

Lazy legumes or busy beans?

Estimating winter cover crop N fixation on the Central Coast

Katie L. Monsen
Carol Shennan

Environmental Studies, CASFS
UC Santa Cruz

2 Nov. 2007

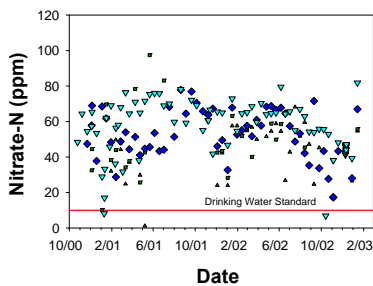


CASFS The CENTER for AGROECOLOGY & SUSTAINABLE FOOD SYSTEMS

Intensive irrigated agriculture is prevalent in the Central Coast



Agriculture is a major contributor to elevated N concentrations in Central Coast



Water samples collected from agricultural drainage ditch in the Central Coast

Excess N has environmental consequences

Biodiversity loss

Freshwater & estuarine eutrophication, acidification

Negative agroecosystem impacts



Llagas Creek, CA Photo by Claire Phillips

Sources: Vitousek et al. 1997, Matson et al. 1997

Some consequences may be complex or unexpected



Photo by Pieter Johnson, Univ. of Colorado at Boulder

The big picture: how well are we conserving N in intensive organic vegetable agroecosystems?



Inputs

Fertility amendments

Outputs

Plant uptake

Soil storage

Loss to environment

The big picture: how well are we conserving N in intensive organic vegetable agroecosystems?



- Do inputs balance outputs?
- Is there excess N at certain points in the cropping cycle?

One key element of nutrient management is legume cover cropping

Cover crops are also promoted for water quality conservation

How do N fixation rates affect total N balance?



Knowing how much legumes fix makes a difference for N budgets



| | | Input (lb/ac) | | | | | | |
|--------------|----|---------------|----|-----|---|---|------------|--|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Compost | | | | 180 | | | | |
| Cover crop* | 90 | 90 | 90 | 90 | | | 75 | |
| Total | | | | | | | 615 | |

| | | Output (lb/ac) | | | | | | |
|--------------|----|----------------|----|----|----|----|------------|--|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Crop | 53 | 48 | 57 | 67 | 57 | 43 | 110 | |
| Total | | | | | | | 445 | |

* assuming 50% Ndfa

N balance = + 170

If we almost double the amount of N fixed...



| | | Input (lb/ac) | | | | | | |
|--------------|-----|---------------|-----|-----|---|---|-------------|--|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Compost | | | | 180 | | | | |
| Cover crop | 162 | 162 | 162 | 162 | | | 135 | |
| Total | | | | | | | 1040 | |

| | | Output (lb/ac) | | | | | | |
|--------------|----|----------------|----|----|----|----|------------|--|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Crop | 53 | 48 | 57 | 67 | 57 | 43 | 110 | |
| Total | | | | | | | 445 | |

* assuming 90% Ndfa

N balance = + 518

If we halve the amount of N fixed...



| | | Input (lb/ac) | | | | | | |
|--------------|----|---------------|----|-----|---|---|------------|--|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Compost | | | | 180 | | | | |
| Cover crop | 45 | 45 | 45 | 45 | | | 38 | |
| Total | | | | | | | 398 | |

| | | Output (lb/ac) | | | | | | |
|--------------|----|----------------|----|----|----|----|------------|--|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Crop | 53 | 48 | 57 | 67 | 57 | 43 | 110 | |
| Total | | | | | | | 445 | |

* assuming 25% Ndfa

N balance = - 47

We are trying to develop regional N fixation estimates using the natural abundance method

Legume cover crops

Reference species



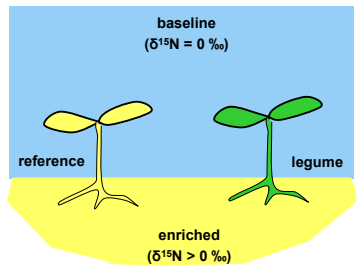
Bell bean
(*Vicia faba*)

Woollypod vetch
(*Vicia dasycarpa*)

Oats
(*Avena sativa*)

Mustard
(*Brassica japonica*)

The natural abundance method compares the ratio of ^{15}N to ^{14}N ($\delta^{15}\text{N}$) in legume & reference spp



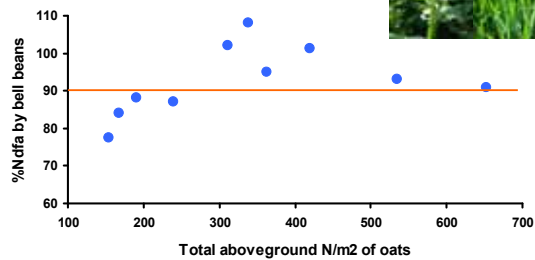
Legumes are often assumed to fix ~50% of their total N

