NORTH CENTRAL SARE Sustainable Agriculture Research & Education

Comparing 50 Years of No-till to Other Tillage Systems

SOUTHERN ILLINOIS SALUKIS

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History

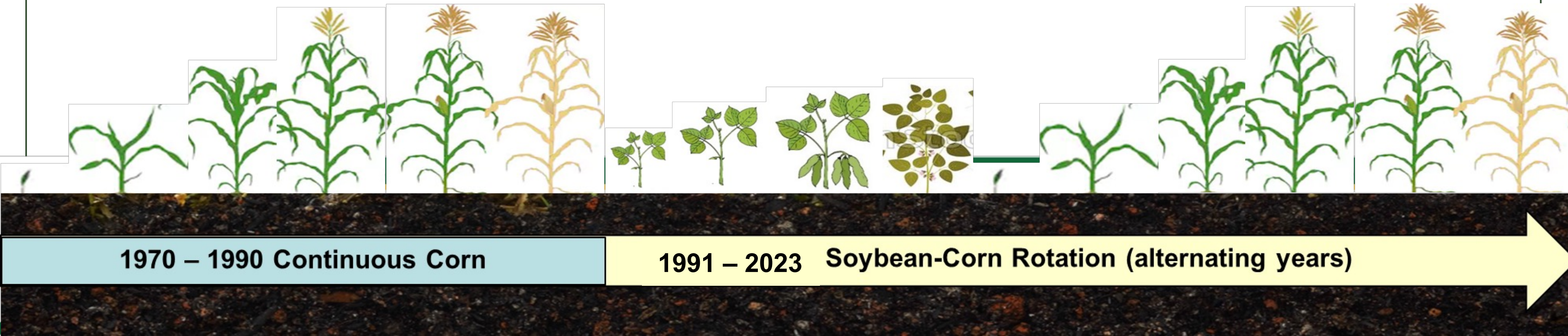
Somewhat poorly drained Bethalto silt-loam

1970-1990

- Continuous grain corn

1991-Present

- Corn-soybean rotation



Experimental Design

4 Replications

Tillage Intensity

Tillage

MP
- Conventional tillage
- Moldboard plow (6-8")

AT
- Alternate tillage/triennial tillage
- No-till (2 yrs); Moldboard plow (1 yr)

CD
- Spring disking followed by chisel-point cultivator (6-8")

NT
- No-till (disturbance by planter)

Fertility

Control
- no fertilization

Nitrogen only
- broadcast (175-0-0)

NPK
- **broadcast (175-80-180)**

New Control

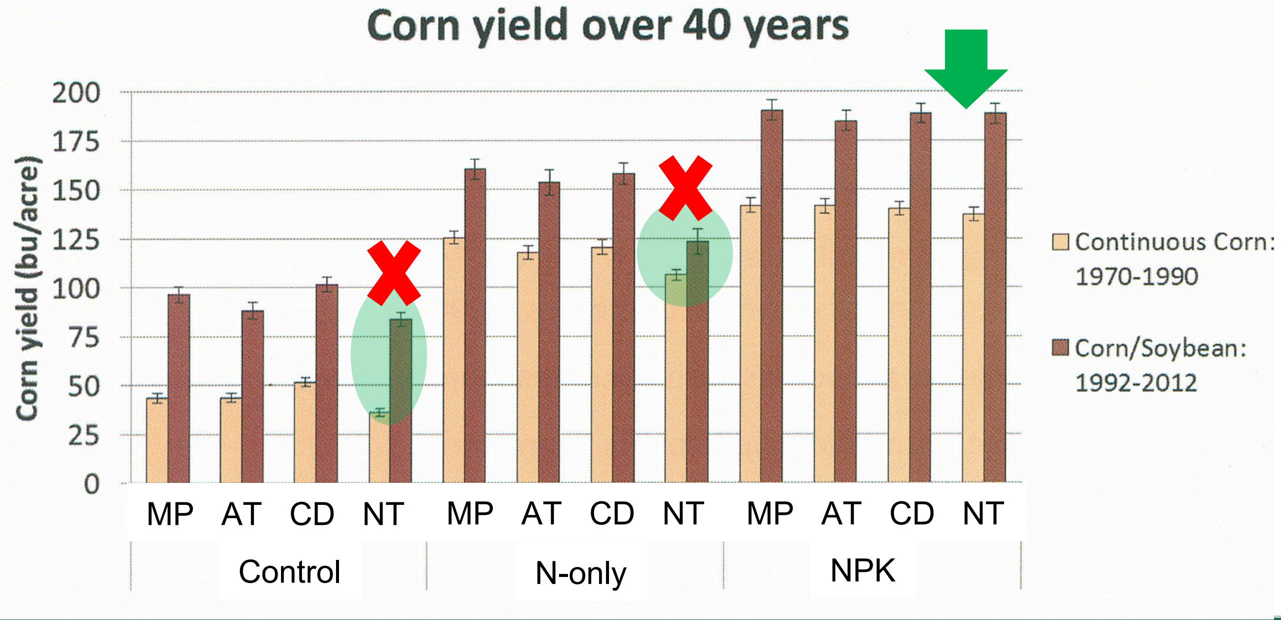
Applications made only in corn years.

