Tightly-coupled plant-soil nitrogen cycling and crop productivity on contrasting organic farms across an intensively-managed agricultural landscape

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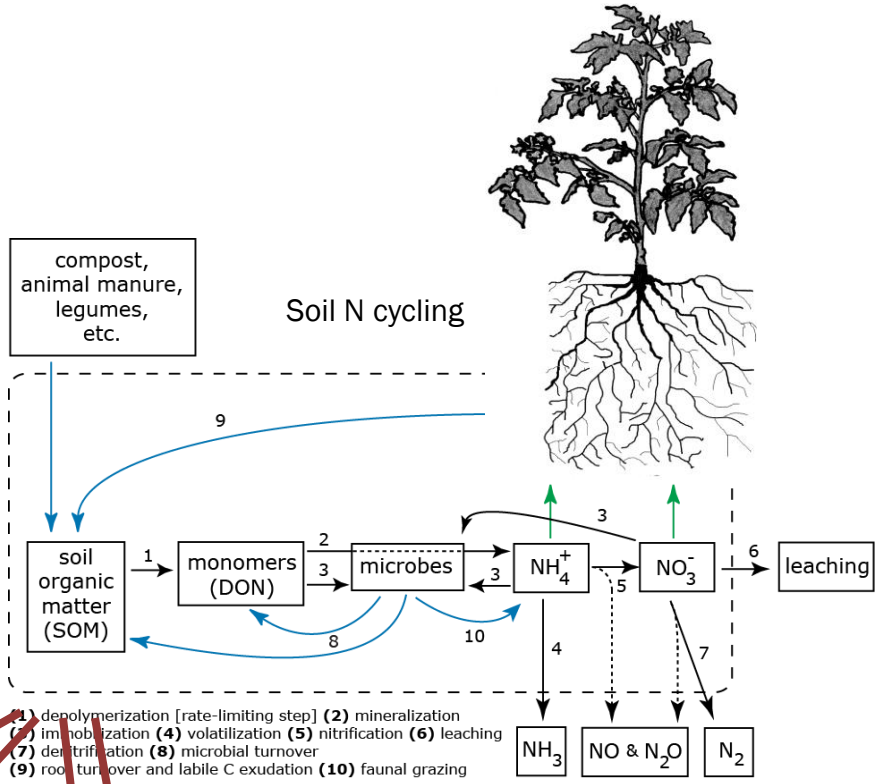
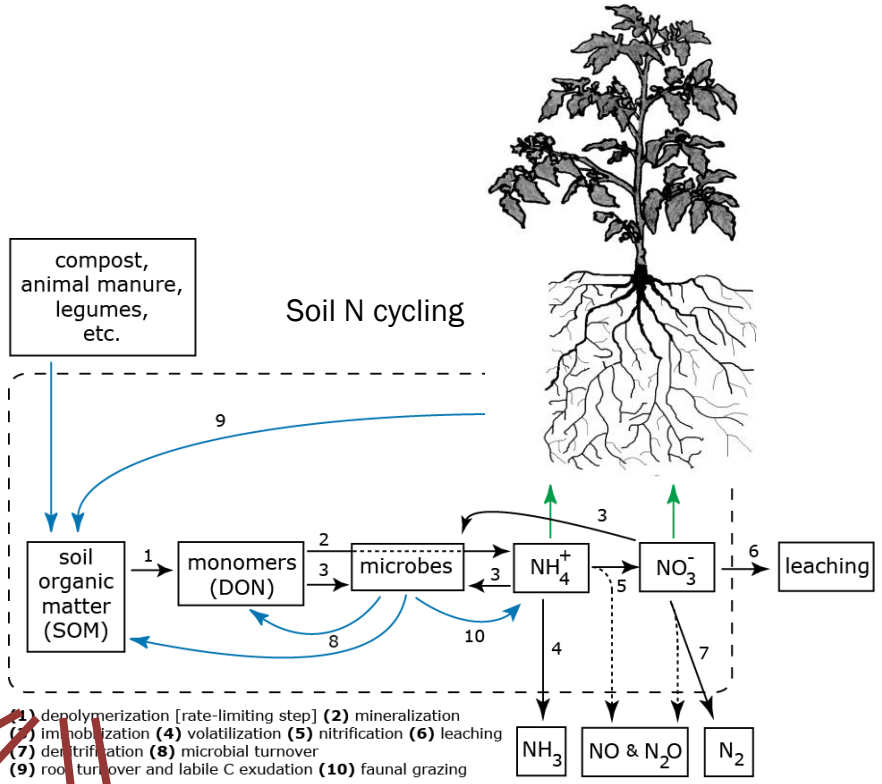
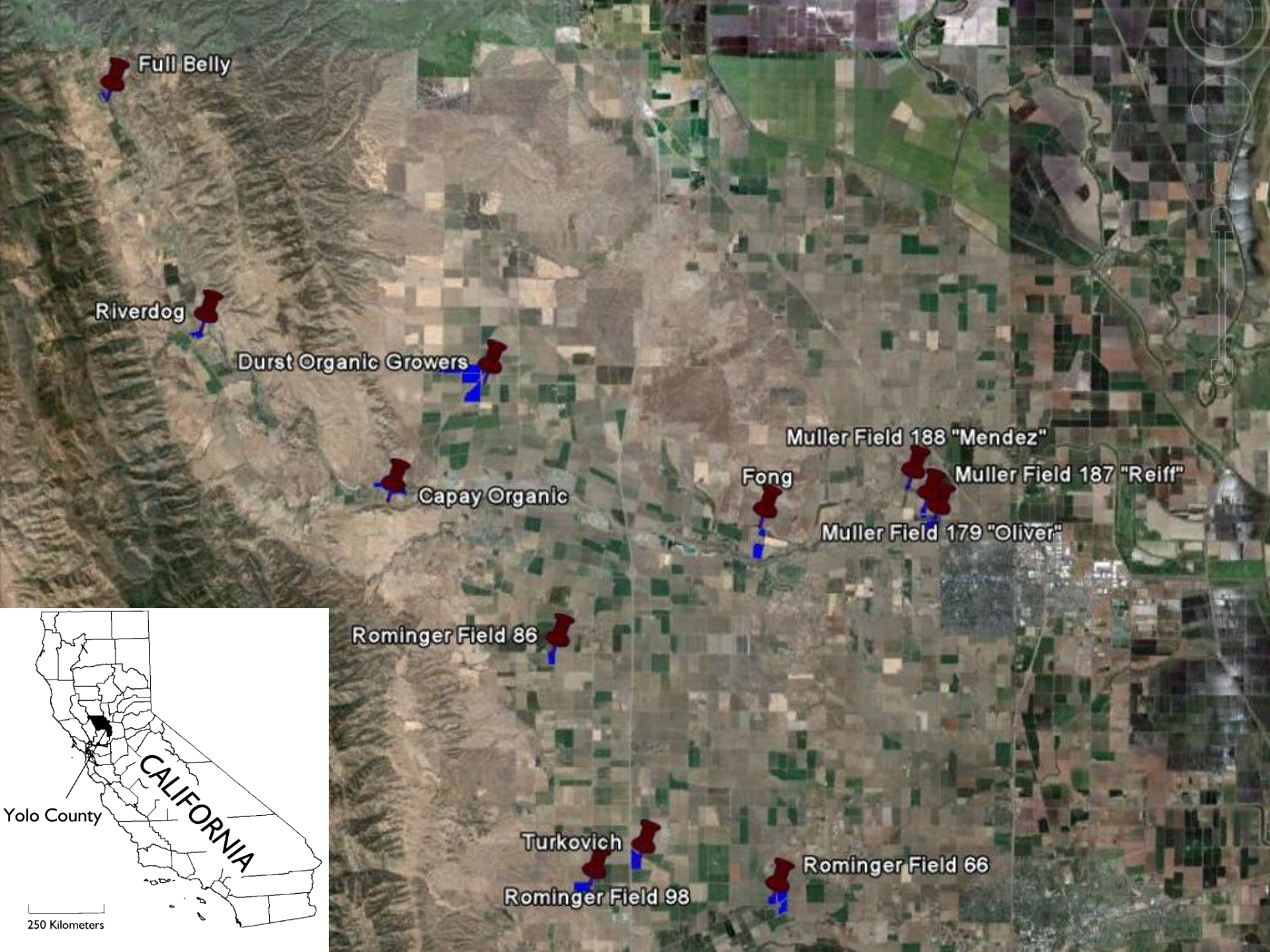
Objectives and on-farm landscape approach



