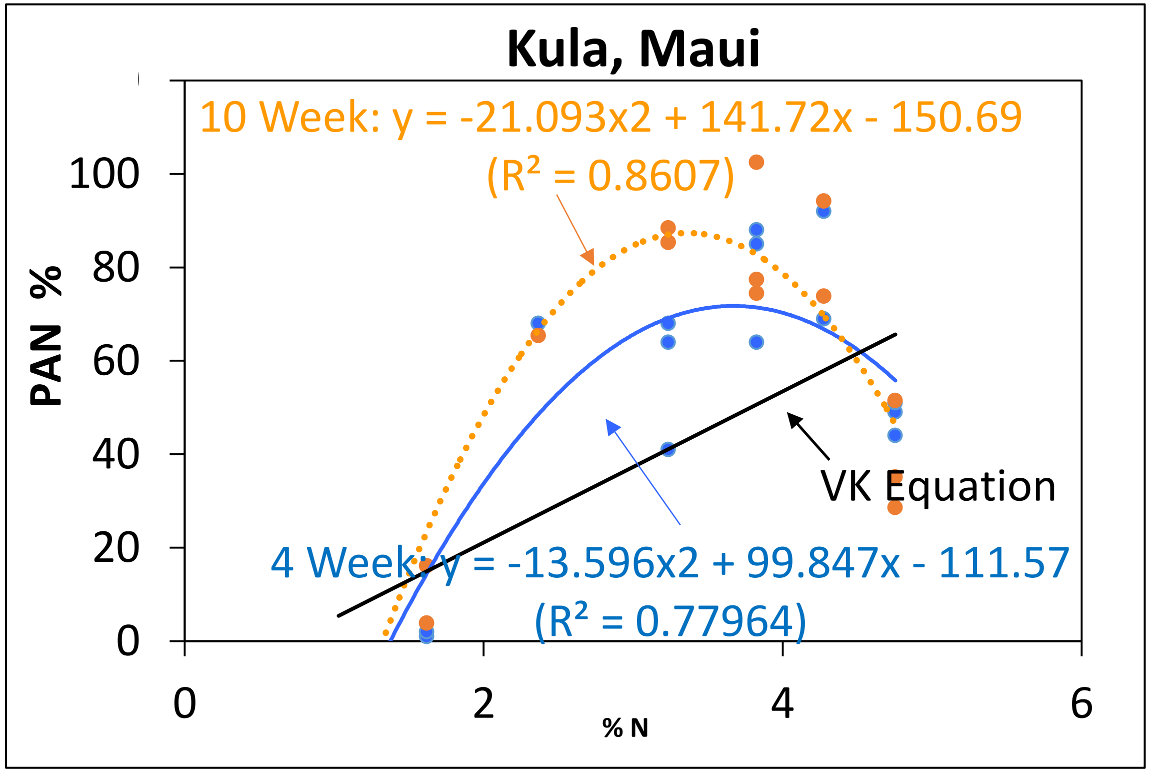
	Fresh wt (lb/sq ft)	Dry content (%)	Tissue N (%)	28 day PAN (%)	28 day Actual PAN (lb/A)	70 day PAN (%)	70 day Actual PAN (lb/A)
Hirayama	0.89	10	4.05	61.73	95.08	68.77	106.03
Bonk	1.32	5	4.77	62.92	90.53	71.42	93.64
Robbs	0.89	14	2.64	62.22	89.60	-	-

	Cover crops mix	PAN estimation using cover crop calculator			
Hirayama	Vetch, red clover, spring pea, oats	56.6	89	65.1	102
Bonk	Oil radish, vetch	60.5	83	67.2	92
Robbs	Cayuse oat, bell beans, [illegible]	43	62	51.7	74

