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

# COVER CROP PLANT AVAILABLE NITROGEN (PAN) CALCULATOR for HAWAII

KOON-HUI WANG, THEODORE RADOVICH, JOSIAH MARQUEZ, ARCHANA PANT, SHELBY CHING, SHOVA MISHRA, JARI SUGANO, JENSEN UYEDA

CRATE
Center of Rural Agricultural Training & Entrepreneurship

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 Mānoa
College of Tropical Agriculture & Human Resources

USDA

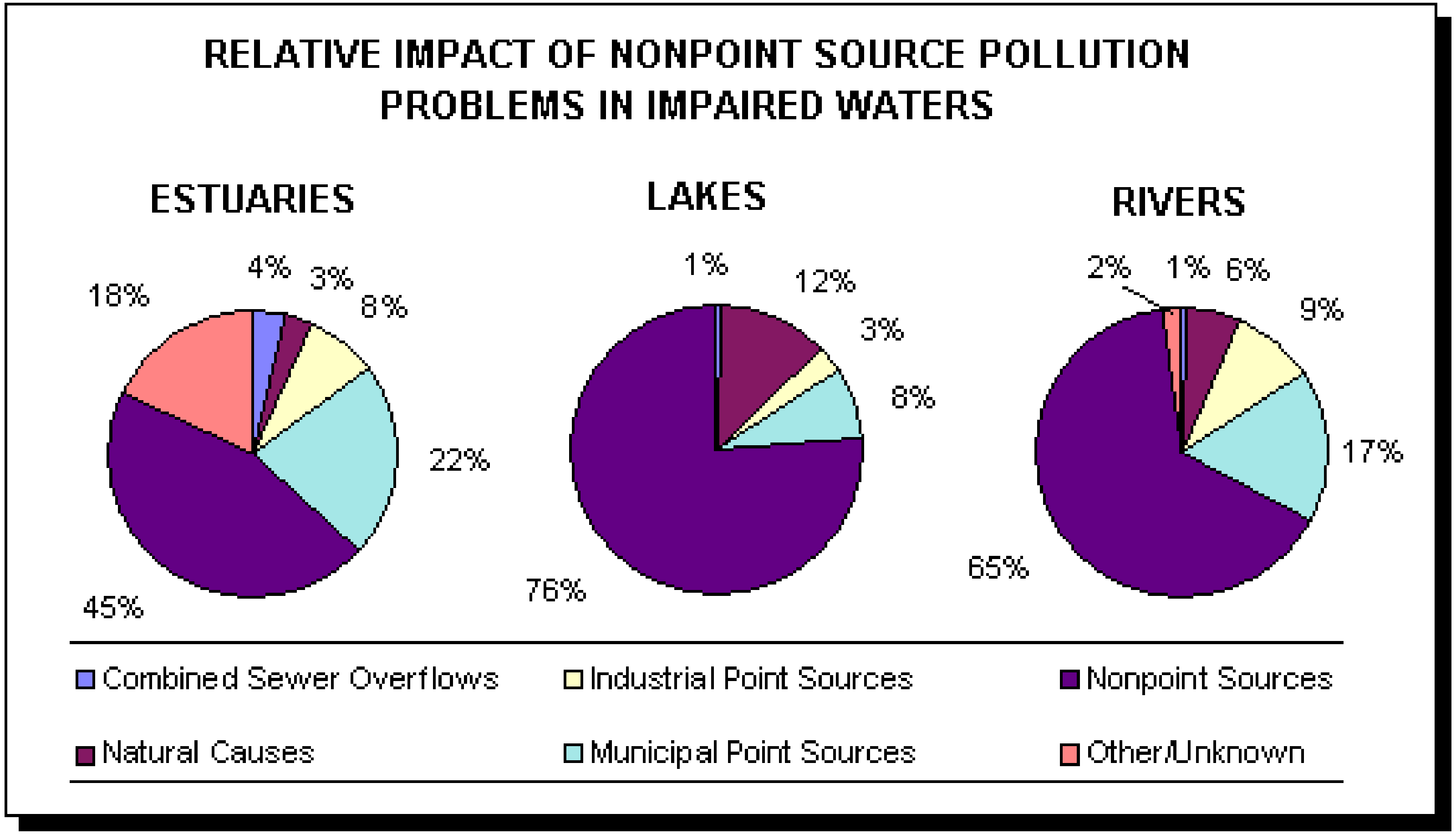
NRCS

# Benefits of cover cropping:

## Soil Health


## Water Health?

# NON-POINT SOURCE POLLUTION




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

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% of the pollution in U.S. waters.

