Crops, Roots and Biological Processes: Synergistic Interactions

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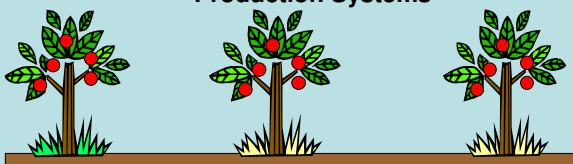
Managing soil ecosystem functions in intensive and extensive systems

Apple orchards in Washington State: conventional and organic production

Managing soil ecosystem functions in intensive and extensive systems

Perennial grassland and annual cropland in Kansas

1994 – 2003 Study of Three Apple Production Systems



Organic	Integrated	Conventional
•Preston Andrews		•Tom Forge
•John Reganold		•Tianna DuPont
•Herb Hinman		•Jerry Glover
•Sasha Kramer		•Harold Mooney
•Greg Peck		•Brendan Bohannon
	• Jennifer Moore Kucera	

1994 – 2003 Study of Three Apple Production Systems

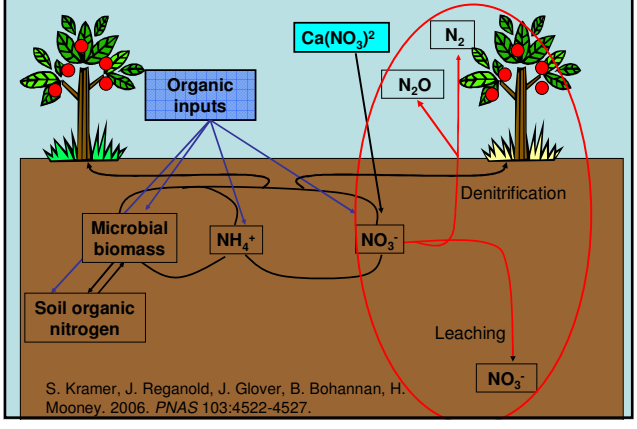
Organic	Integrated	Conventional
•Organic fertilizers (compost, alfalfa)	• Calcium-nitrate & organic fertilizers	• Calcium-nitrate
•Only organic pesticides	• Reduced herbicides	• Herbicides
	• Integrated pest mngmt	• Integrated pest mngmt

• Similar amounts of nitrogen applied to all three systems

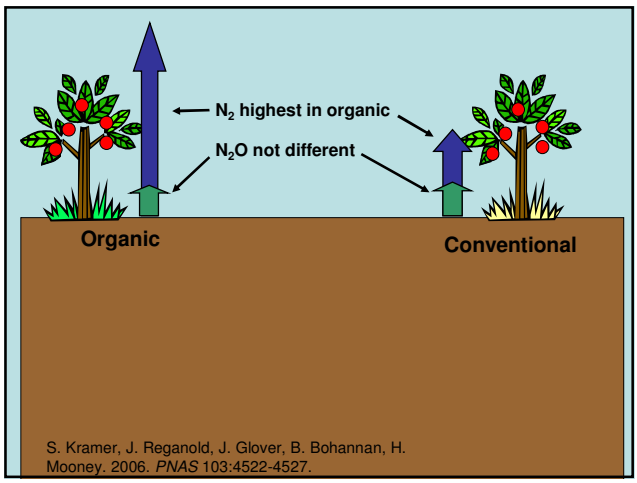
Organic **Integrated** **Conventional**

- Organic had higher soil quality than Conventional
- Similar cumulative yields
- Organic fruit were sweeter and as firm or firmer
- Firmness linked to fruit N and soil NO_3-N

J. Glover, J. Reganold, P. Andrews. 2000. *Ag. Ecosys. Env.* 80: 29-45.
J. Reganold, J. Glover, P. Andrews, H. Hinman. 2001. *Nature* 410: 926-930.