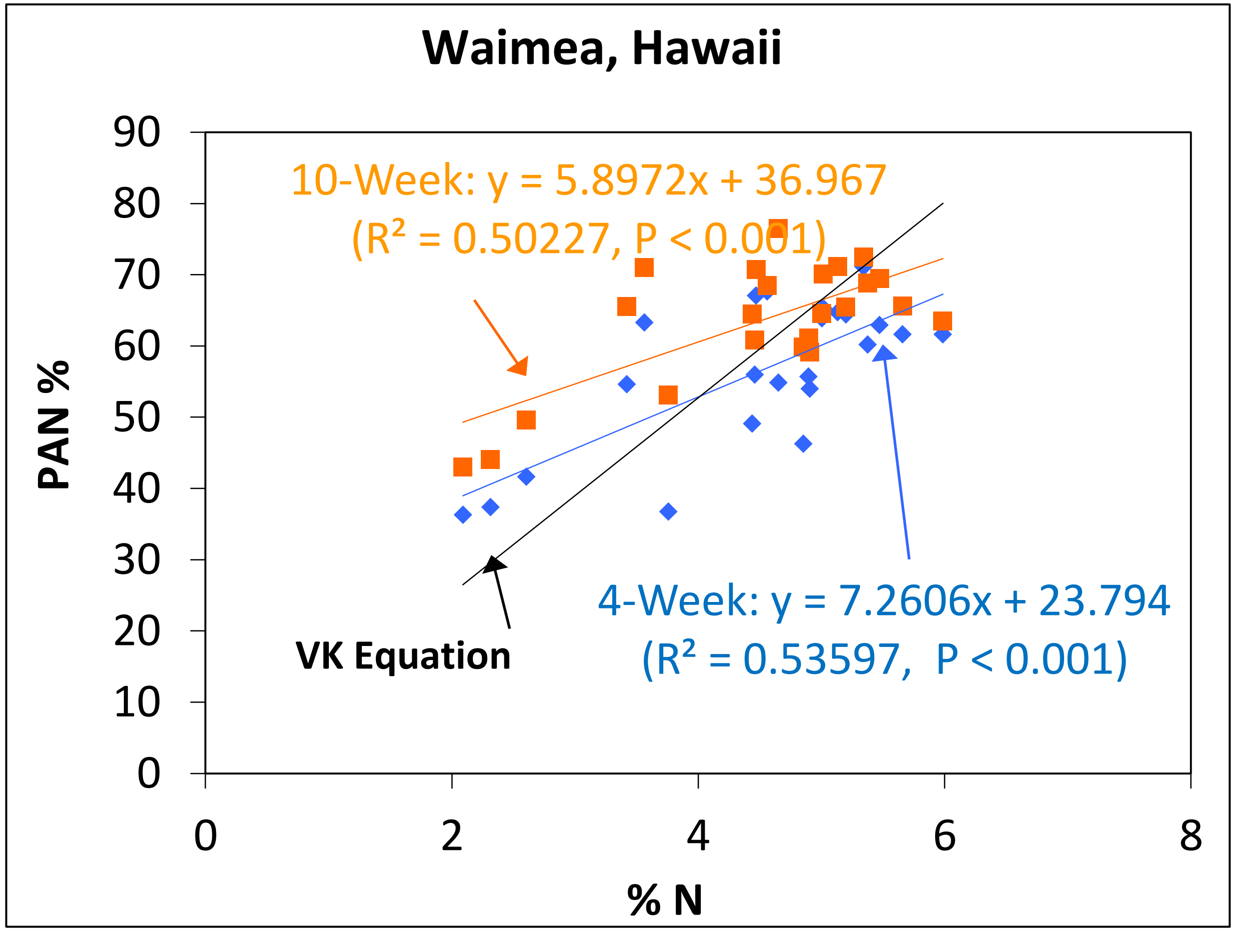
PAN% PREDICTION CURVES IN HI

- In some areas, PAN% prediction curves in HI is higher than that from VK-equation.