# EUTROPHICATION

## Excess Nitrogen and Phosphorous Spur Algal Growth, Deplete Oxygen and Kill Fish.

George Eberling, Maryland DNR

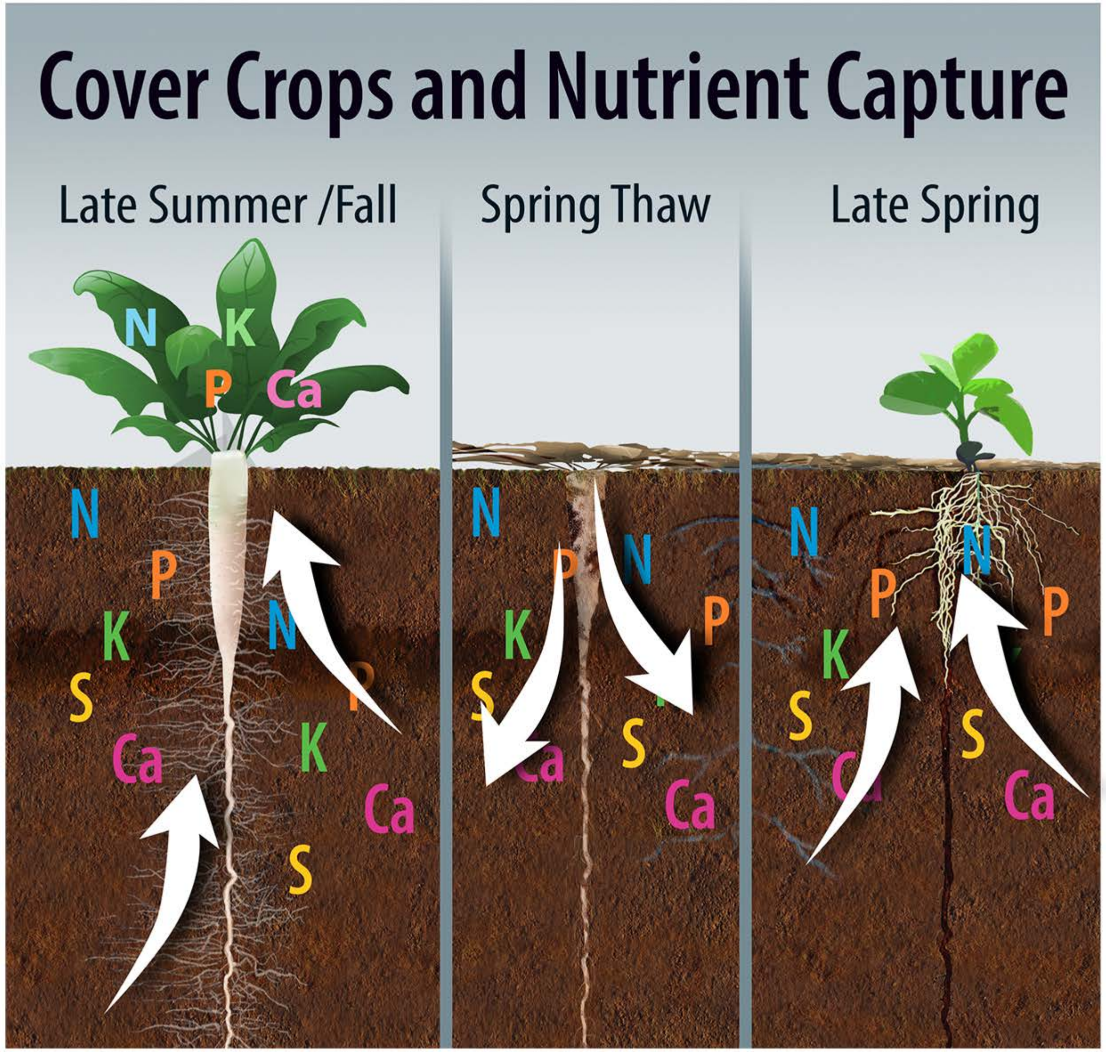
Algae bloom

USDA Forest Service

Many species, including fish, are sensitive to low oxygen levels and die as a result.

# OUTLINE

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




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*

# 1. COVER CROP SCAVENGE SOIL NUTRIENTS

- Fibrous-rooted cereal grains or grasses – scavenging excess N left in soil after a cash crop, reduce nutrient leach.
- **Need to plant early:** Rye can took up 70 lb **N**/A 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 profile to upper soil surface.
- Although P doesn't leach, it is not readily available for plant to uptake. Cover crops such as buckwheat and lupins, secrete acids into soil that put P into a more soluble form for plant to uptake.
- Cover crops could also enhance plant P uptake by hosting mycorrhizae fungi.

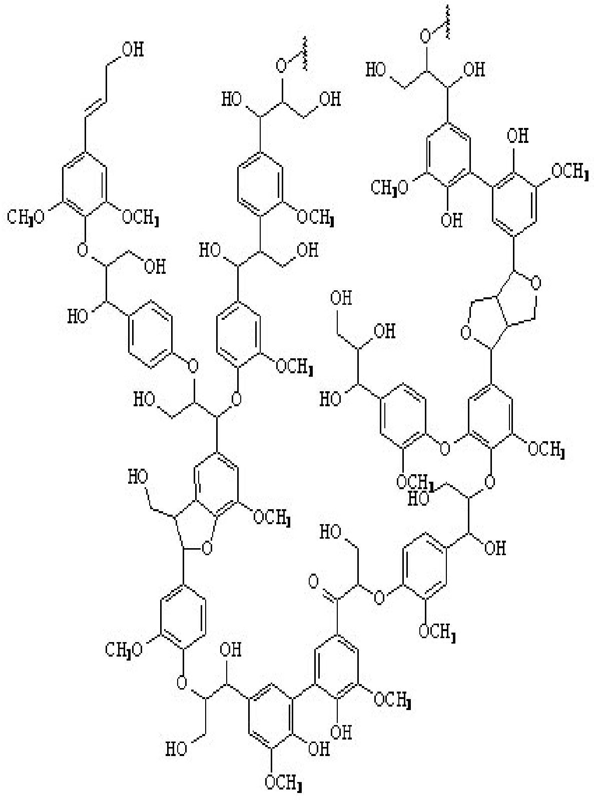

Oil radish


Lupin

# 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)
- But 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 (responsible for the release of most N, P, K from organic matter)
  - Stable fraction – rich in celluloses and lignins, tougher to break down, contribute to humus (responsible for real soil organic matter, dark content, water holding capacity, cation exchange capacity or CEC)