S. Kramer, J. Reganold, J. Glover, B. Bohannan, H. Mooney. 2006. *PNAS* 103:4522-4527.


N_2 highest in organic
N_2O not different
Organic
Conventional
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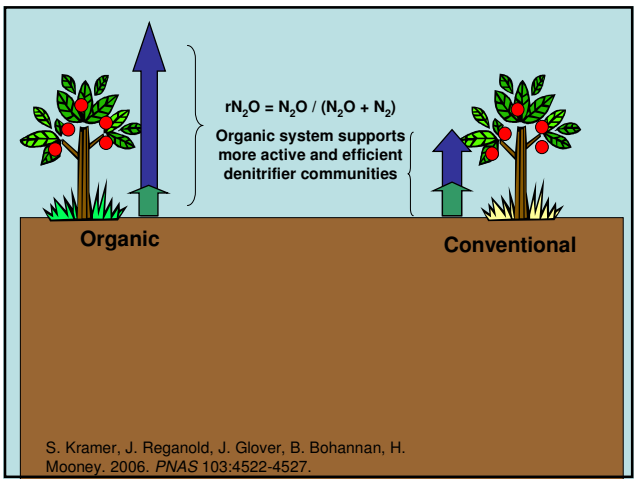
$rN_2O = N_2O / (N_2O + N_2)$
Organic system supports more active and efficient denitrifier communities
Organic
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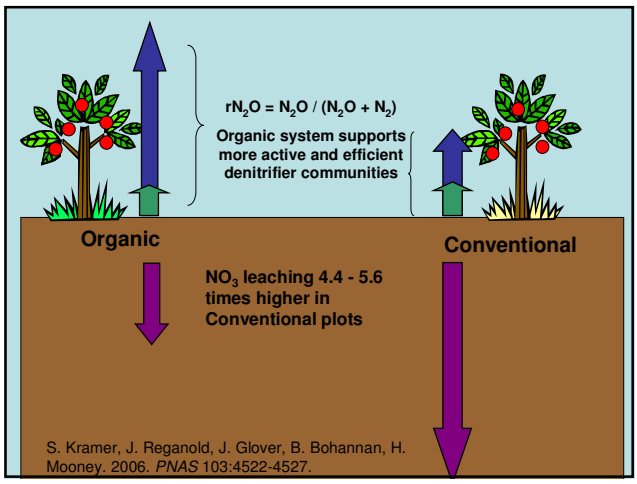
$rN_2O = N_2O / (N_2O + N_2)$
Organic system supports more active and efficient denitrifier communities
Organic
Conventional
NO_3 leaching 4.4 - 5.6 times higher in Conventional plots
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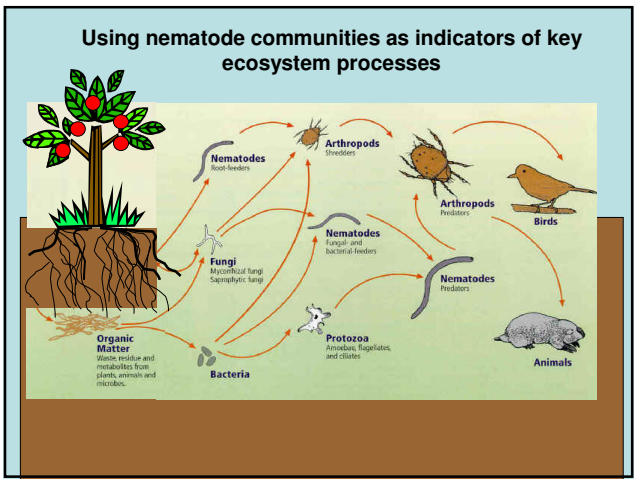
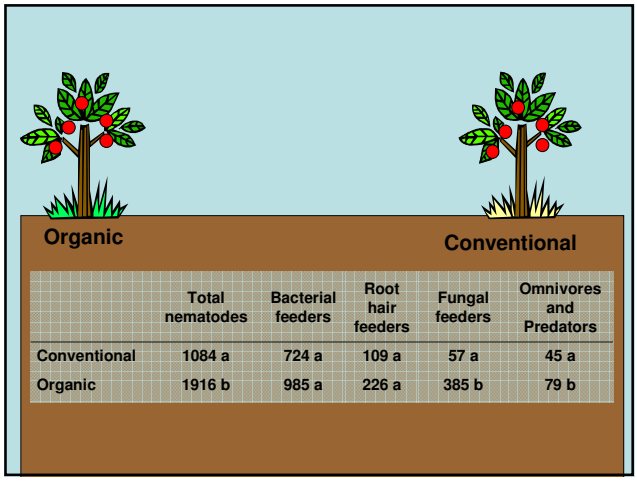
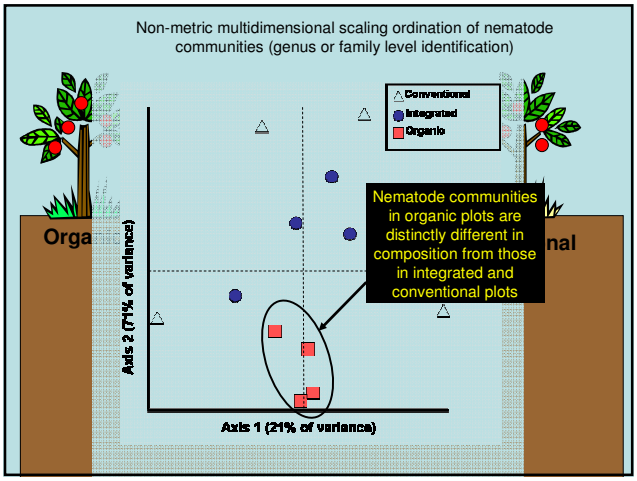
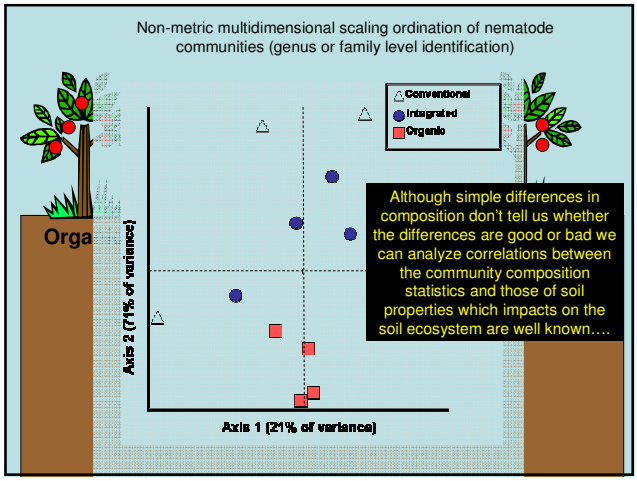
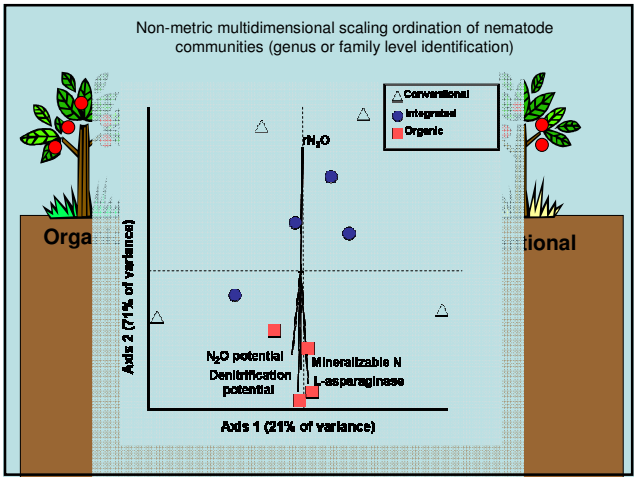