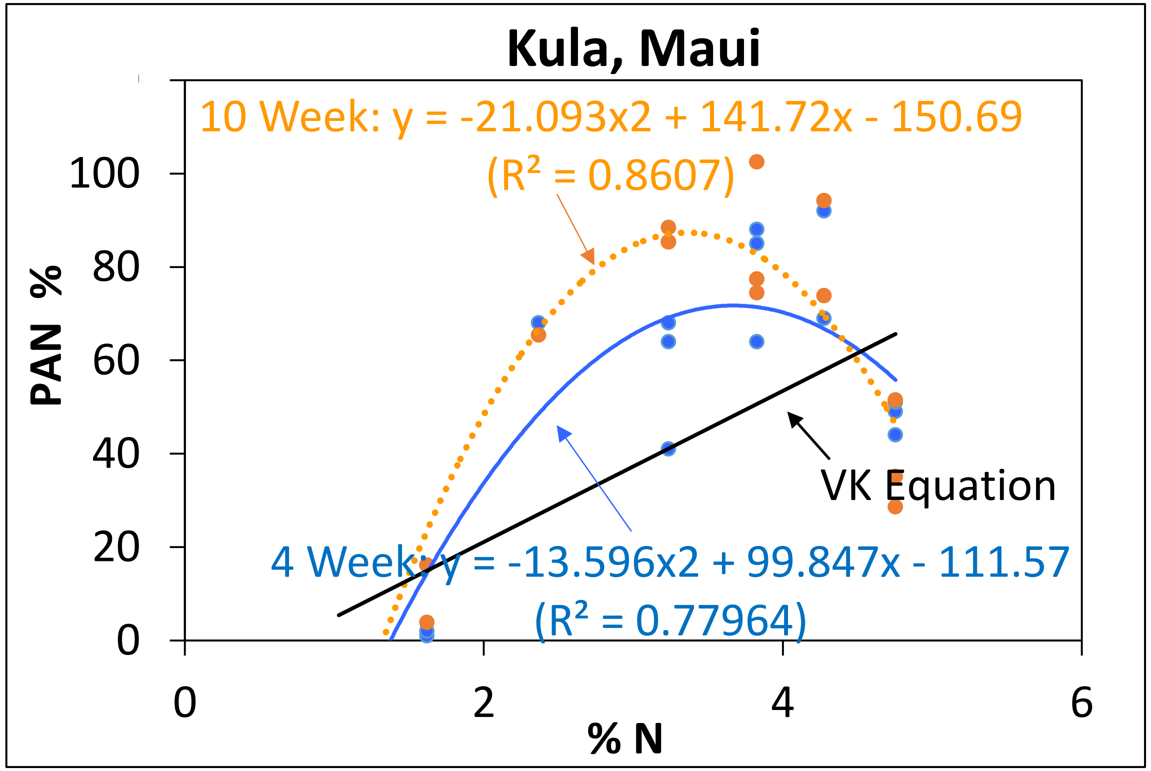


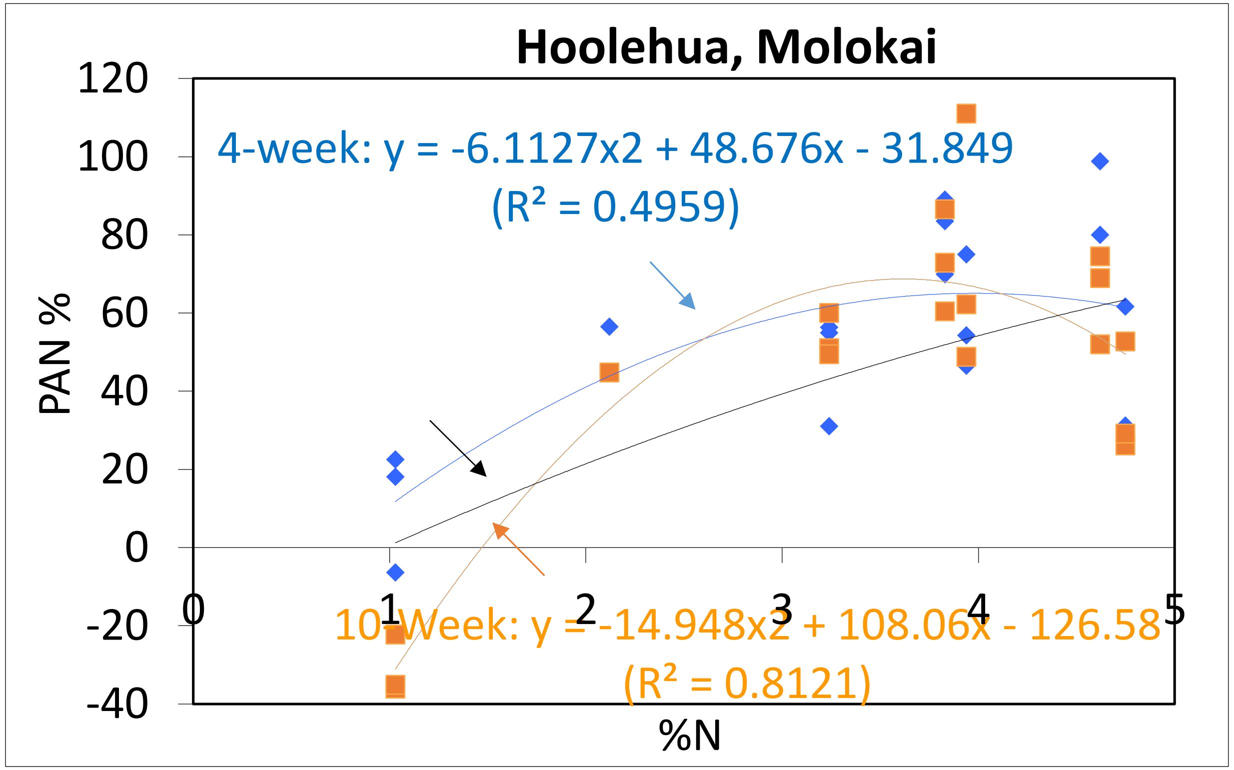
PAN% PREDICTION CURVES IN HI