# *EFFECTS OF COVER CROPS ON SOM*

Crimson clover
*Trifolium incarnatum*

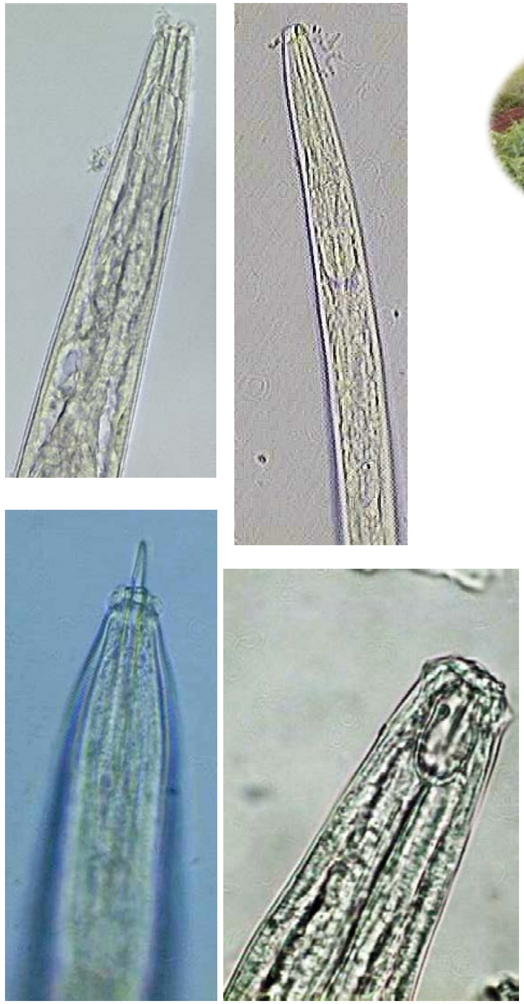
Oat
*Avena sativa*

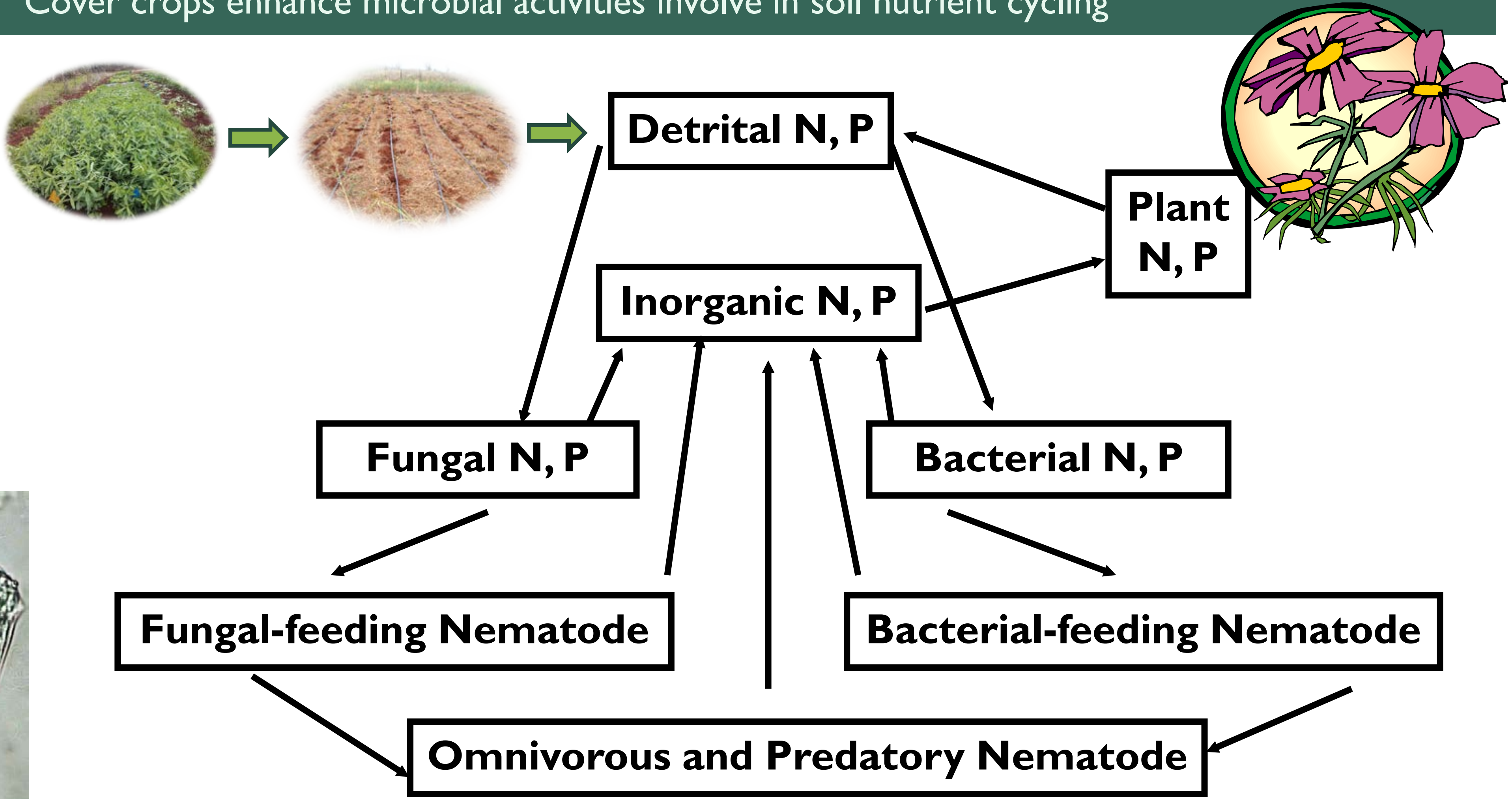
White clover
*Trifolium repens*

- **Annual legumes:** Produce plant materials that are succulent and rich in proteins and sugars – leave little long-term organic matter.
- **Grain and grasses, non-legumes:** Produce plant materials that are woodier or more fibrous – promote more stable organic matter (humus), increase soil structure, CEC, but might tie up nutrients temporarily.
- **Perennial legumes/Long-term annuals** such as perennial peanut, white clover or sunn hemp (if let sunn hemp grown for months) may fall in both categories – leaves will break down quickly, but stems and root systems can contribute to humus accumulation.

# 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

CRATE

## Cover Crop Chart for Hawaii

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

High Elevation ⟷ Low Elevation

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

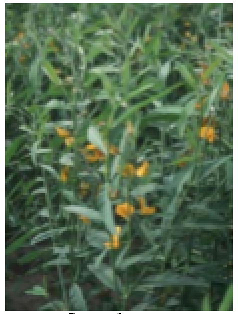
* = seedig rate

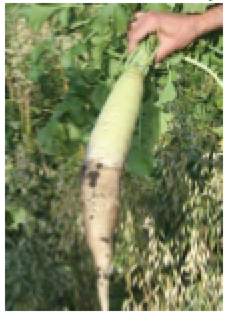
A = annual; B= Biennial; P = Perennial; SP = Short-term perennial.

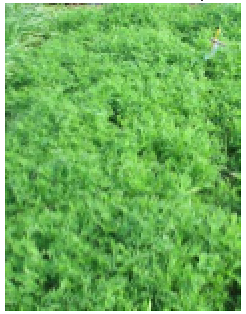
R = resistant to root-knot but not reniform nematode; (note: only certain cultivars are resistant to root-knot nematodes for alfalfa and cowpea; cowpea is very susceptible to reniform nematode).