Using nematode communities as indicators of key ecosystem processes
Nematodes
Root-feeders
Arthropods
Shredders
Arthropods
Predators
Birds
Nematodes
Fungal- and bacterial-feeders
Fungi
Mycorrhizal fungi
Saprophytic fungi
Nematodes
Predators
Organic Matter
Waste, residue and metabolites from plants, animals and microbes.
Bacteria
Protozoa
Amoebae, flagellates, and ciliates
Animals

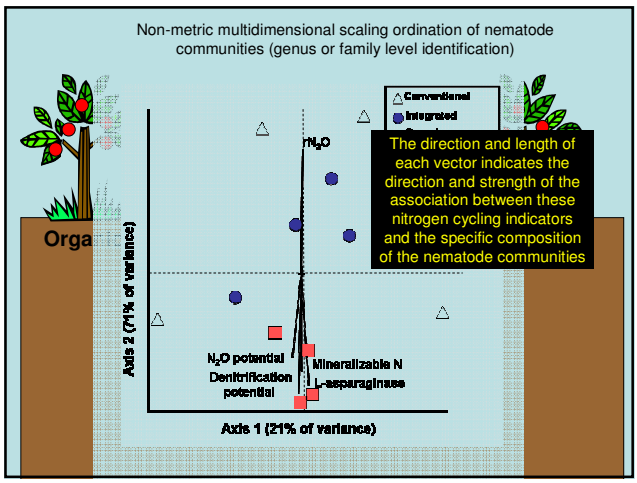


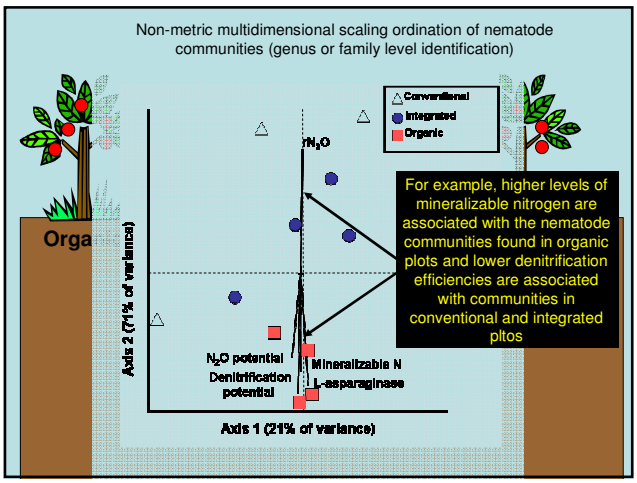
	Total nematodes	Bacterial feeders	Root hair feeders	Fungal feeders	Omnivores and Predators
Conventional	1084 a	724 a	109 a	57 a	45 a
Organic	1916 b	985 a	226 a	385 b	79 b