Objectives and on-farm landscape approach

- Identify patterns of plant-soil N cycling on organic tomato fields
- Examine biogeochemical indicators of N cycling and a novel approach based on root gene expression
- Use an on-farm landscape approach to capture biophysical variability and growers' strategies

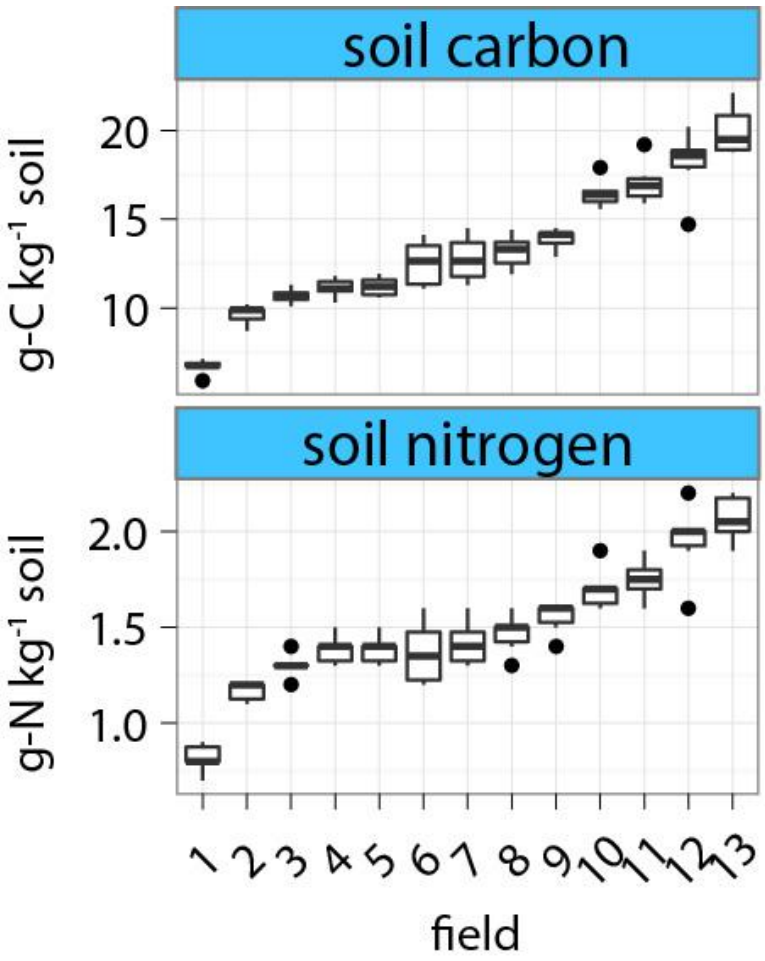



Full Belly
Riverdog
Durst Organic Growers
Capay Organic
Muller Field 188 "Mendez"
Fong
Muller Field 187 "Reiff"
Muller Field 179 "Oliver"
Rominger Field 86
Turkovich
Rominger Field 66
Rominger Field 98
CALIFORNIA
Yolo County
250 Kilometers

Landscape survey of organic Roma-type tomato fields

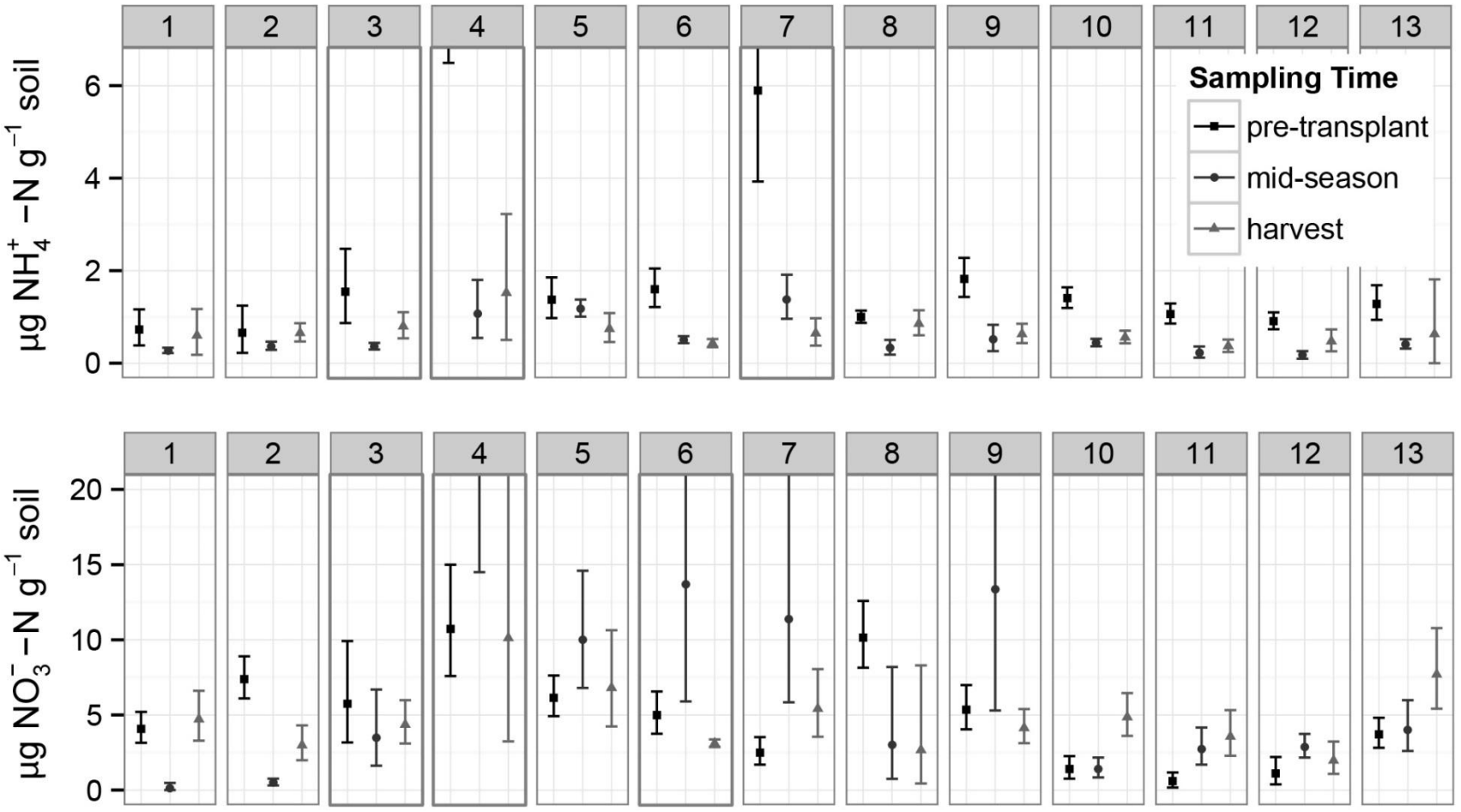
- 8 growers managing 13 fields in Yolo Co., CA
- 4 fresh market and 4 processing growers
- Wide variety of practices (e.g. manure vs. composted green waste; vetch cover crops; commercial organic fertilizers)
- Monitoring study over 2011 growing season
  - biogeochemical indicators of soil N cycling at three keys times: pre-transplant, anthesis, harvest
    - Soil NH_4^+ and NO_3^-;
    - potentially mineralizable N (PMN)
    - soil organic matter (SOM): total C & total N, DOC, POXC, IR spectra
  - root gene expression
  - plant N status
  - crop yields