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

$[NO_3^-]$

$[NO_3^-]$

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

% N in tissue × cover crop biomass = Total N

***Amount of N fertilizer input that farmers can cut back***

Actual PAN = % N × cover crop dry biomass × 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

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

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

# PAN FROM COVER CROPS IN POAMOHO, OAHU (WINTER)

| Cover Cropping Practice | | | | Cover Crop Tissue | | | 28 Days | | 70 Days | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season/tillage | 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) |
| Winter/Till | Sunn hemp | 1.2 | 23.10% | 12074.83 | 1.66 | 200.44 | 55.24 | 110.72 | 67.82 | 135.94 |
| Winter/Till | Cowpea (Blackeye #5) | 1.04 | 13.70% | 6206.43 | 2.87 | 178.12 | 63.74 | 113.54 | 75.17 | 133.90 |
| Winter/Till | Lablab | 0.78 | 14.89% | 5059.15 | 2.75 | 139.13 | 62.72 | 87.26 | 75.22 | 104.65 |
| Winter/Till | Pigeon pea | 0.55 | 20.47% | 4904.20 | 3.47 | 170.18 | 66.14 | 112.55 | 81.69 | 139.02 |
| Winter/Till | Woolypod vetch | 0.55 | 9.21% | 2206.53 | 4.43 | 97.75 | 70.52 | 68.93 | 84.19 | 82.30 |

- % Tissue N varied among cover crop species.
- Some cover crop released PAN more efficiently than others (70.5% vs 55.2%).
- Actual PAN can be strongly influenced by cover crop biomass.

http://www.ctahr.hawaii.edu/WangKH/cover-crop.html

# PAN FROM COVER CROPS IN POAMOHO, OAHU (SUMMER)

| Cover Cropping Practice | | | | Cover Crop Tissue | | | 28 Days | | 70 Days | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season/tillage | 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) |
| Winter/No-till | Sunn hemp | 1.07 | 24.62% | 11475.19 | 2 | 229.50 | 56.85 | 130.47 | 66.72 | 153.12 |
| Winter/No-till | Cowpea (Blackeye #5) | 1.47 | 14.20% | 9092.71 | 2 | 181.85 | 56.6 | 102.93 | 65.42 | 118.97 |
| **Summer** | | | | | | | | | | |
| Summer/No-till | Sunn hemp | 0.72 | 21.34% | 6692.91 | 2.72 | 182.05 | 60.54 ✓ | 110.21 | 75.14 ✓ | 136.79 |
| Summer/No-till | Cowpea | 1.54 | 14.24% | 9552.53 | 2.83 | 270.34 | 67.57 ✓ | 182.67 | 74.43 ✓ | 201.21 |
| Summer/No-till | Lablab | 0.34 | 13.31% | 1971.26 | 3.13 | 61.70 | 78.05 | 48.16 | 81.91 | 50.54 |
| Summer/No-till | Sudex | 0.96 | 16.02% | 6699.18 | 1.33 | 89.10 | 43.48 | 38.74 | 54.95 | 48.96 |
| Summer/No-till | Oat (TAM406) | 0.51 | 14.72% | 3270.14 | 1.84 | 60.17 | 46.25 | 27.83 | 62.55 | 37.64 |
| Summer/No-till | Oil Radish | 0.55 | 6.40% | 1533.31 | 2.49 ✓ | 38.18 | 70.8 ✓ | 27.03 | 77 ✓ | 29.40 |

- PAN released % was higher in summer than winter.
- Grassy cover crops had lower % N and slower PAN released % compared to legumes, but that in oil radish was equivalent or higher than legumes, thus a good nutrient scavenging crop.

# PAN FROM COVER CROPS IN LALAMILO, HAWAII

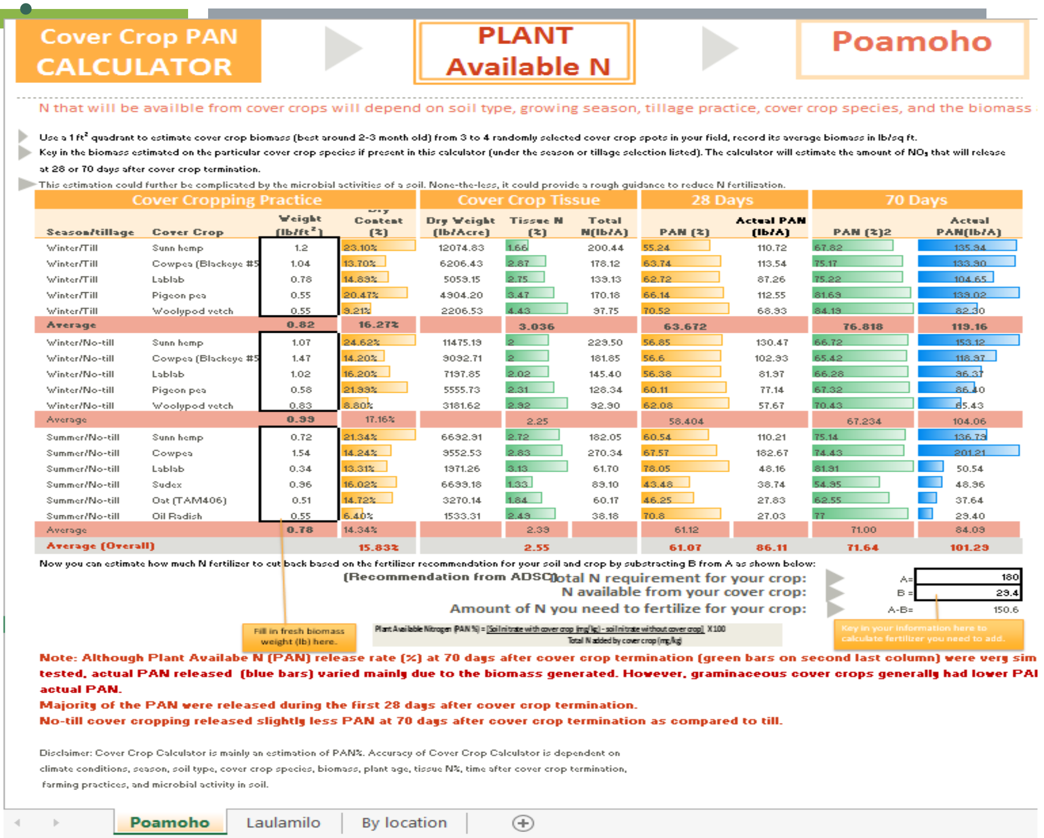
| Cover Cropping Practice | | | | Cover Crop Tissue | | | 28 Days | | 70 Days | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season/tillage | Cover Crop | Fresh Weight ($lb/ft^2$) | Dry Content (%) | Dry Weight (lb/Acre) | Tissue N (%) | Total N(lb/A) | PAN (%) | Actual PAN (lb/A) | PAN (%)2 | Actual PAN(lb/A) |
| Winter/Till | Bell bean | 0.78 | 10.60% | 3601.54 | 4.2 | 151.26 | 64.03 | 96.85 | 69.95 | 105.81 |
| Winter/Till | Austrian Winter Pea | 0.6 | 11.70% | 3057.91 | 4.9 | 149.84 | 63.34 | 94.91 | 67.72 | 101.47 |
| Winter/Till | Annual ryegrass | 0.36 | 13.42% | 2104.47 | 4.72 | 99.33 | 54.76 | 54.39 | 60.58 | 60.17 |
| Winter/Till | Woolypod vetch | 0.45 | 11.20% | 2195.42 | 5.32 | 116.80 | 58.46 ✓ | 68.28 | 66.57 | 77.75 |
| Winter/Till | Oat (Cayuse) | 1.15 | 17.20% | 8616.17 | 2.34 | 201.62 | 42.55 | 85.79 | 53.28 | 107.42 |