But our previous field studies have shown high %Ndfa estimates

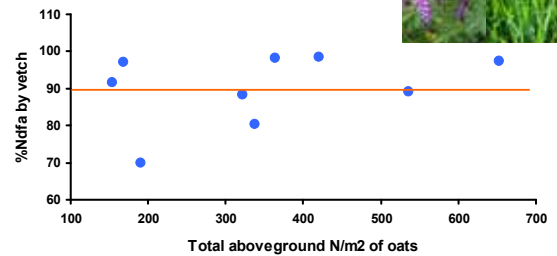
Example: legume & ref spp plots; 2 subplots/spp, 5 plots across a single farm



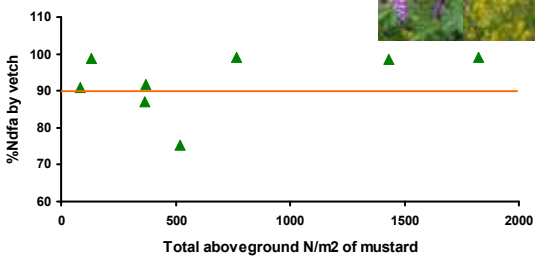
An overall problem: estimated %Ndfa was very high, even in high N sites



This held for both bell beans and vetch...



This held for both bell beans and vetch with both reference species

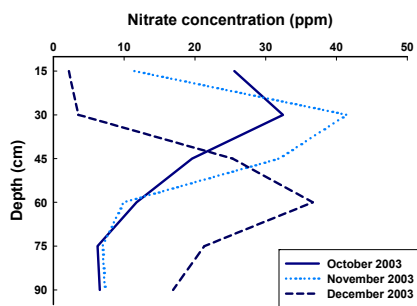


Legumes are also assumed to have low fixation rates when available soil N is high

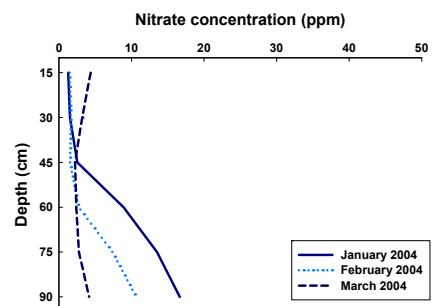
But from soil sampling we know that...



Soil nitrate is highest in fall...



And decreases through the winter



... yet fall is when we have also seen seedlings with pink nodules



We conducted two greenhouse experiments to pursue four questions:



We conducted two greenhouse experiments to pursue three questions:

- 1) does nodule initiation and production by seedlings vary with N level?



We conducted two greenhouse experiments to pursue three questions:

- 1) does nodule initiation and production by seedlings vary with N level?
- 2) does %Ndfa vary with farm site and fertility level?



We conducted two greenhouse experiments to pursue three questions:

- 1) does nodule initiation and production by seedlings vary with N level?
- 2) does %Ndfa vary with farm site and fertility level?
- 3) are oats appropriate for calculating vetch %Ndfa?



The first expt. examined early nodule development in three fertility levels

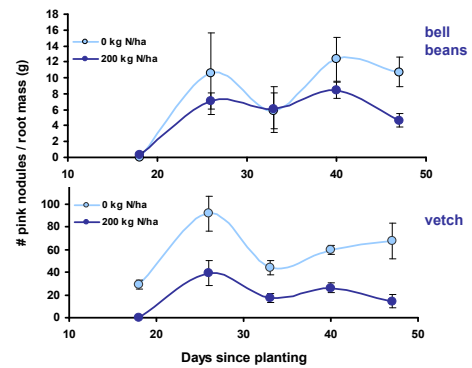


Bell beans & vetch grown in fertility-amended field soil
Phytamin added at 0, 75 or 200 lb N/ac rate (n = 18)
Harvest ~3 pots per wk, with ~ 6 pots ea. harvested at the end (6.5 wks)

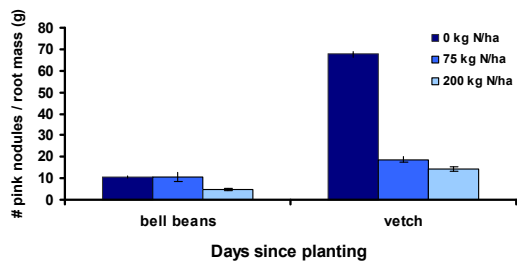
Nodules were excised from harvested plants to determine how many were pink



Both legumes had active nodules early in growth



Active nodules / fresh root mass was lowest in higher fertility treatments



What did we learn in Expt. 1?