3-fold gradient of soil C and N



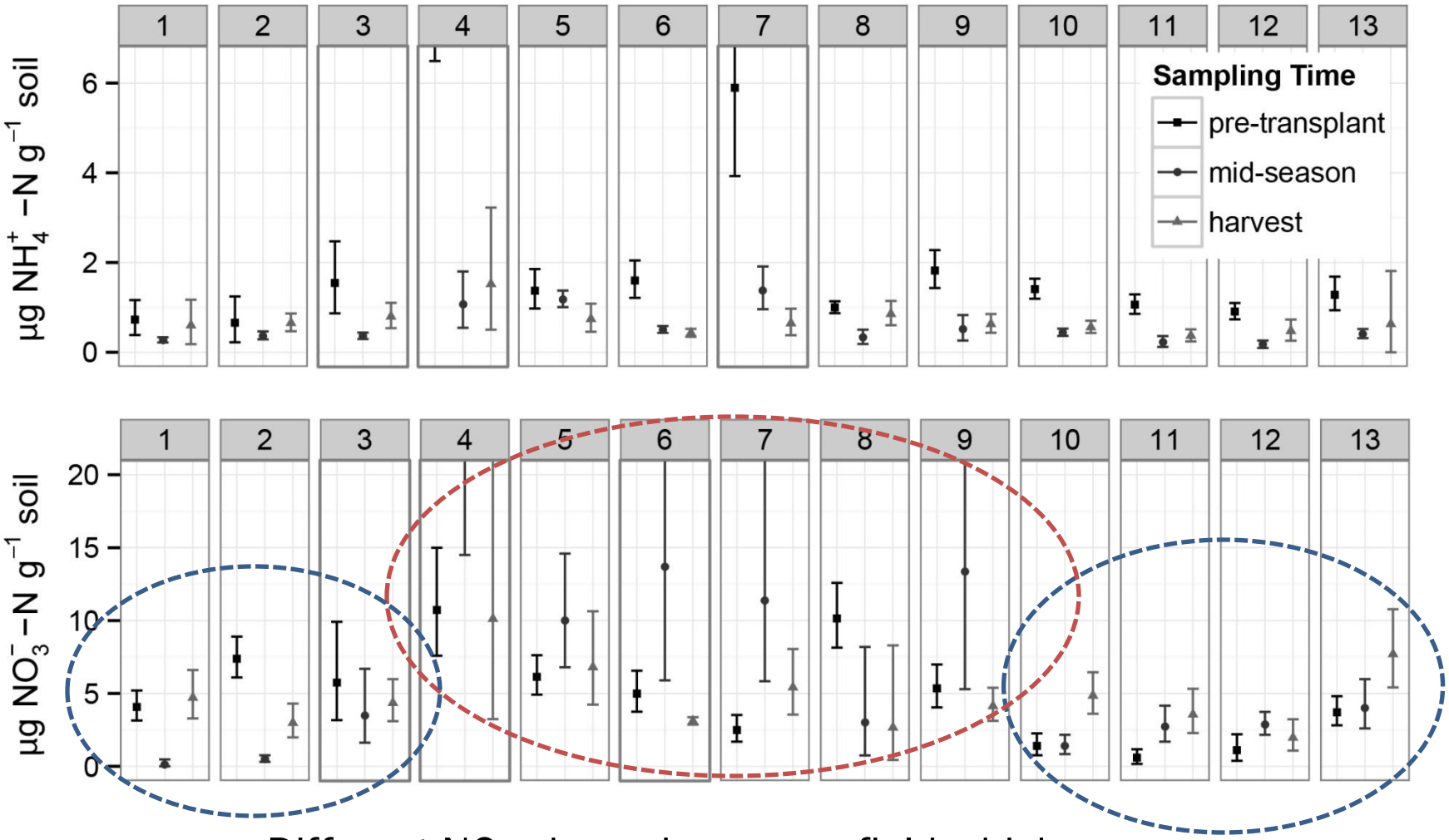
- Similar texture (10 silt loams, 3 loams) and parent material (mixed alluvium)
- Little variation in pH (6.3-7.2)

Soil inorganic N across fields



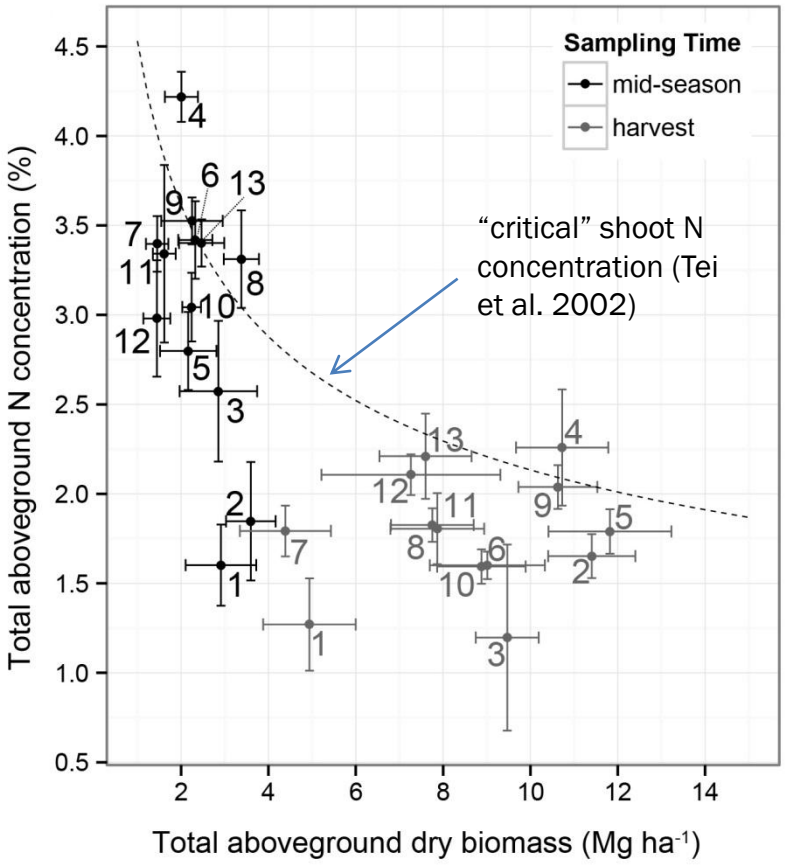
- Soil NH_4^+ generally low, but large variability in soil NO_3^- (e.g. 0.2 – 44.9 µg-N g^{-1} soil for mid-season)

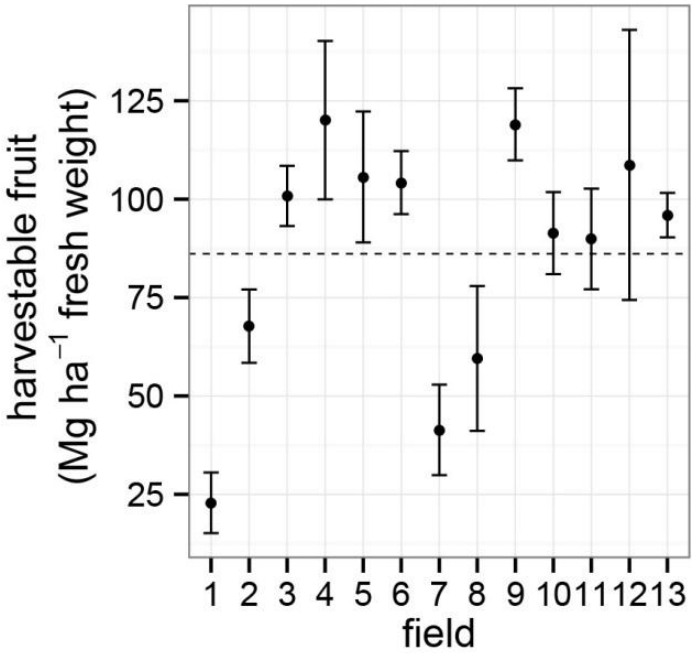
Soil inorganic N across fields



- Different NO_3^- dynamics across fields: higher, more variable (red); lower, less variable (blue)

Tomato N status and yields





Average 2011 Yolo Co yield: 86 Mg ha^{-1}

- At mid-season, 11/13 fields close to critical N
- 9/13 fields above Yolo Co. average for crop yield

Why link root gene expression to soil N processes?