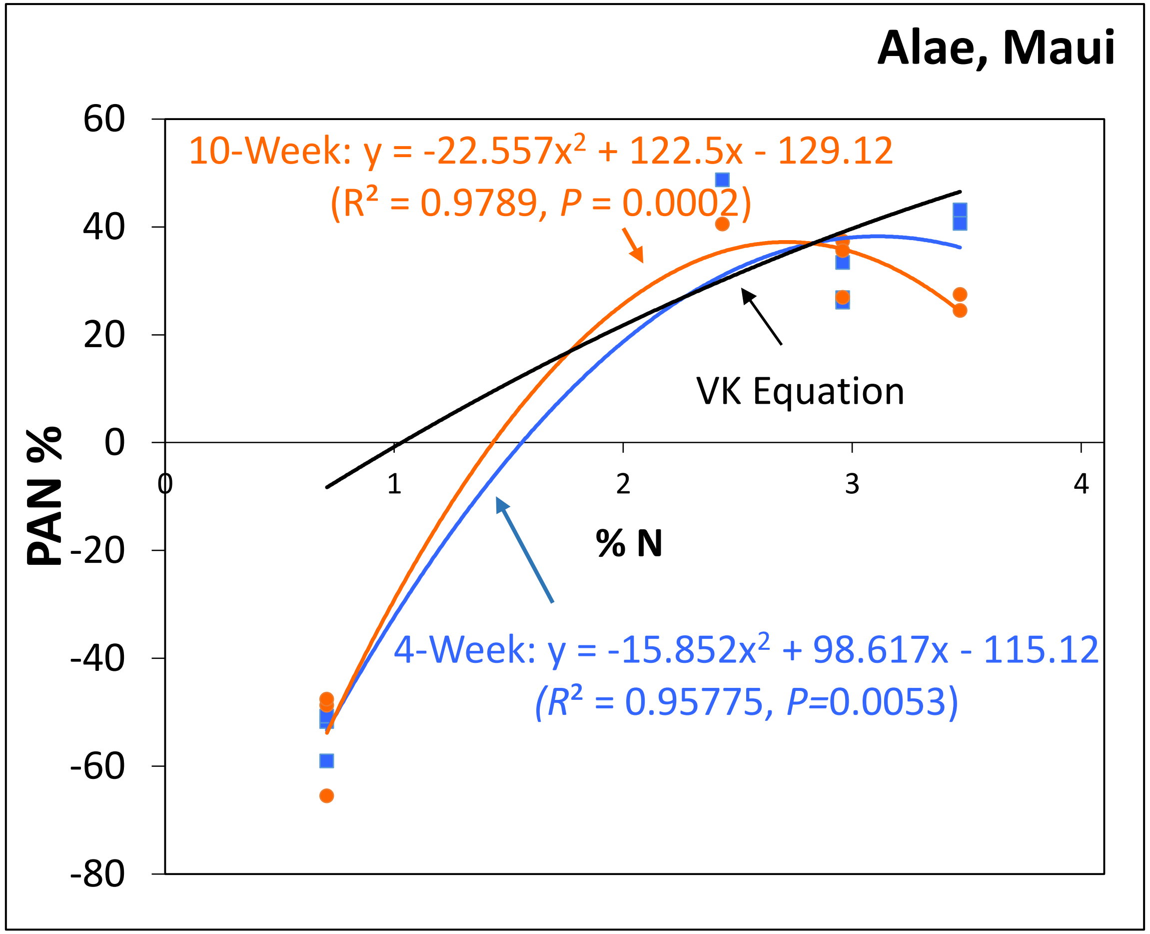
- However, PAN% estimated in cool season at higher elevation in Hawaii is very similar to VK-equation.