Research Questions

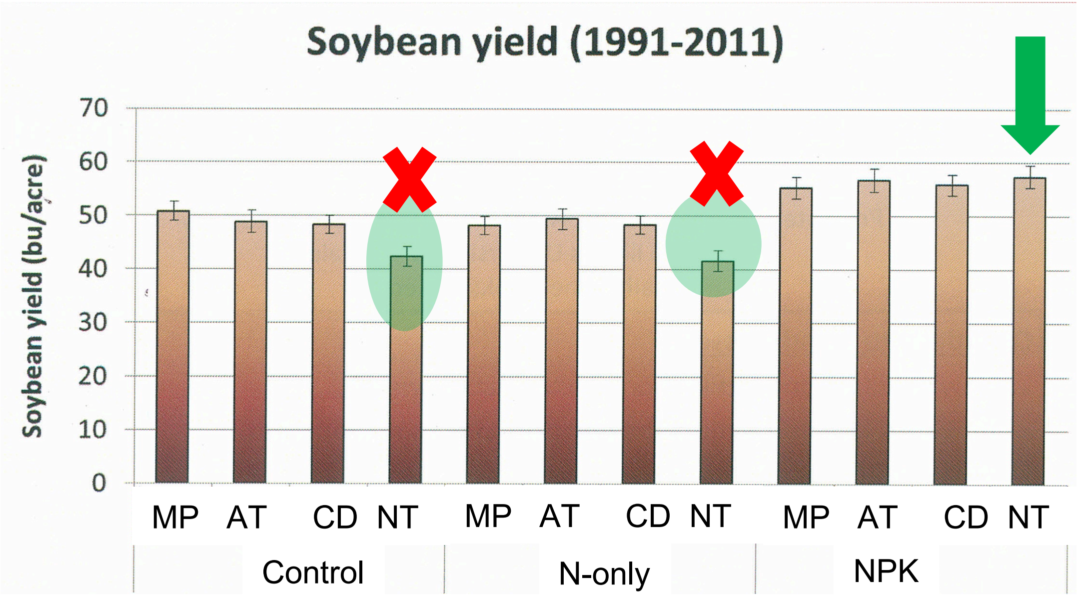
1. What **yield** benefits does no-till incur after 50 years?
2. What **soil** benefits does no-till incur after 50 years?
    a. What changes in soil **chemical** properties occur after 50 years?
    b. What changes in soil **physical** properties occur after 50 years?
    c. What changes in soil **biological** properties occur after 50 years?