- Plants turn on/off genes involved in N uptake and assimilation –transcription levels in roots may be “plant’s eye view” of soil N cycling

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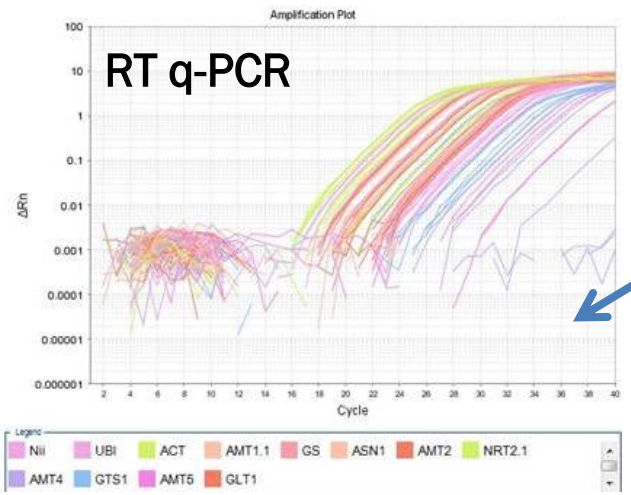
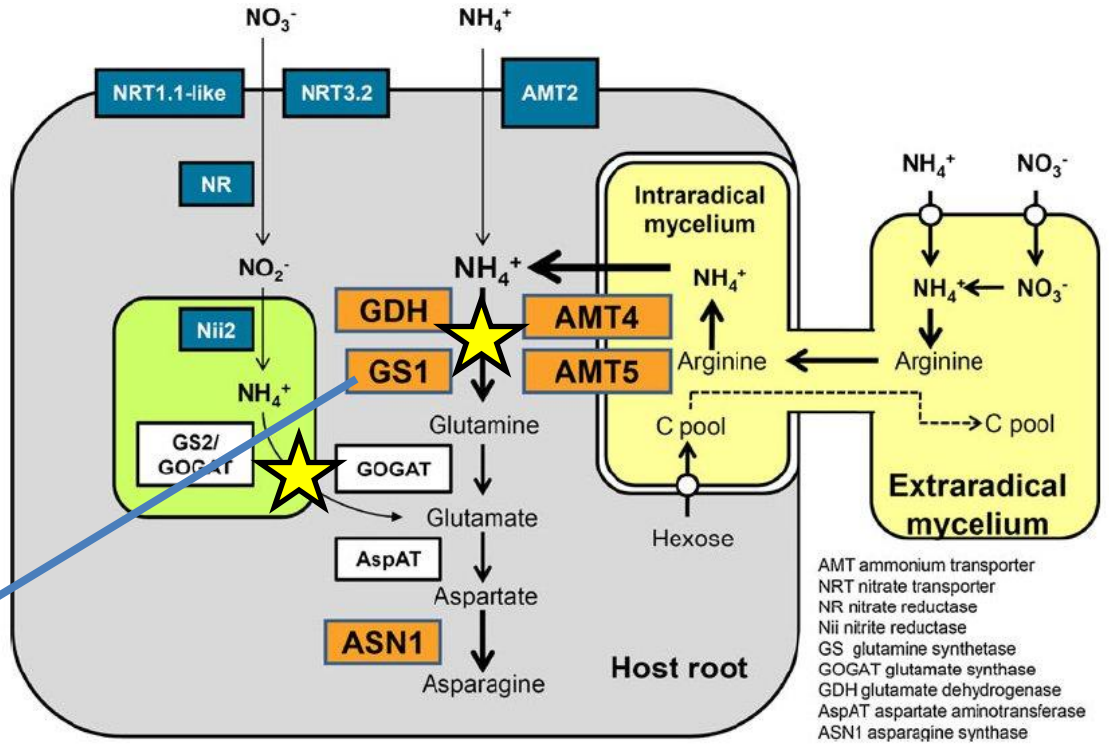


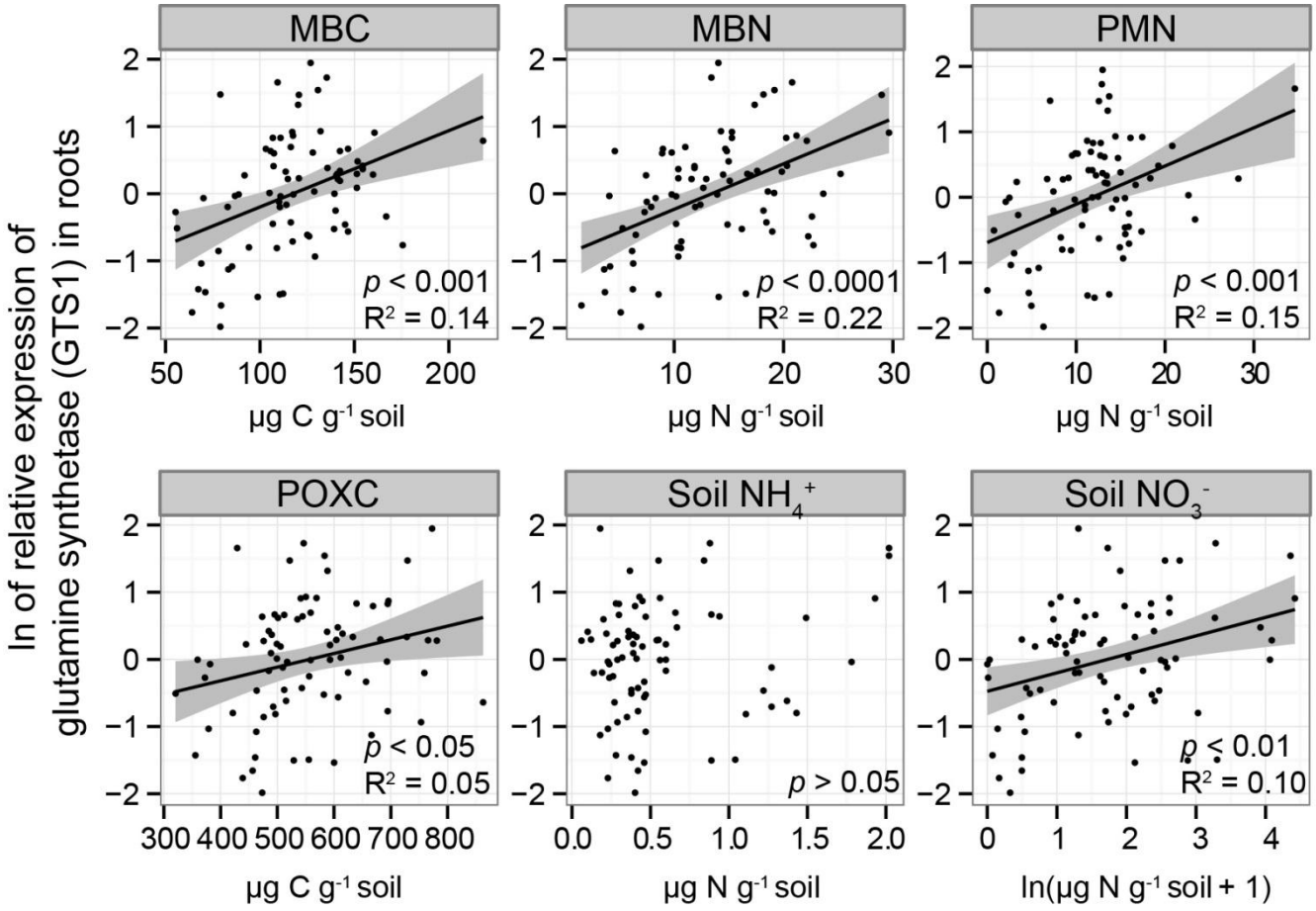
Soil N uptake and assimilation in plant roots



★ Glutamine synthetase (GTS1)

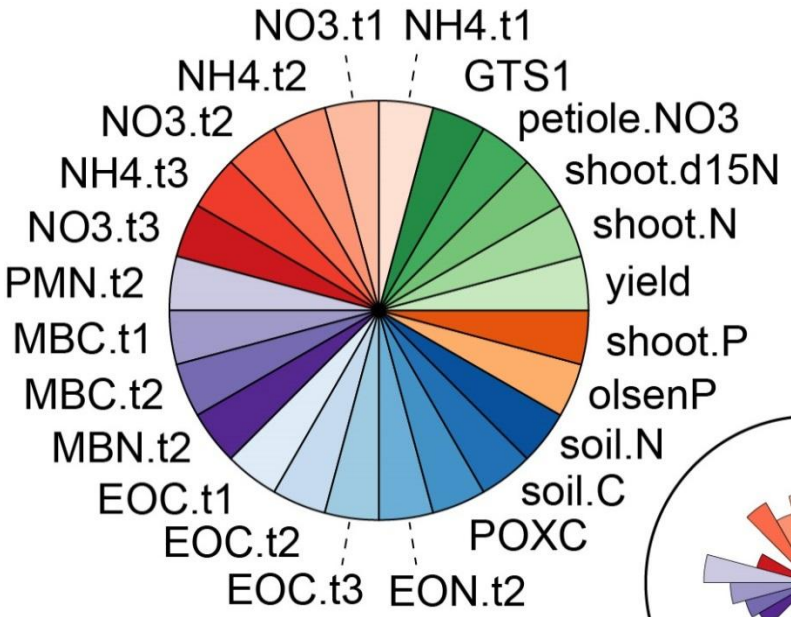
Ruzicka et al. (2011)