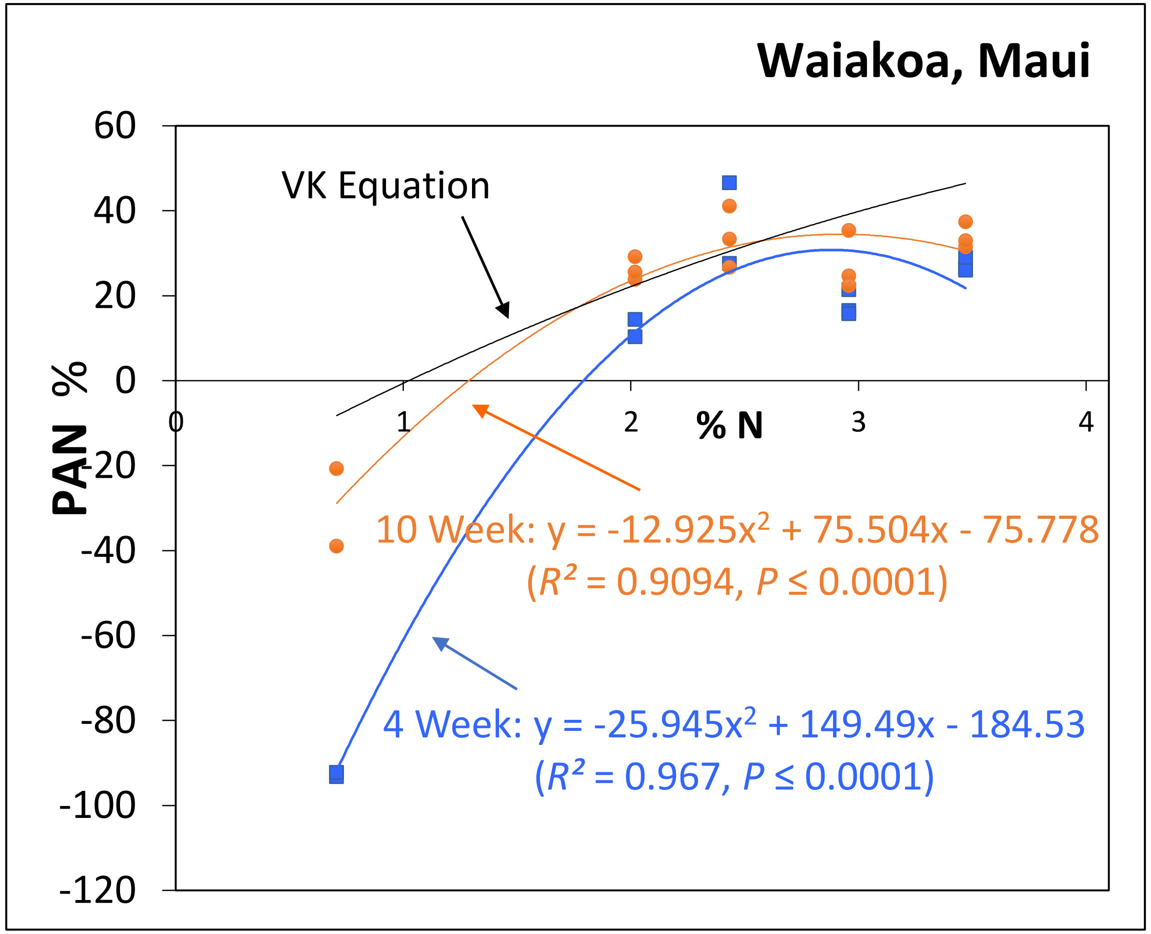
THERE IS A TREND THAT PAN% DECREASED WHEN %N OF COVER CROP TISSUES IS HIGHER THAN 4%





Some time, PAN% prediction curves in HI is lower than that of VK-equation. Suggesting that soil health conditions can affect PAN mineralization rate significantly.





Outline

- Benefits of cover crop for soil fertility management
- Cover crop calculator
- ✓ Factors affecting plant available N% (PAN%)