Early fixation activity observed even with high N availability!
Bell beans showed less sensitivity to fertility – seed size?



The second expt. examined ¹⁵N in vetch and oats across farm sites and fertility treatments

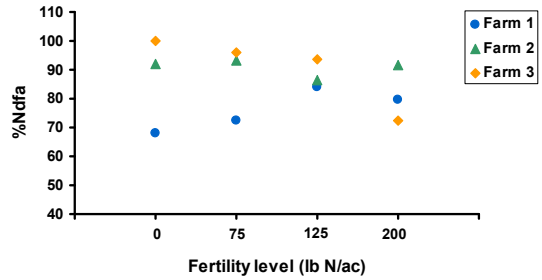
Grown in field soil from 3 organic farms

Phytamin added at rate of 0, 75, 125 or 200 lb N/ac (n = 5)

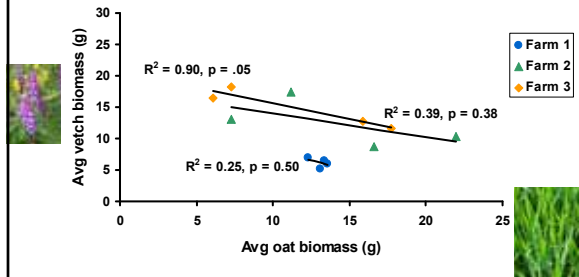
Plants harvested at 17 wks



Relationship between %Ndffa and fertility varied across farms



Oat biomass was negatively related to vetch biomass, but the relationship strength varied



What did we learn in Experiment 2?

Fixation were similar to field estimates, 85 -100% range

Much higher than common 50% rule of thumb

Low sensitivity to N availability, except at farm 3 – other factors?



Data show fixation around 90%, tripling estimates of potential losses for this field

| | | Input (lb/ac) | | | | | | |
|------------|--|----------------|-----|-----|-----|-----|-----|------|
| Year | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Compost | | | | | 180 | | | |
| Cover crop | | 162 | 162 | 162 | 162 | 162 | 162 | 135 |
| Total | | | | | | | | 1040 |
| | | Output (lb/ac) | | | | | | |
| Year | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Crop | | 53 | 48 | 57 | 67 | 57 | 43 | 110 |
| Total | | | | | | | | 445 |

N balance goes from + 170 to + 518

Oats may not be an appropriate reference species for this system

Weak relationship between oat biomass or N uptake and vetch biomass

Plants may be taking up available N at different times, rates



≠



Another tool to examine N dynamics is NDICEA

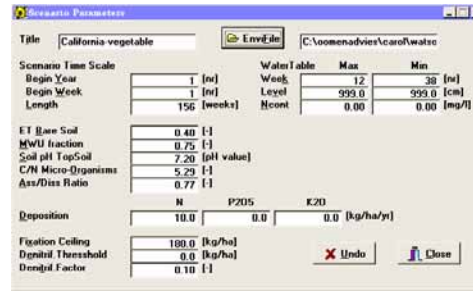


Created in the Netherlands for organic systems
(Louis Bolk Institute)

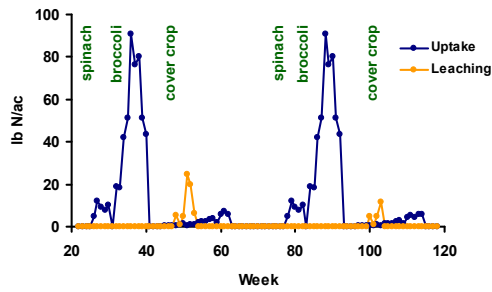
Researcher and grower versions

<http://www.ndicea.nl/>

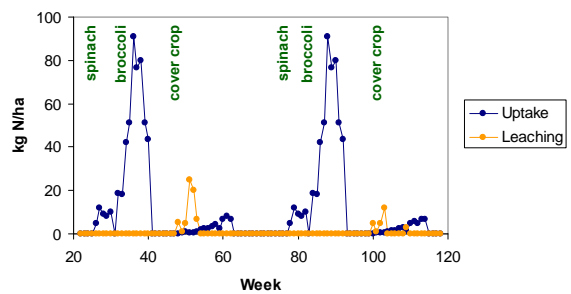
Input includes soil, crop and climate data



Allows user to examine effects of management practices on crop, total N balance, water balance



We're using this to examine effects of %Ndfa estimates on N dynamics



Contact:
kmonsens@ucsc.edu

Thanks to:
USDA-CSREES NRI
program,
SARE graduate
student grant,
UCSC CASFS