Non-metric multidimensional scaling ordination of nematode communities (genus or family level identification)
Conventional
Integrated
Organic
N_2O
N_2O potential
Denitrification potential
Mineralizable N
L-asparaginase
Axis 1 (21% of variance)
Axis 2 (71% of variance)
The direction and length of each vector indicates the direction and strength of the association between these nitrogen cycling indicators and the specific composition of the nematode communities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N_2O
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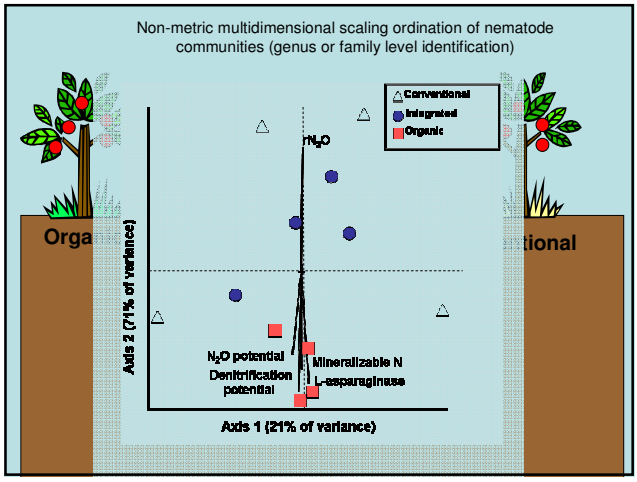
Denitrification potential
Mineralizable N
L-asparaginase
Axis 1 (21% of variance)
Axis 2 (71% of variance)
For example, higher levels of mineralizable nitrogen are associated with the nematode communities found in organic plots and lower denitrification efficiencies are associated with communities in conventional and integrated pltos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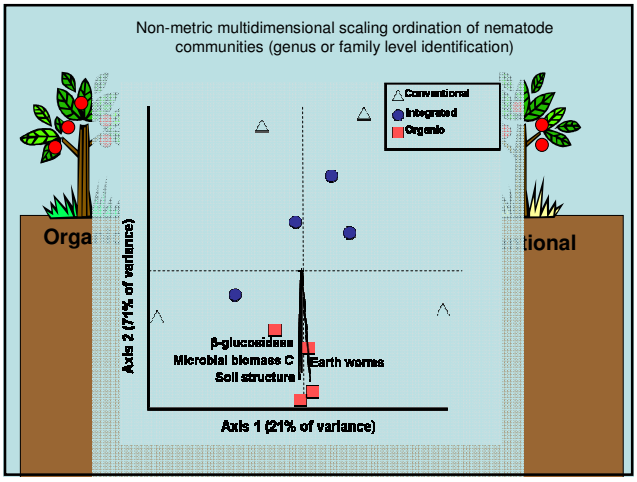
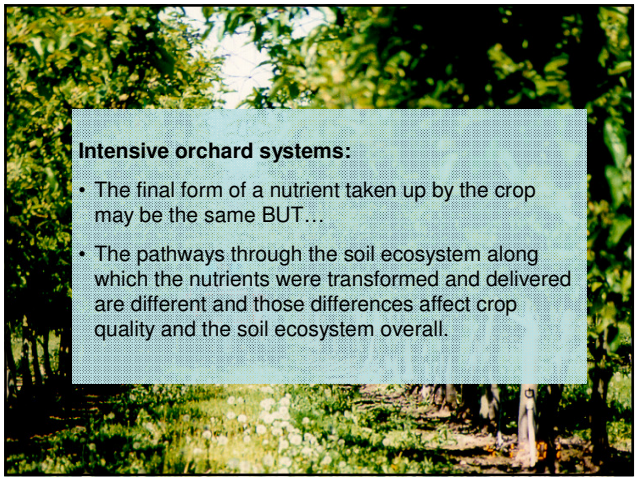
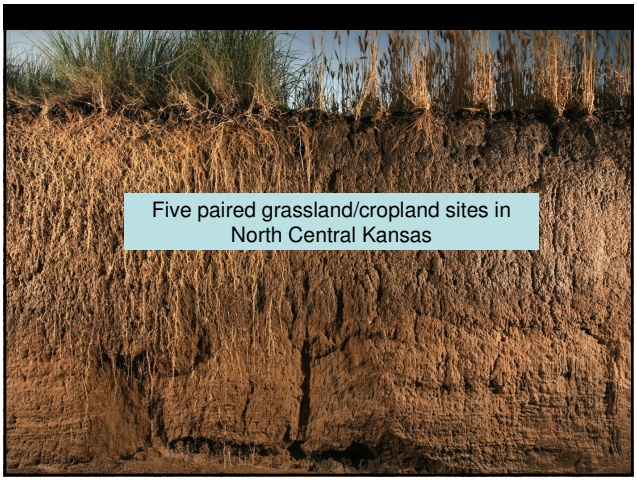
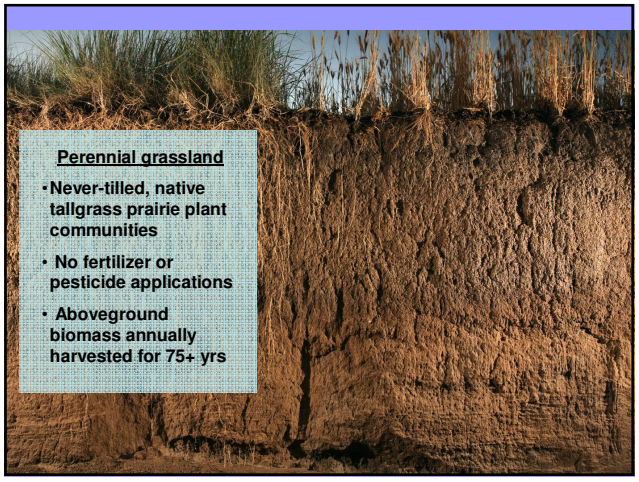
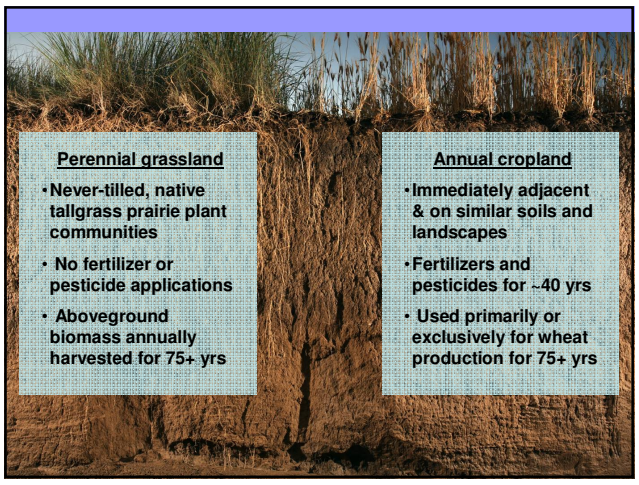