FACTORS AFFECTING PAN% FROM COVER CROP

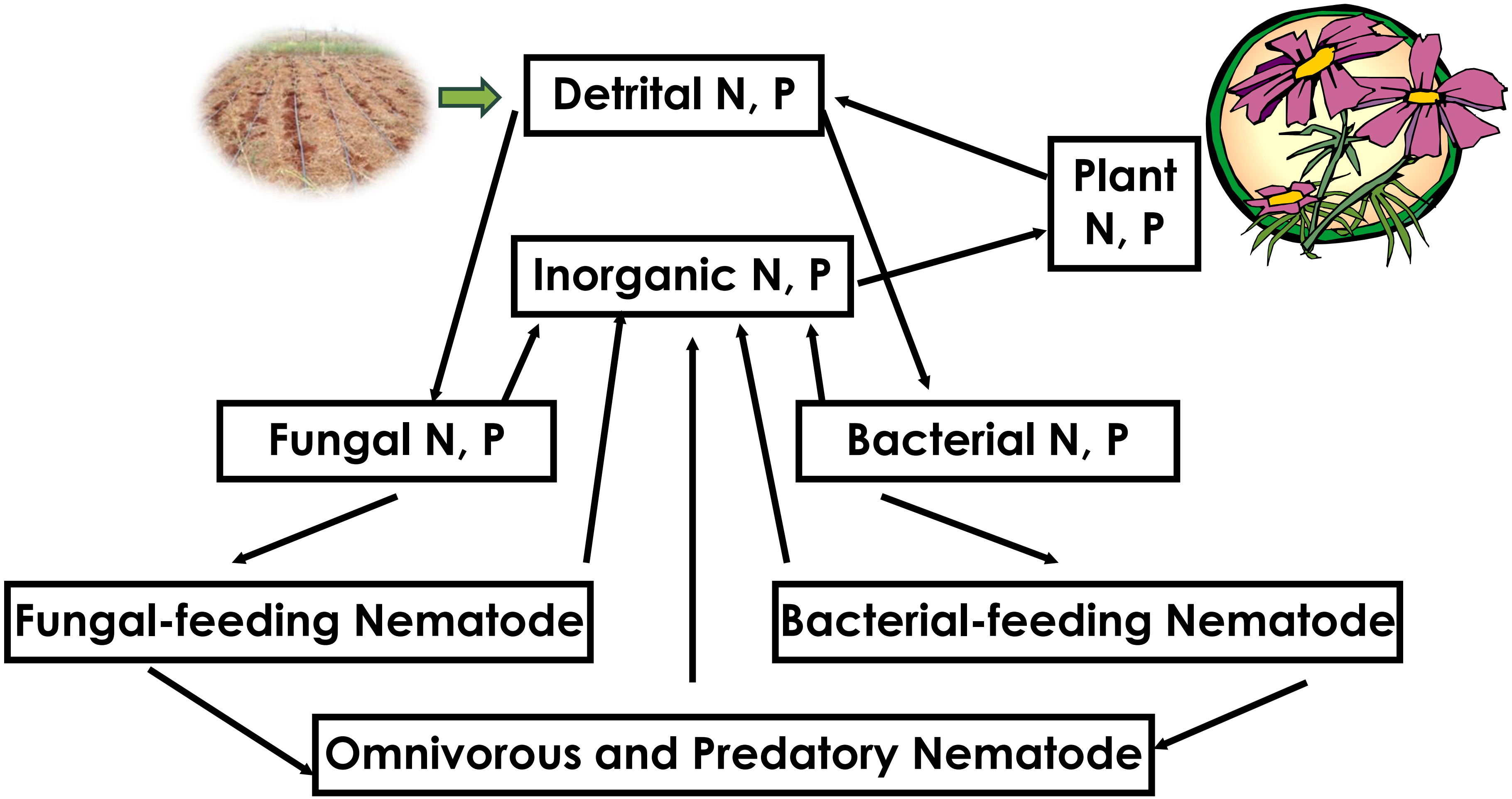
- climate conditions, season
- soil types
- cover crop species
- biomass, plant age, % N in tissue
- time after cover crop termination
- farming practice (till vs no-till)
- microbial activities in your soil

Based on studies in Kansas, Vigil and Kissel (1991) found strong correlation between PAN released % with % N in tissues

$$PAN\ (\%) = -53.44 + 16.98\ (\%\ N\ in\ tissue \times 10)^{1/2}$$

However, Hawaii has many micro-climates and soil types. Thus, different PAN prediction models need to be developed for different regions in Hawaii.............

More Complex Soil Food Web Increase Soil Nutrient Mineralization



Nematodes as Indicators of Soil Health

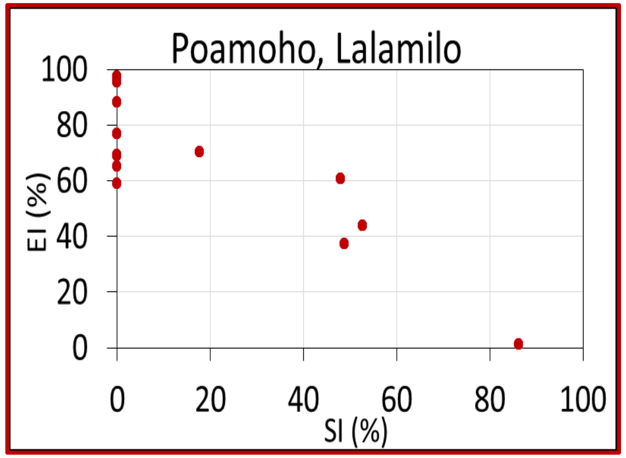
Bacterivore **Fungivore** **Herbivore** **Omnivore** **Predator**