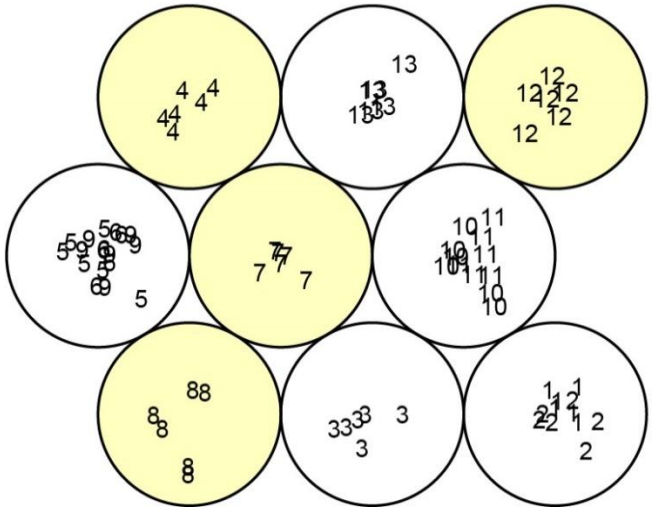
Root N assimilation linked to soil biology



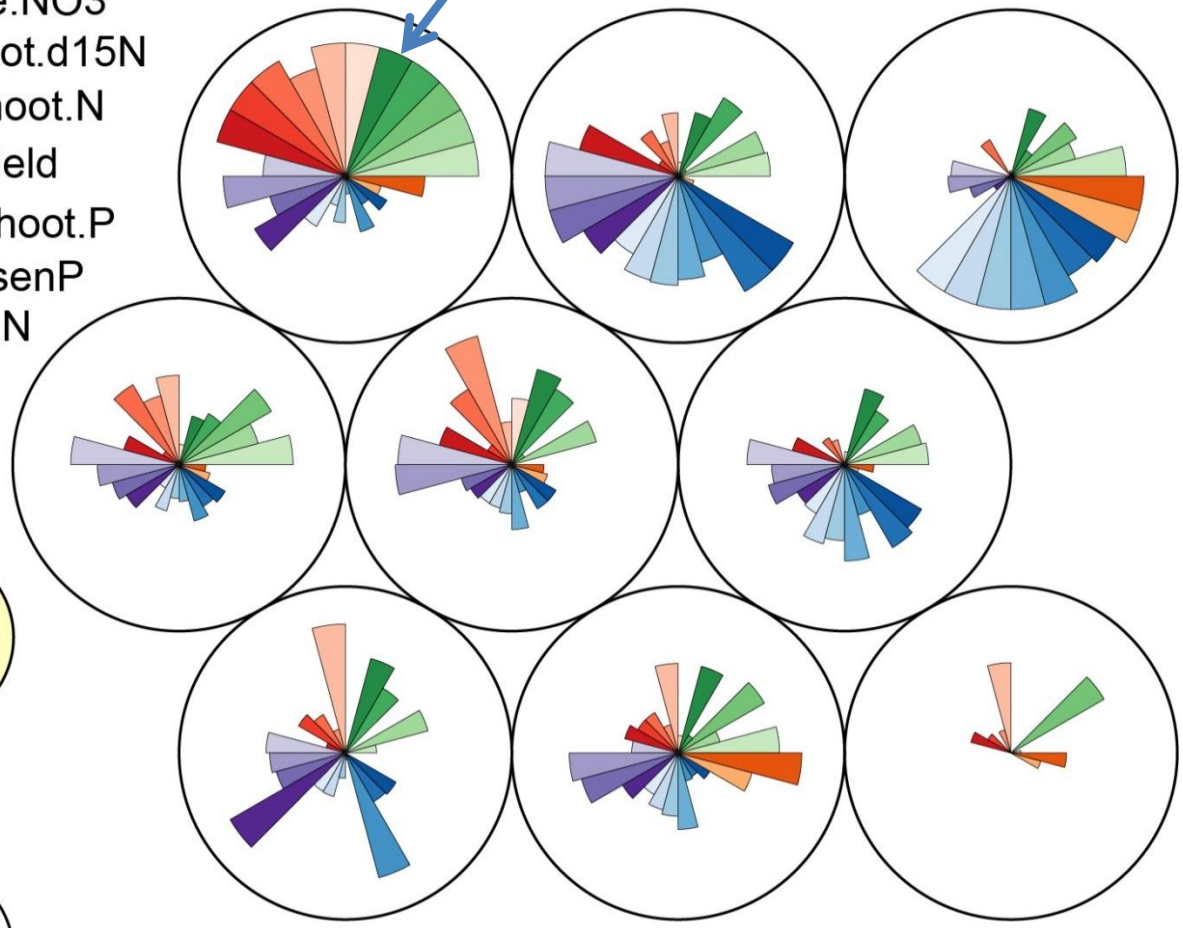
- Root GTS1 expression better associated with indicators of soil biology than with NH_4^+ and NO_3^- pools
- Root N assimilation thus may be elevated when soil inorganic N pools are low but when microbial activity is high