Non-metric multidimensional scaling ordination of nematode communities (genus or family level identification)
Conventional
Integrated
Organic
β-glucosidase
Microbial biomass C
Soil structure
Earth worms
Axis 1 (21% of variance)
Axis 2 (71% of variance)


Intensive orchard systems:
• The final form of a nutrient taken up by the crop may be the same BUT…
• The pathways through the soil ecosystem along which the nutrients were transformed and delivered are different and those differences affect crop quality and the soil ecosystem overall.


Five paired grassland/cropland sites in North Central Kansas


Perennial grassland
• Never-tilled, native tallgrass prairie plant communities
• No fertilizer or pesticide applications
• Aboveground biomass annually harvested for 75+ yrs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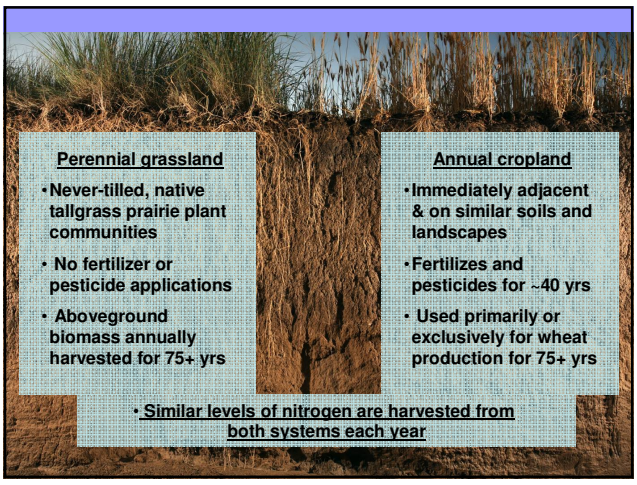
Annual cropland
• Immediately adjacent & on similar soils and landscapes
• Fertilizers and pesticides for ~40 yrs
• Used primarily or exclusively for wheat production for 75+ yrs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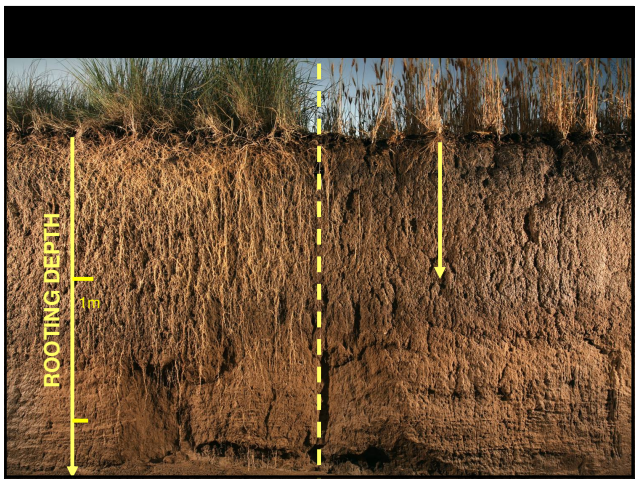
• Aboveground biomass annually harvested for 75+ yrs
Annual cropland
• Immediately adjacent & on similar soils and landscapes
• Fertilizes and pesticides for ~40 yrs
• Used primarily or exclusively for wheat production for 75+ yrs
• Similar levels of nitrogen are harvested from both systems each year