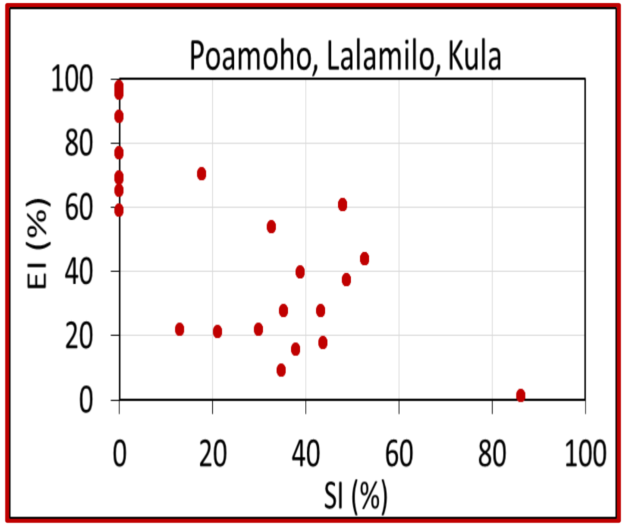
EI=Enrichment index

CI=Channel index

SI=Structure index

+ richness, diversity

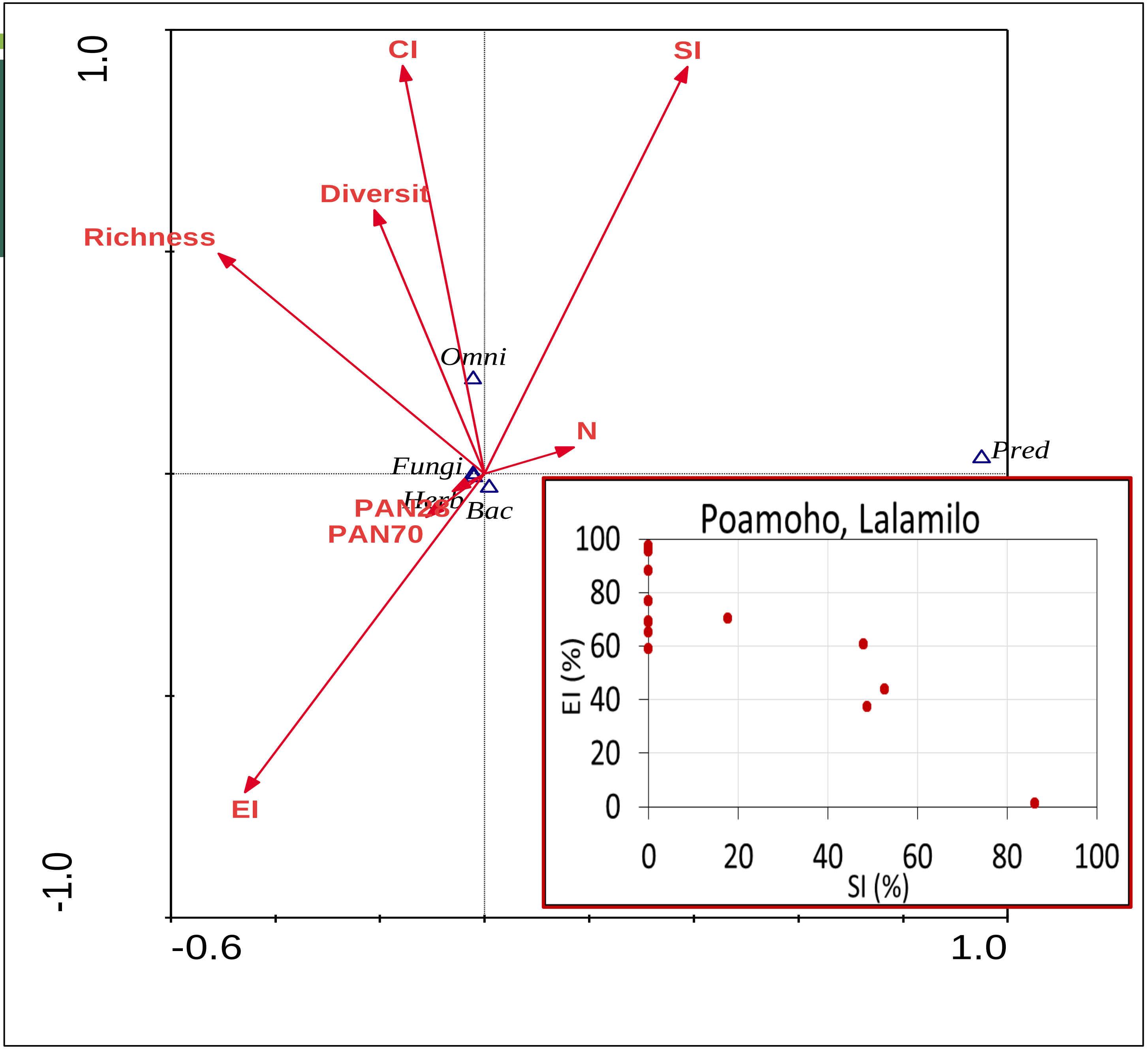




LESS STRUCTURED SOIL FOOD WEB

- When analyzing PAN% in soil samples with less structured soil food web (dominated by high EI):
- PAN% was positively correlated with EI and abundance of bacterivores and negatively correlated with SI and CI.

Nematode soil health indicators explained 99.6% of the cumulative variance of CCA between abundance of nematode trophic groups and environmental variables.