- PAN released % could change from location to location.
- Although N % in these cover crops were higher than the tropical legumes tested earlier, the actual PAN released were lower.
- Farmers could calculate amount of N fertilizer needed to full-fill the crop requirement.

| | | |
|---|---|---|
| Total N requirement for your crop: (Recommended by ADSC) | A = | 180 |
| N available from your cover crop: | B = | 105 |
| Amount of N you need to fertilize for your crop: | A-B = | 75 |

# How to use Cover Crop Calculator?

Tissue N%



Cover Crop PAN CALCULATOR ▶ PLANT Available N ▶ Poamoho

N that will be availble from cover crops will depend on soil type, growing season, tillage practice, cover crop species, and the biomass

- Use a 1 ft² quadrant to estimate cover crop biomass (best around 2-3 month old) from 3 to 4 randomly selected cover crop spots in your field, record its average biomass in lb/sq ft.
- Key in the biomass estimated on the particular cover crop species if present in this calculator (under the season or tillage selection listed). The calculator will estimate the amount of $NO_3$ that will release at 28 or 70 days after cover crop termination.
- This estimation could further be complicated by the microbial activities of a soil. None-the-less, it could provide a rough guidance to reduce N fertilization.

| Cover Cropping Practice | | | | Cover Crop Tissue | | | 28 Days | | 70 Days | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season/tillage | Cover Crop | Weight (lb/ft²) | Dry Content (%) | Dry Weight (lb/Acre) | Tissue N (%) | Total N(lb/A) | PAN (%) | Actual PAN (lb/A) | PAN (%)2 | Actual PAN(lb/A) |
| Winter/Till | Sunn hemp | 1.2 | 23.10% | 12074.83 | 1.66 | 200.44 | 55.24 | 110.72 | 67.82 | 135.94 |
| Winter/Till | Cowpea (Blackeye #5 | 1.04 | 13.70% | 6206.43 | 2.87 | 178.12 | 63.74 | 113.54 | 75.17 | 133.90 |
| Winter/Till | Lablab | 0.78 | 14.83% | 5059.15 | 2.75 | 139.13 | 62.72 | 87.26 | 75.22 | 104.65 |
| Winter/Till | Pigeon pea | 0.55 | 20.47% | 4904.20 | 3.47 | 170.18 | 66.14 | 112.55 | 81.69 | 139.02 |
| Winter/Till | Woolypod vetch | 0.55 | 9.21% | 2206.53 | 4.43 | 97.75 | 70.52 | 68.93 | 84.19 | 82.30 |
| Average | | 0.82 | 16.27% | | 3.036 | | 63.672 | | 76.818 | 119.16 |
| Winter/No-till | Sunn hemp | 1.07 | 24.62% | 11475.19 | 2 | 229.50 | 56.85 | 130.47 | 66.72 | 153.12 |
| Winter/No-till | Cowpea (Blackeye #5 | 1.47 | 14.20% | 9092.71 | 2 | 181.85 | 56.6 | 102.93 | 65.42 | 118.97 |
| Winter/No-till | Lablab | 1.02 | 16.20% | 7197.85 | 2.02 | 145.40 | 56.38 | 81.97 | 66.28 | 96.37 |
| Winter/No-till | Pigeon pea | 0.58 | 21.99% | 5555.73 | 2.31 | 128.34 | 60.11 | 77.14 | 67.32 | 86.40 |
| Winter/No-till | Woolypod vetch | 0.83 | 8.80% | 3181.62 | 2.92 | 92.90 | 62.08 | 57.67 | 70.43 | 65.43 |
| Average | | 0.99 | 17.16% | | 2.25 | | 58.404 | | 67.234 | 104.06 |
| Summer/No-till | Sunn hemp | 0.72 | 21.34% | 6692.91 | 2.72 | 182.05 | 60.54 | 110.21 | 75.14 | 136.73 |
| Summer/No-till | Cowpea | 1.54 | 14.24% | 9552.53 | 2.83 | 270.34 | 67.57 | 182.67 | 74.43 | 201.21 |
| Summer/No-till | Lablab | 0.34 | 13.31% | 1971.26 | 3.13 | 61.70 | 78.05 | 48.16 | 81.91 | 50.54 |
| Summer/No-till | Sudex | 0.96 | 16.02% | 6699.18 | 1.33 | 89.10 | 43.48 | 38.74 | 54.95 | 48.96 |
| Summer/No-till | Oat (TAM406) | 0.51 | 14.72% | 3270.14 | 1.84 | 60.17 | 46.25 | 27.83 | 62.55 | 37.64 |
| Summer/No-till | Oil Radish | 0.55 | 6.40% | 1533.31 | 2.49 | 38.18 | 70.8 | 27.03 | 77 | 29.40 |
| Average | | 0.78 | 14.34% | | 2.39 | | 61.12 | | 71.00 | 84.09 |
| Average (Overall) | | | 15.83% | | 2.55 | | 61.07 | 86.11 | 71.64 | 101.29 |