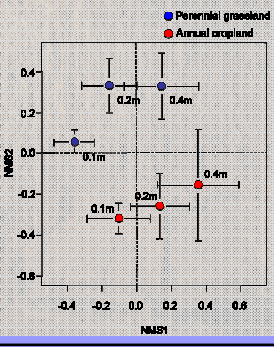

ROOTING DEPTH
1 m


Sept
Dec
March
June
1 m
2 m
12 mos
21 mos

Despite high levels of nutrient removal and no fertilization perennial grasslands maintained high soil quality (0 – 1m)

		Perennial grass	Annual cropland	p-value
Soil organic carbon	Mg ha^{-1}	182.2	138.8	0.027
Total nitrogen	Mg ha^{-1}	15.4	11.7	0.013
Readily oxidizable carbon	Mg ha^{-1}	4.3	3.3	0.025
Water stable aggregates		0.87	0.68	0.011

Non-metric multidimensional scaling ordination of nematode communities in surface 3 depths



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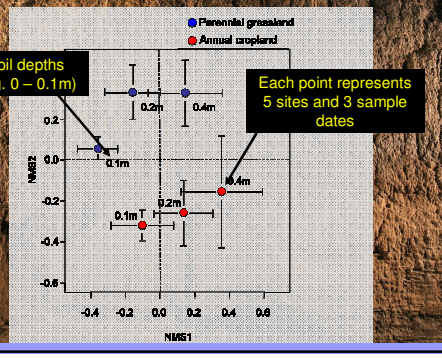

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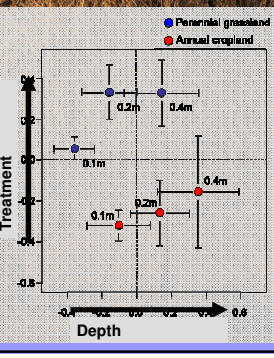

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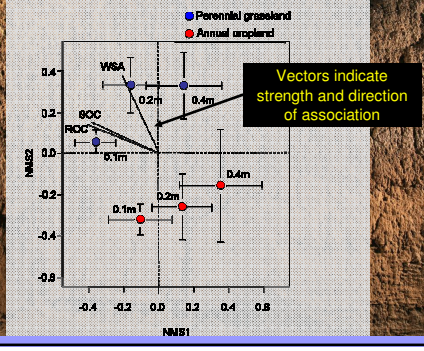
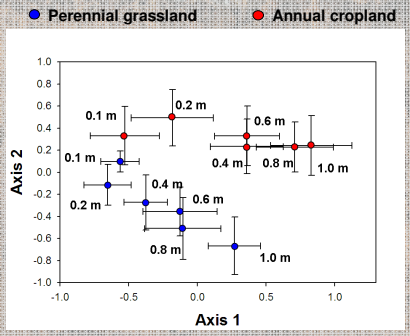


Vectors indicate strength and direction of association

Non-metric multidimensional scaling ordination of nematode communities to 1 m



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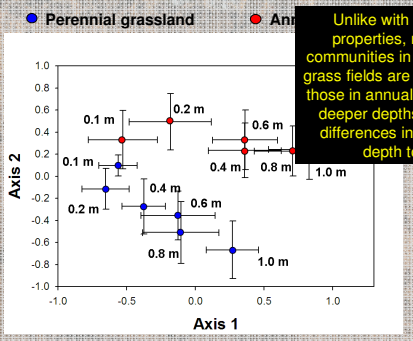
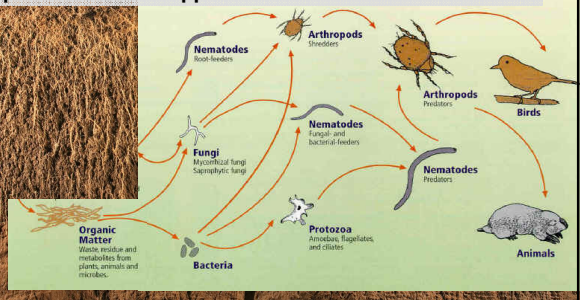


Unlike with many soil properties, nematode communities in the perennial grass fields are less similar to those in annual crop fields at deeper depths; treatment differences increase with depth to 1m.