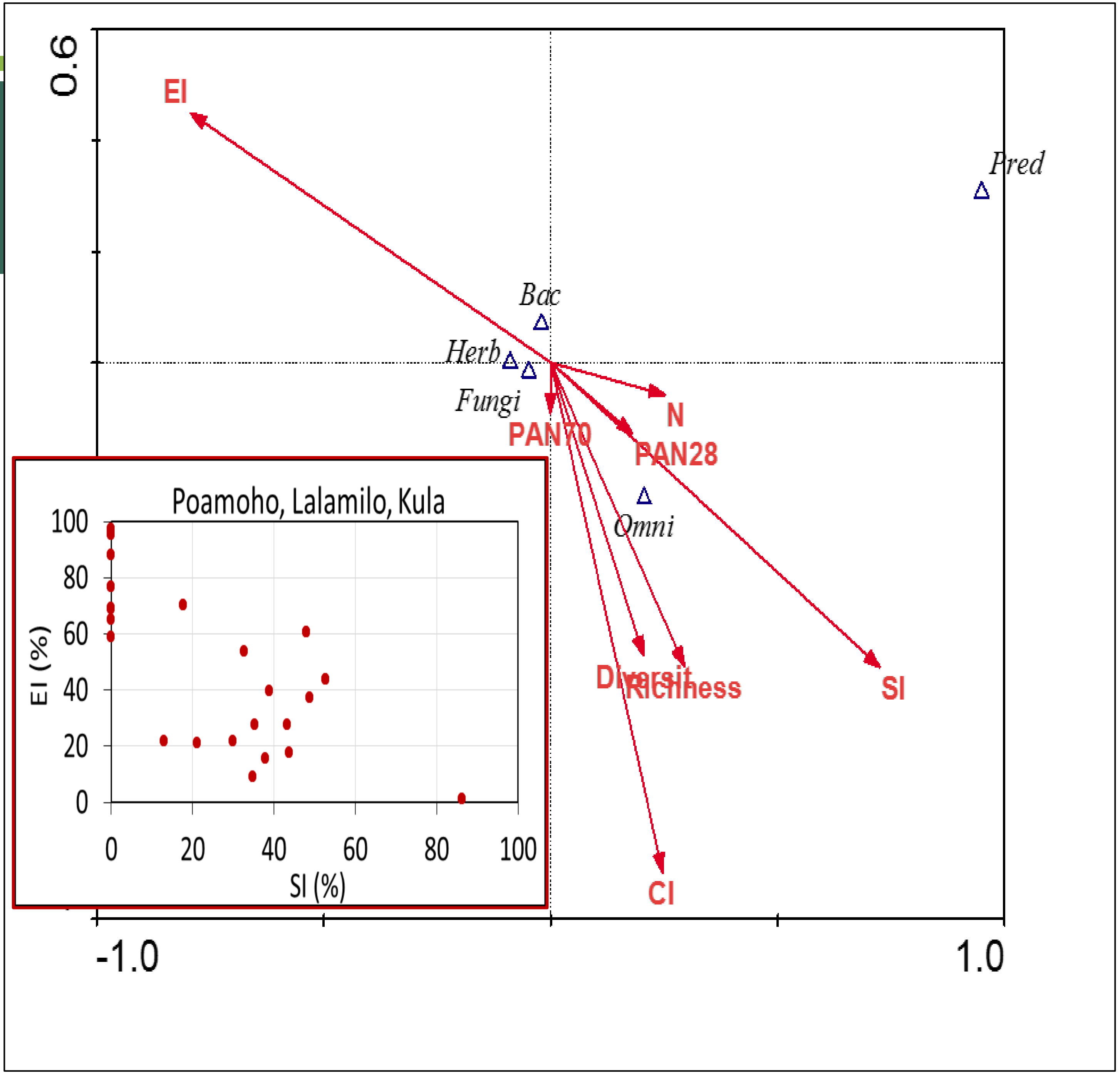


PAN28 and PAN70 = PAN mineralization rate at 28 and 70 days after cover

MORE STRUCTURED SOIL FOOD WEB

- When analyzing soil with a wider range of distribution in EI-SI trajectories,:
- PAN% were positively correlated with SI, CI and abundance of omnivores, but negatively correlated with EI.

Nematode soil health indicators explained 96.7% of the cumulative variance of CCA between abundance of nematode trophic groups and environmental variables



CONCLUSION

- Estimating mineralization rate of N from cover crop residues can provide a guideline for farmers to reduce fertilizer inputs.
- However, accuracy of PAN% estimate from this Cover Crop Calculator might change over time pending on a series of factors, including soil health conditions.
- More structured soil food webs with more diverse decomposition channels were stronger driven force for N mineralization than the simpler soil food web.
- Use Cover Crop Calculator as a reference, good observation on crop response is inevitable.

Reference links

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- http://www.ctahr.hawaii.edu/WangKH/Downloads/CRATE-Wang-HanaiAi.pdf
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