Plant-soil-microbial interrelationships via KSOM

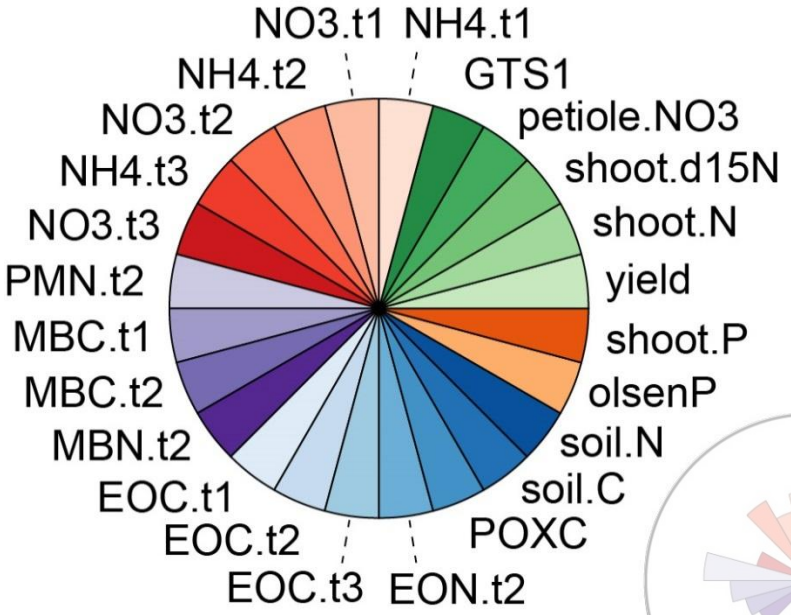


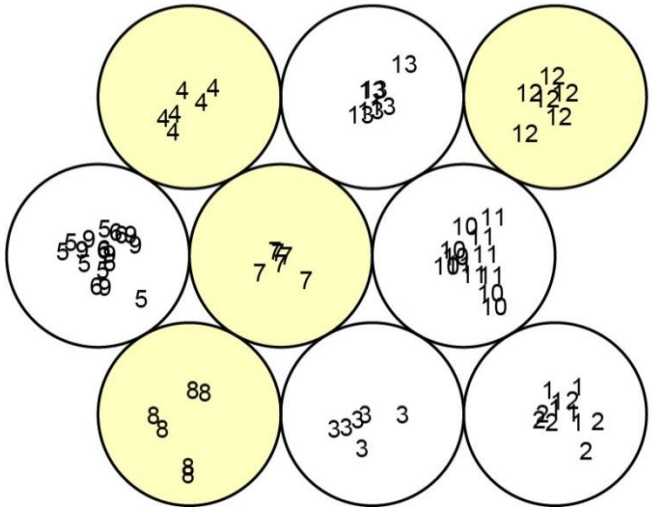


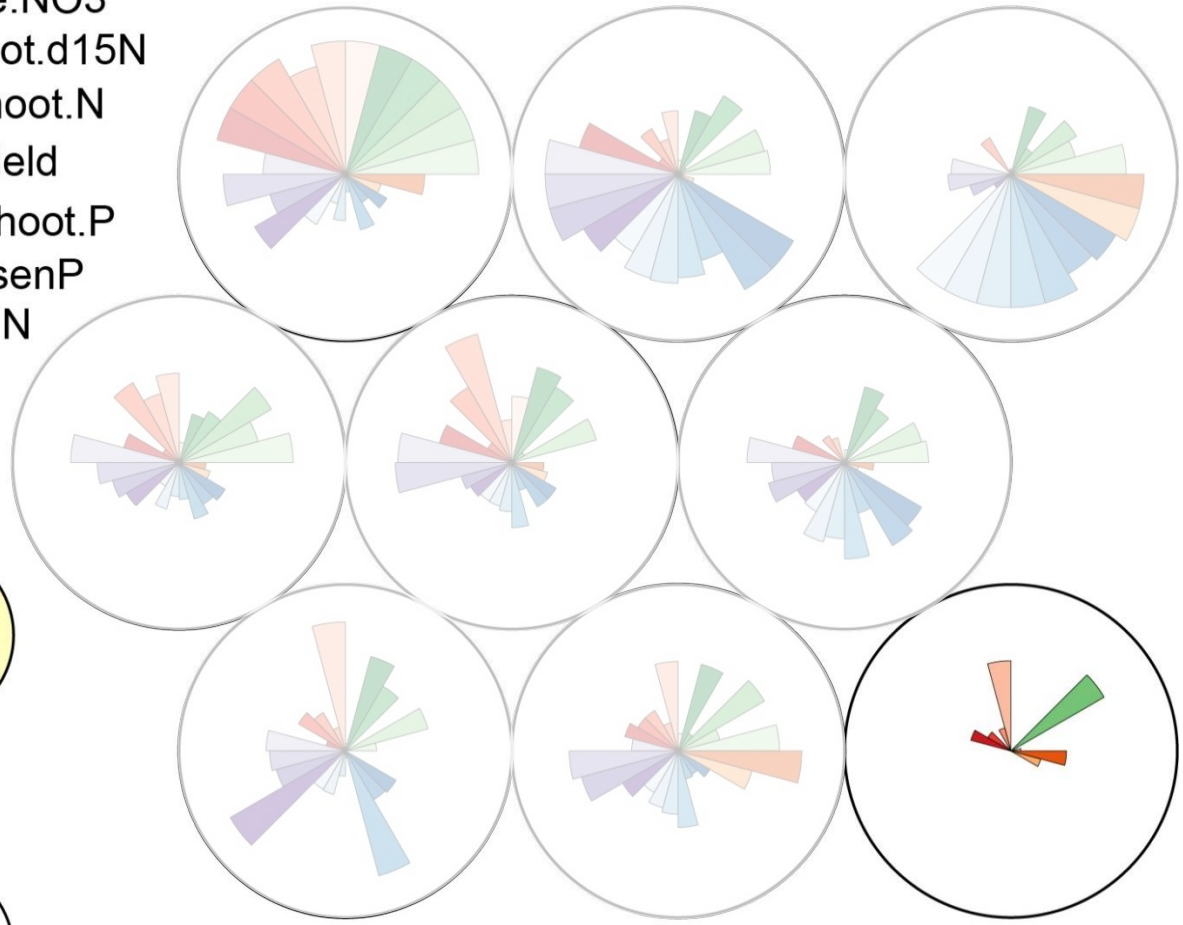
Size of wedge represents relative value of variable for each cluster



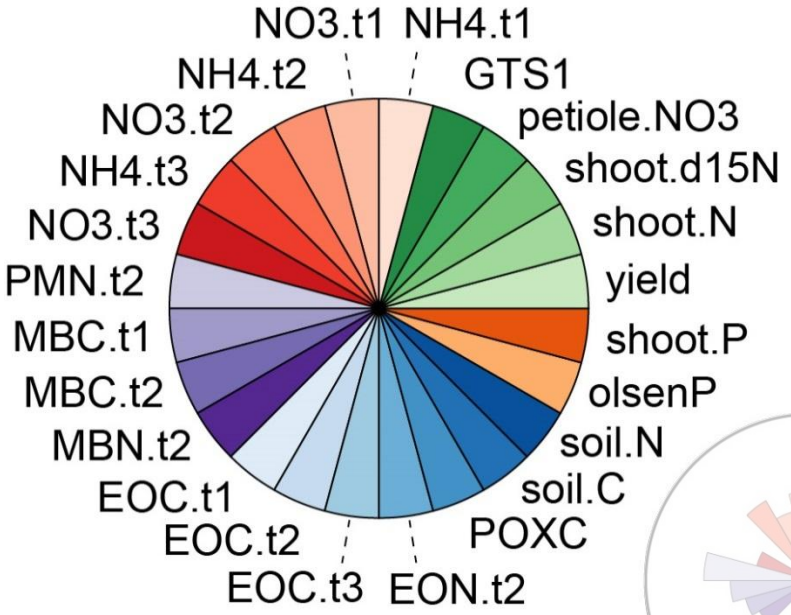
Neighboring clusters more similar than those farther away







N deficiency



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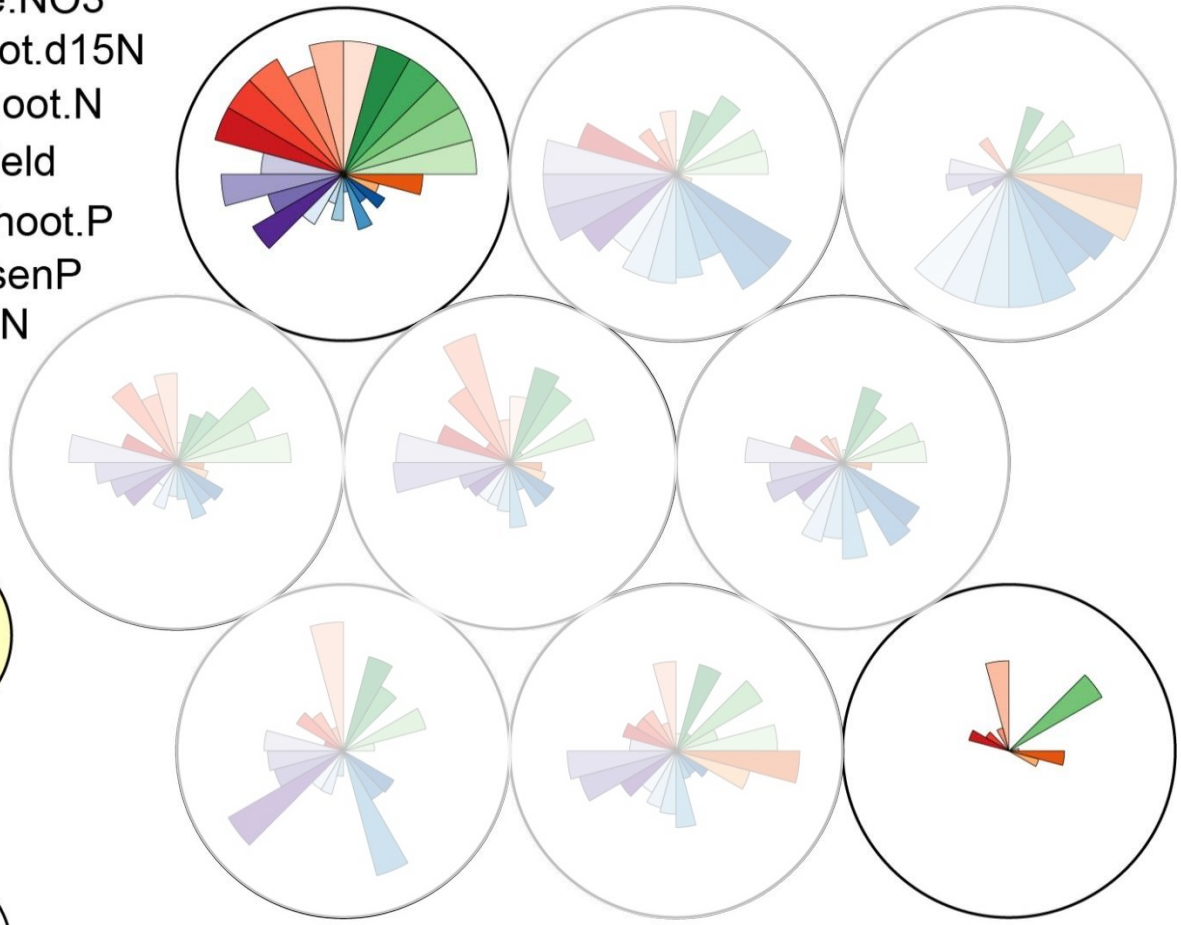