Now you can estimate how much N fertilizer to cut back based on the fertilizer recommendation for your soil and crop by substracting B from A as shown below:

(Recommendation from ADSC) Total N requirement for your crop: ▶ A= 180

N available from your cover crop: ▶ B = 29.4

Amount of N you need to fertilize for your crop: ▶ A-B= 150.6

Fill in fresh biomass weight (lb) here.

$$\text{Plant Available Nitrogen (PAN \%)} = \frac{\text{Soil nitrate with cover crop (mg/kg)} - \text{soil nitrate without cover crop}}{\text{Total N added by cover crop (mg/kg)}} \times 100$$

Key in your information here to calculate fertilizer you need to add.

**Note: Although Plant Availabe N (PAN) release rate (%) at 70 days after cover crop termination (green bars on second last column) were very sim tested, actual PAN released (blue bars) varied mainly due to the biomass generated. However, graminaceous cover crops generally had lower PAI actual PAN.**

**Majority of the PAN were released during the first 28 days after cover crop termination.**

**No-till cover cropping released slightly less PAN at 70 days after cover crop termination as compared to till.**

Disclaimer: Cover Crop Calculator is mainly an estimation of PAN%. Accuracy of Cover Crop Calculator is dependent on climate conditions, season, soil type, cover crop species, biomass, plant age, tissue N%, time after cover crop termination, farming practices, and microbial activity in soil.

Poamoho | Laulamilo | By location

**1. Estimate cover crop dry biomass (lbs/acre)**

**2. Send tissue to analyze for tissue N content (%)**

**3. Find a location in Cover Crop Calculator similar to your area, calculate actual PAN at 4 or 10 weeks after cover crop termination.**

***Amount of N fertilizer input that farmers can cut back*** = Actual PAN = % N × cover crop dry biomass × PAN%

Cover Crop PAN CALCULATOR

PLANT Available N

By location

- In the event that you grow a cover crop mix, you can send a sample of your cover crop tissue at crop termination to Agriculture Diagnostic Service Center (ADSC) to assay for **tissue N (%)**, and estimate the **dry weight** of your cover crop biomass in lb/acre. Estimate **dry weight** by collecting fresh cover crop biomass in $lb/ft^2$, dry tissue in sun, and weigh.
- Estimate plant available Nitrogen (PAN) from your cover crop mix by using PAN-N regression lines generated for your location.

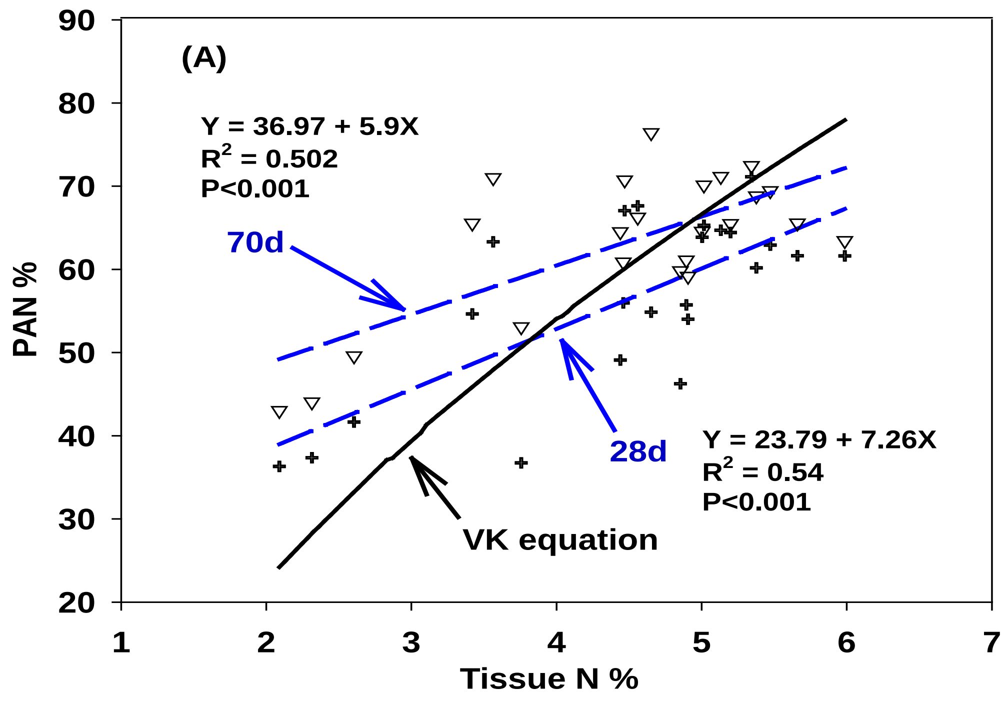
Key in

| | Cover Crop Tissue | | | | 28 Days | | 70 Days | |
|---|---|---|---|---|---|---|---|---|
| Location | Dry Weight ($lb/ft^2$) | Dry Weight (lb/Acre) | Tissue N (%) | Total N(lb/A) | PAN (%) | Actual PAN (lb/A) | PAN (%)2 | Actual PAN(lb/A) |
| Poamoho | 0.15 | 6534 | 2 | 131 | 55.4 | 72 | 66.7 | 87.16356 |
| Waimea | 0.15 | 6534 | 2 | 131 | 38.31 | 50 | 48.77 | 63.732636 |
| Kula | 0.15 | 6534 | 2 | 131 | 39.342 | 51 | 54.518 | 71.2441224 |
| Hoolehua | 0.15 | 6534 | 2 | 131 | 30.179 | 39 | 39.912 | 52.1570016 |