Standardized indices of food web structure (Ferris et al.):

- Based on characteristics of nematode assemblages
- Indicates environmental conditions, nutrient cycling, pest & disease suppressiveness



Structure Index (SI):

- Measure of relative abundance of higher trophic groups sensitive to stress and with long life cycles
- Higher SI values indicative of greater diversity, greater complexity and more abundant resources

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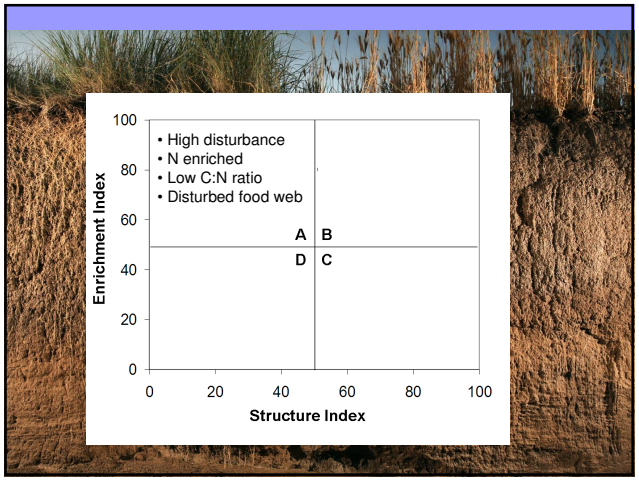
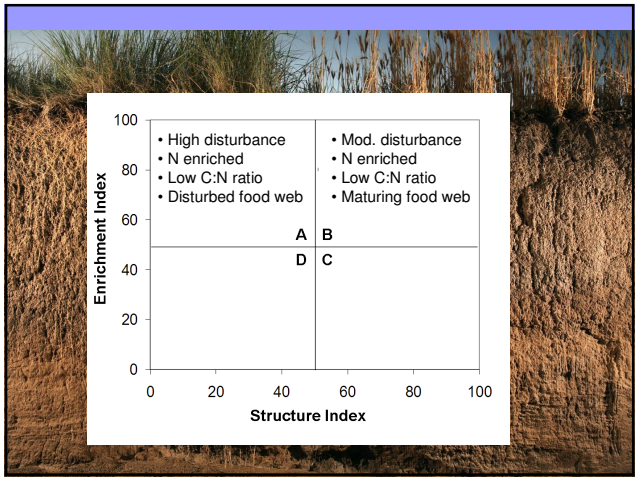
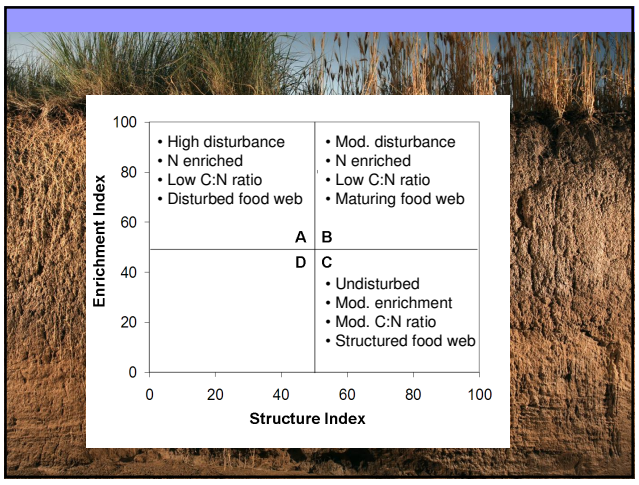
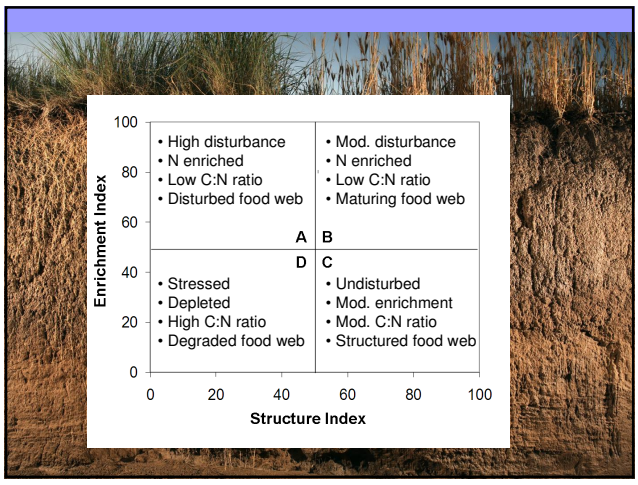
Enrichment Index (EI):