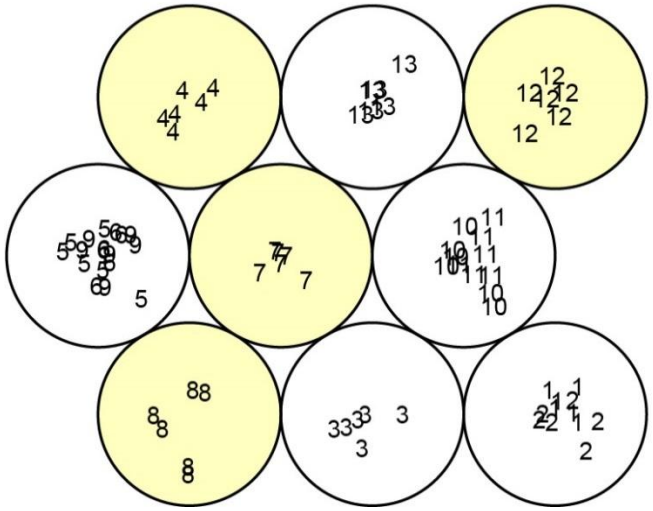

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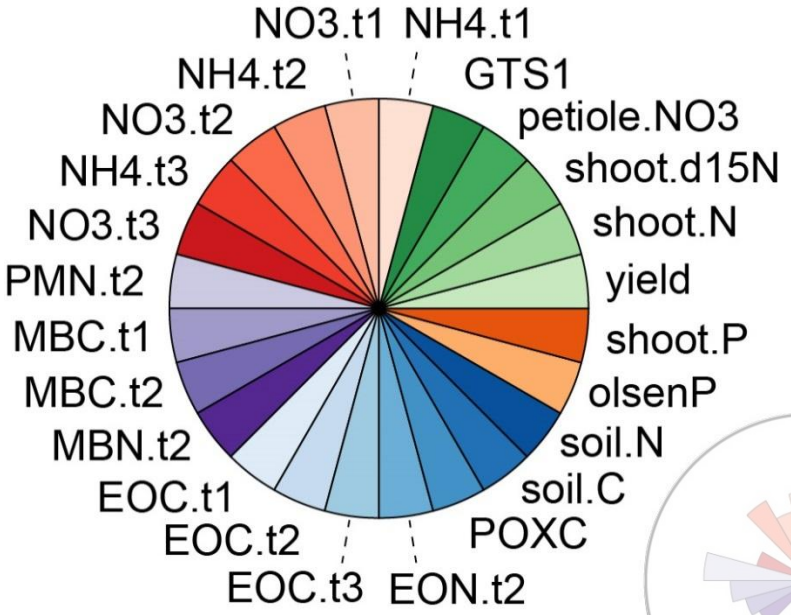
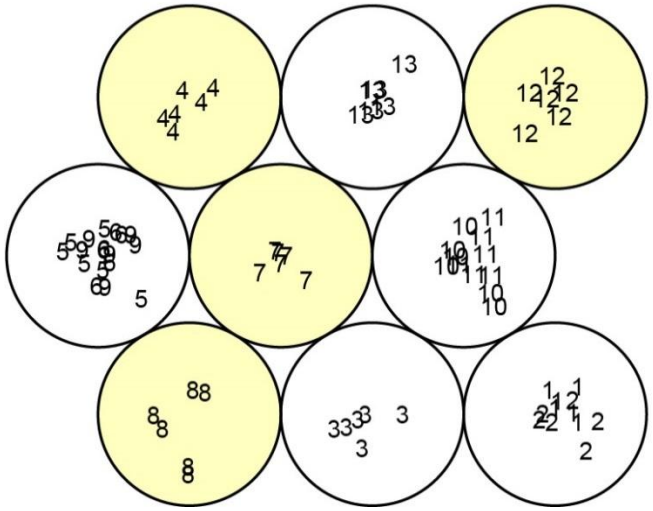
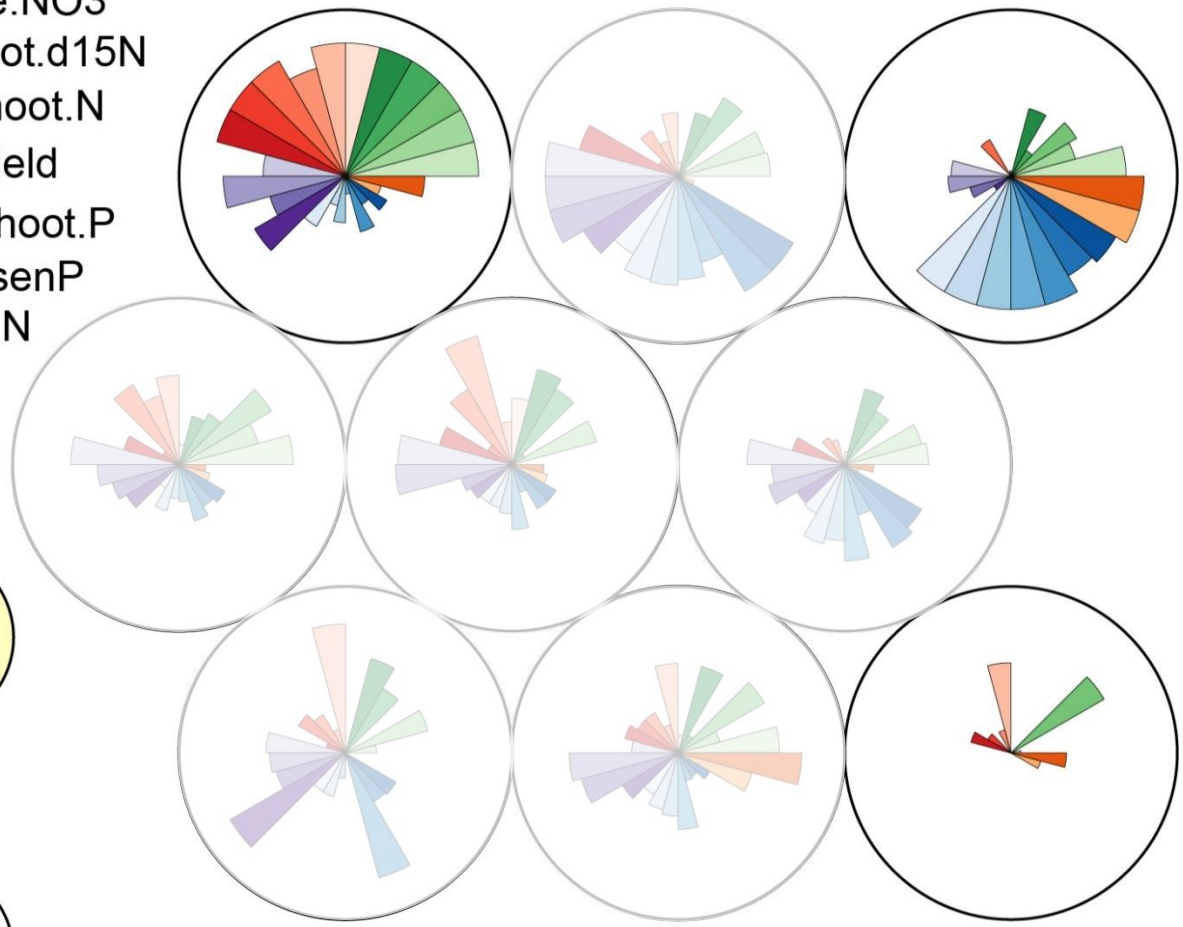