Actual PAN = Cover crop biomass (dry weight in lb/acre) × Tissue N% × PAN%

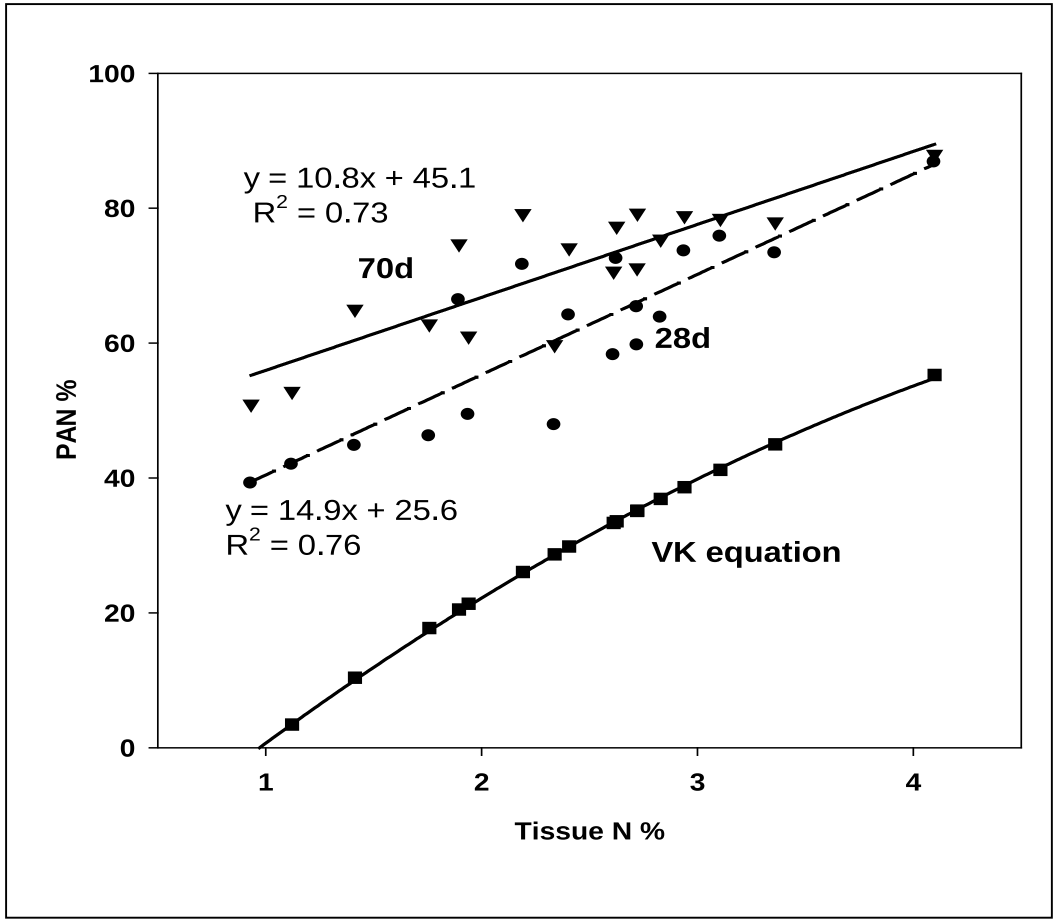
# PAN% PREDICTION CURVES IN HI

## PAN% Prediction Curve at Waiamea

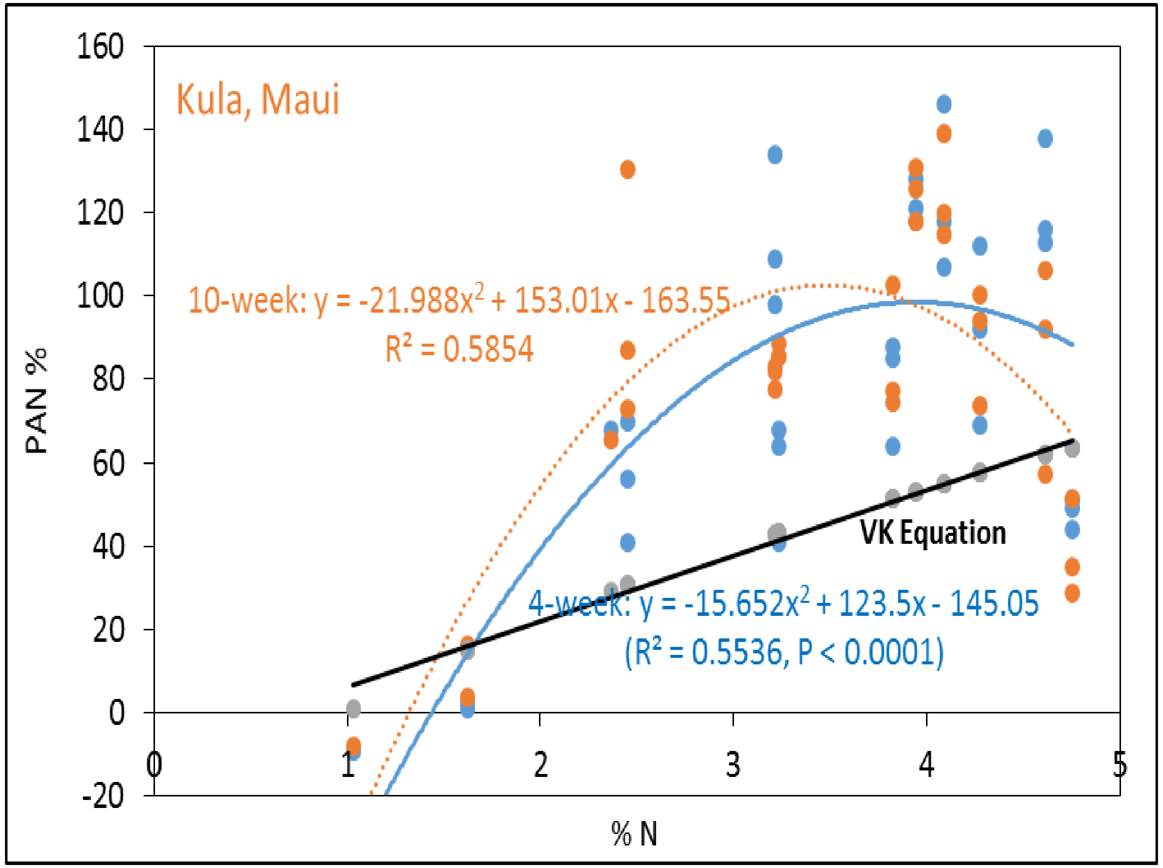


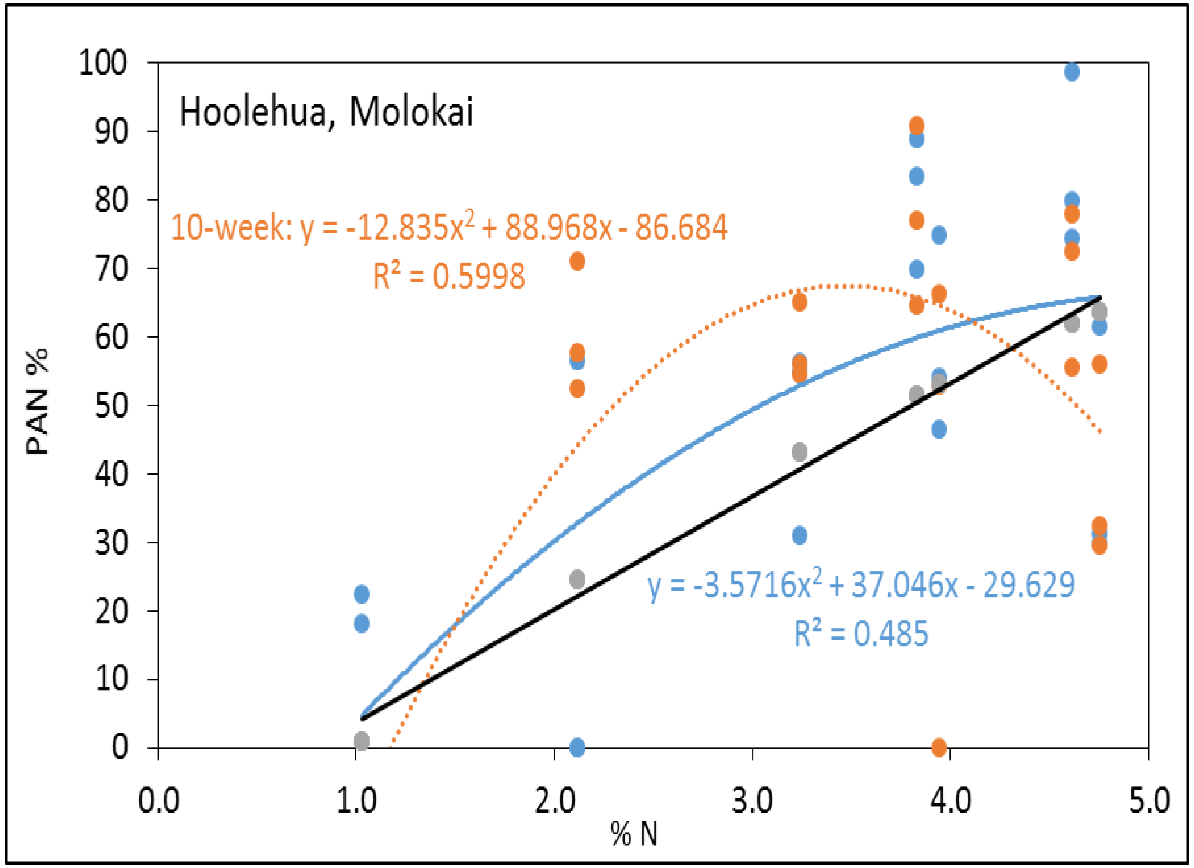

PAN% prediction curve based on %N in cover crop tissues (any cover crop mix will work) generated from Waiamea and Poamoho are very different from that predicted by VK equation.

## PAN% Prediction Curve at Poamoho



# PAN% PREDICTION CURVES IN HI




- In general, PAN% of tissues with %N between 2-4% are higher in Hawaii than that using VK prediction.
- But PAN% of tissues with %N higher than 4% might result in reduction of PAN% in HI possibly due to N immobilization.

# FARMER'S SAMPLES

| | Dry wt (tons/A) | Tissue N (%) | 28 day PAN (%) | 28 day Actual PAN (lb/A) | 40 day PAN (%) | 40 day Actual PAN (lb/A) |
|---|---|---|---|---|---|---|
| Hirayama | 1.94 | 4.05 | 61.73 | 95.08 | 68.77 | 106.03 |
| Bonk | 1.38 | 4.77 | 62.92 | 90.53 | 71.42 | 93.64 |
| Robbs | 2.64 | 2.64 | 62.22 | 89.60 | - | - |

| | Cover crops mix |
|---|---|
| Hirayama | Vetch, red clover, spring pea, oats |
| Bonk | Oil radish, vetch |
| Robbs | Cayuse oat, bell beans, purple vetch, Austrian winter peas |