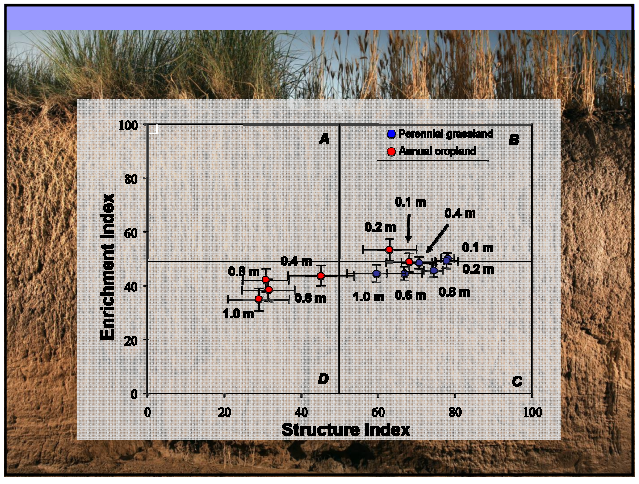
- Measure of relative dominance by bacterivorous and fungivorous taxa
- Higher EI values indicative of pulses of nutrient-rich inputs and increased bacterial production and nutrient mineralization

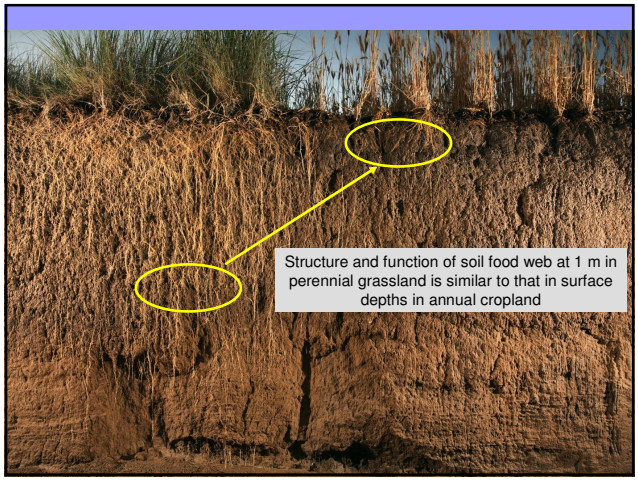


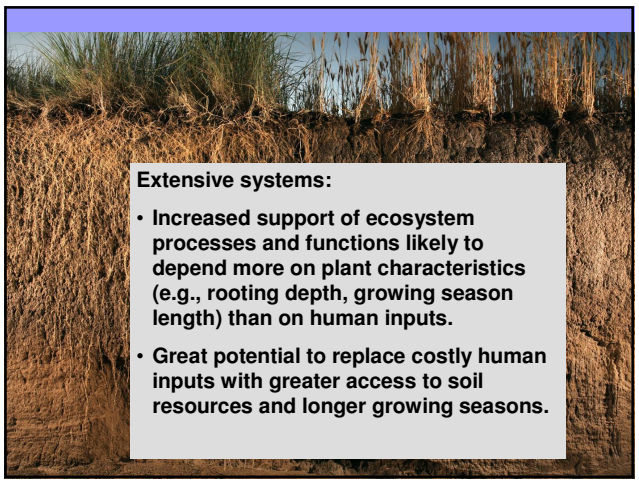



Enrichment Index
Structure Index
• High disturbance
• N enriched
• Low C:N ratio
• Disturbed food web
A
• Mod. disturbance
• N enriched
• Low C:N ratio
• Maturing food web
B
D
C
• Undisturbed
• Mod. enrichment
• Mod. C:N ratio
• Structured food web


Enrichment Index
Structure Index
• High disturbance
• N enriched
• Low C:N ratio
• Disturbed food web
A
• Mod. disturbance
• N enriched
• Low C:N ratio
• Maturing food web
B
D
• Stressed
• Depleted
• High C:N ratio
• Degraded food web
C
• Undisturbed
• Mod. enrichment
• Mod. C:N ratio
• Structured food web


Perennial grassland
Annual cropland
Enrichment Index
Structure Index
0.1 m
0.2 m
0.4 m
0.1 m
0.2 m
0.4 m
0.8 m
0.8 m
1.0 m
1.0 m
0.6 m
0.8 m


Structure and function of soil food web at 1 m in perennial grassland is similar to that in surface depths in annual cropland



Green Lands, Blue Waters

"…supports development of a new generation of agricultural systems in the Mississippi River Basin that integrate more perennial crops into the agricultural landscape."

www.greenlandsbluewaters.org

Glover et al. 2007. *Scientific American* August 2007:66-73

Jordan et al. 2007. *Science* 316:1570-1571.