N excess

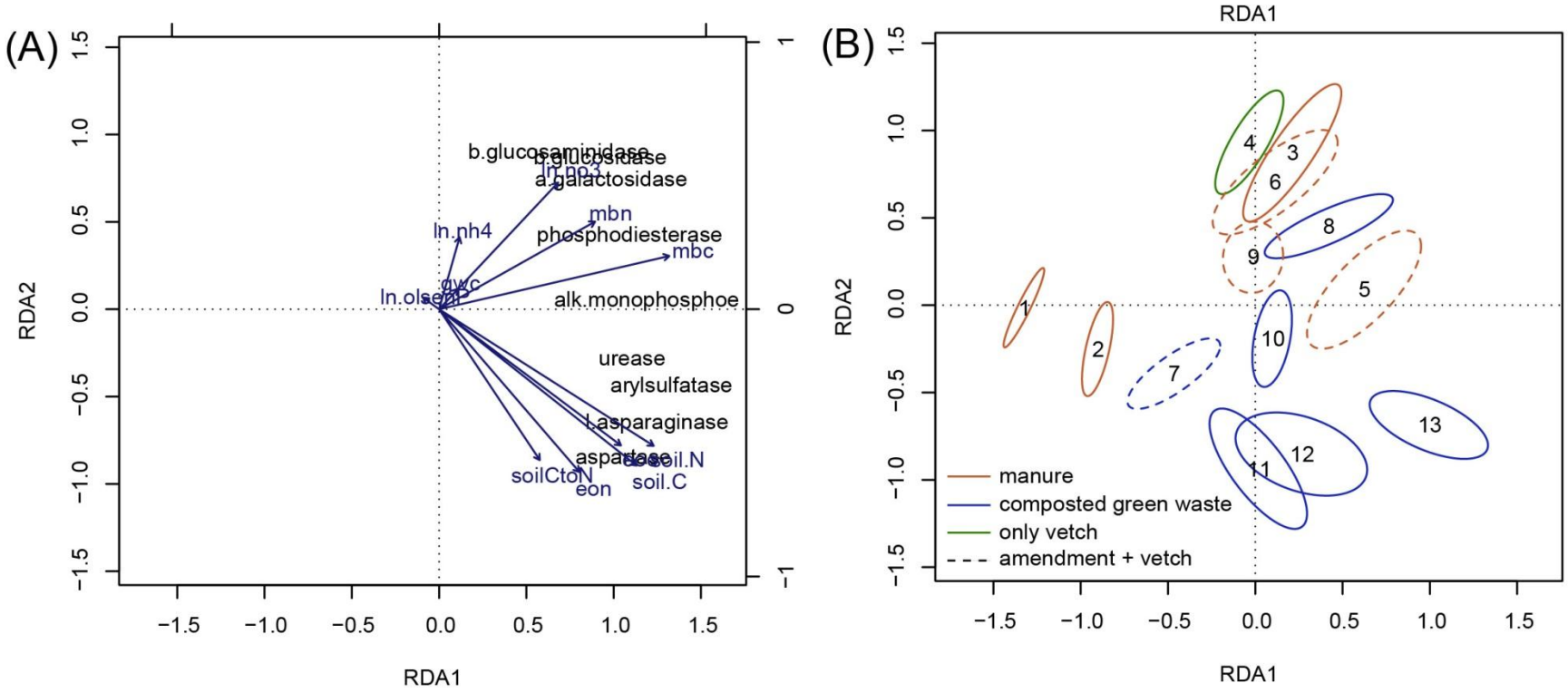
Tightly-coupled
N cycling



N deficiency

Soil potential enzyme activity

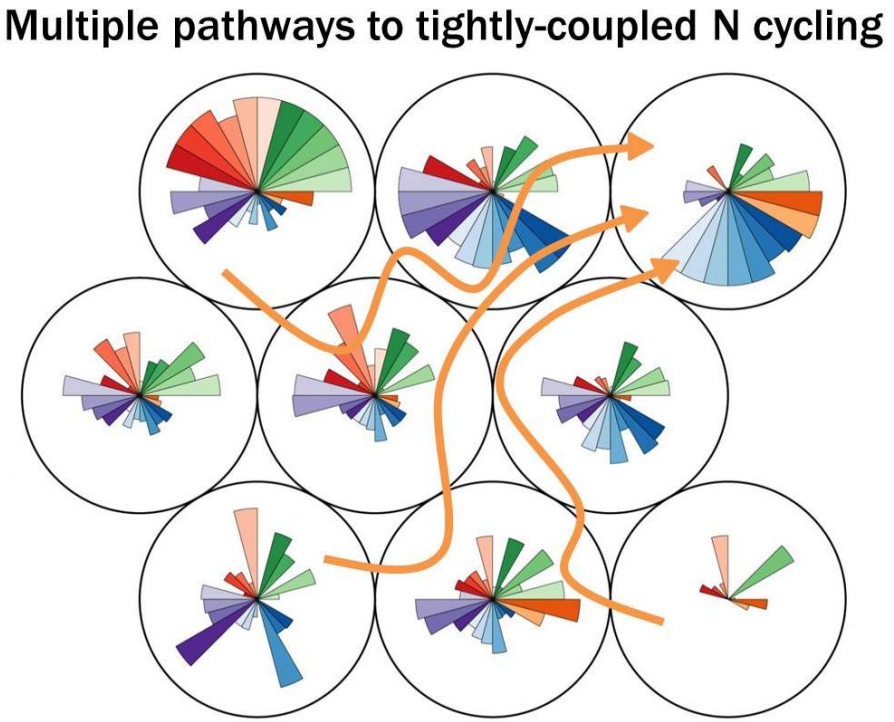
- Activities of C and N cycling soil enzymes show opposing trends:
  - C cycling enzymes: greater activity in “N excess” fields
  - N cycling enzymes: greater activity in “Tightly coupled N cycling” fields
- High rates of N cycling and turnover mean plants can acquire N even when N pools (NH_4^+ and NO_3^-) do not build up



Bowles et al. (2014), *Soil Biology and Biochemistry*

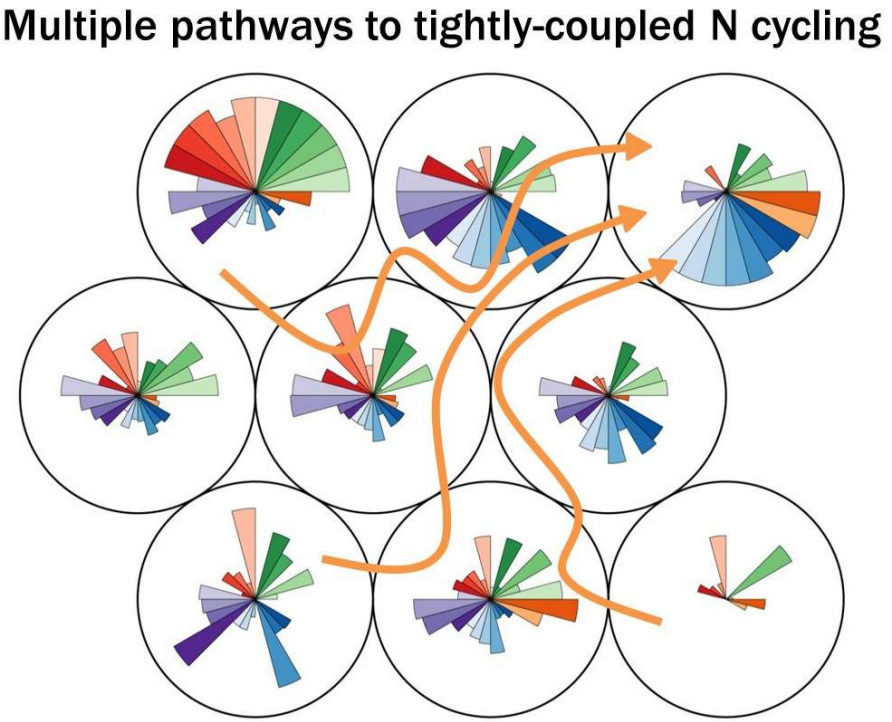
Multiple ecosystem services in organic production

- Three N cycling “scenarios” found on organic farms: tradeoffs among yields, N availability, and potential for N retention
  - 1) N deficiency (- - +)
  - 2) N excess (+ + -)
  - 3) **Tightly-coupled plant-soil N cycling** (+ + +)



Multiple ecosystem services in organic production

- Three N cycling "scenarios" found on organic farms: tradeoffs among yields, N availability, and potential for N retention
  - 1) N deficiency (- - +)
  - 2) N excess (+ + -)
  - 3) **Tightly-coupled plant-soil N cycling** (+ + +)
- Multiple indicators required to support adaptive management along pathways to tighter N cycling:
  - SOM and biological activity
    - High soil C and N pools, high bioassays of N availability
  - Soil inorganic N pools
    - Low soil NO_3^- (N deficiency *OR* tightly coupled N cycling) vs. high soil NO_3^- (more potential for N loss)
  - Plant N status
    - Elevated expression of GTS1 indicates higher plant N assimilation even if soil inorganic N pools are low



- Tightly-coupled N cycling comes with slightly reduced yields:
  - Are some tradeoffs inevitable?

Many thanks to:

- The 8 Yolo County growers who collaborated on this project: Thaddeus Barsotti, Andrew Brait, Jim Durst, Cliff Fong, Tim Mueller, Frank Muller, Bruce Rominger, and Tony Turkovich
- Collaborators: Veronica Acosta-Martinez, John Yoder
- Members of the Jackson lab

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