Majority of the PAN was released during the first 28 days after cover crop termination, thus **additional fertilizer should be added there after.** This is the amount of fertilizer to cut back.

# Reference links


- Donna Meyer, Gareth Nagai, Noelle Lee, Jon Kam, Kaori Suda, Caio Sausa, Bryan Januar
- Marla Fergerstrom, Susan Migita, Pam S and Farm Crews from Mealani, Poamoho and Kula Stations
- Randy Hamasaki, Maria Derval Diaz, Brian Bush, Ray Uchida, Ag Diagnostic Service Center (ADSC)
- J. McHugh, Pioneer; A. Archinas, Monsanto; Hirayama, Bonk, C. Robb.


- http://www.ctahr.hawaii.edu/WangKH/cover-crop.html
- http://www.ctahr.hawaii.edu/WangKH/Downloads/CRATE-Wang-HanaiAi.pdf
- http://www.ctahr.hawaii.edu/WangKH/Downloads/CCChart-Hawaii-KHWang.pdf
- http://www.ctahr.hawaii.edu/WangKH/Downloads/CRATE_CCPANCalculatorPoster.pdf
- http://www.ctahr.hawaii.edu/WangKH/Downloads/P-High-elevation-covercrops.pdf
- http://www.ctahr.hawaii.edu/sustainag/news/articles/V19-Pant-CoolSeasonCC.pdf

USDA NRCS

## ACKNOWLEDGEMENT

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 Mānoa
College of Tropical Agriculture & Human Resources

CRATE


This project is in part supported by NRCS CIG 69-3A75-14-231, NIFA AFRI 2013-04774, and CTAHR Hatch 9022H.