1. What **yield** benefits does no-till incur after 50 years?

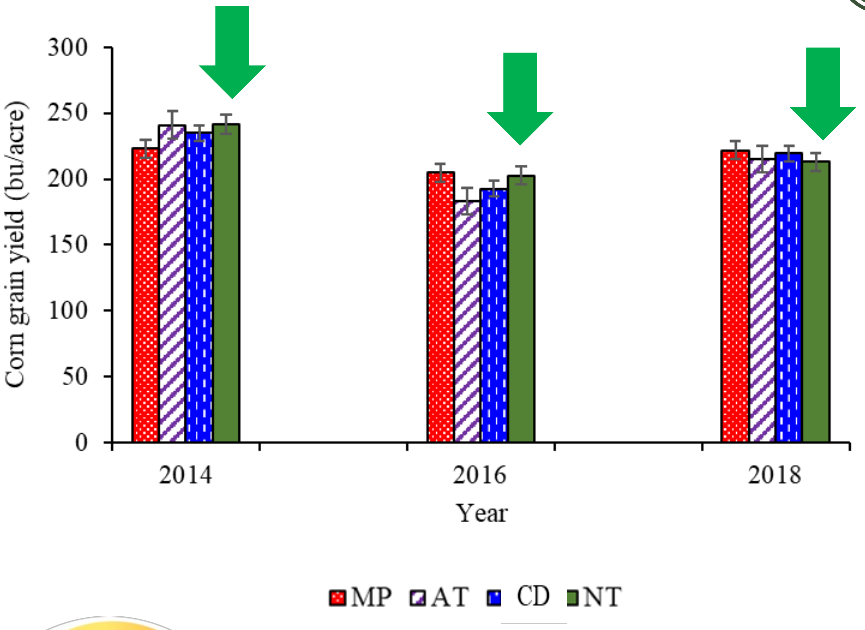
Historic corn yield data

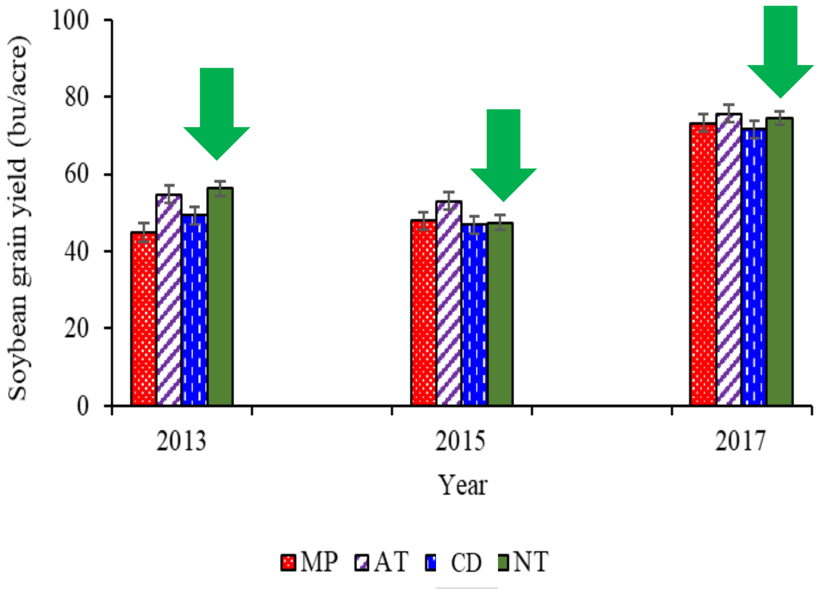


Historic soybean yield data



Corn and soybean yield data (2013-2018)





1. What **yield** benefits does no-till incur after 50 years?

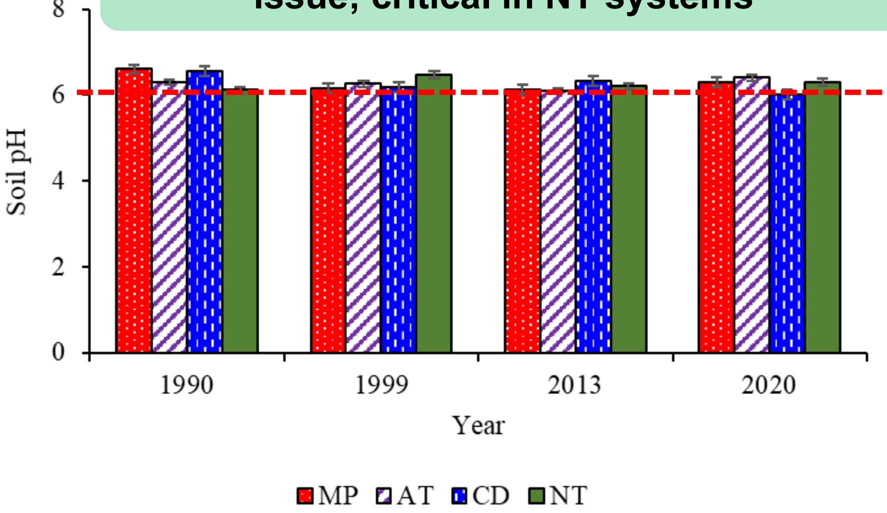
Historically: as long as NPK is applied, NT is competitive

Recent data: no gain for corn; gain for soybean

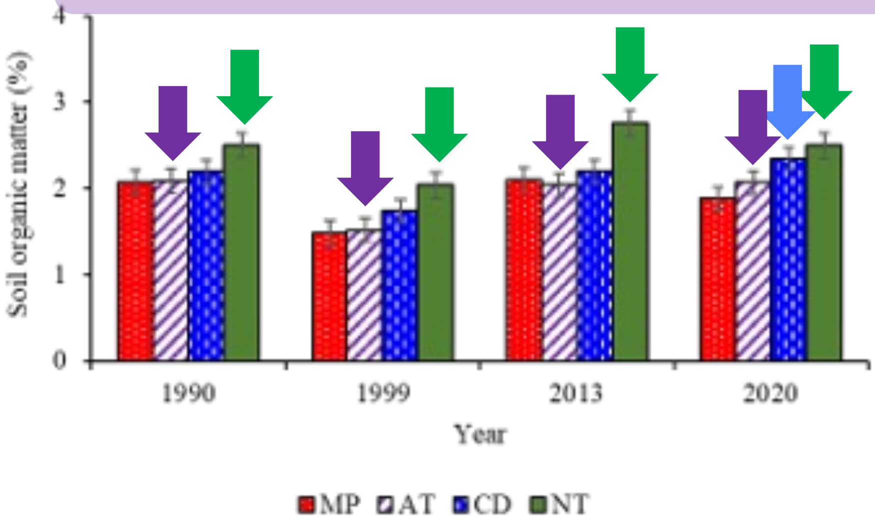
2.a What changes in soil **chemical** properties occur after 50 years?

Soil pH and SOM trends (1990-2020)

Periodically checking and liming = no pH issue; critical in NT systems

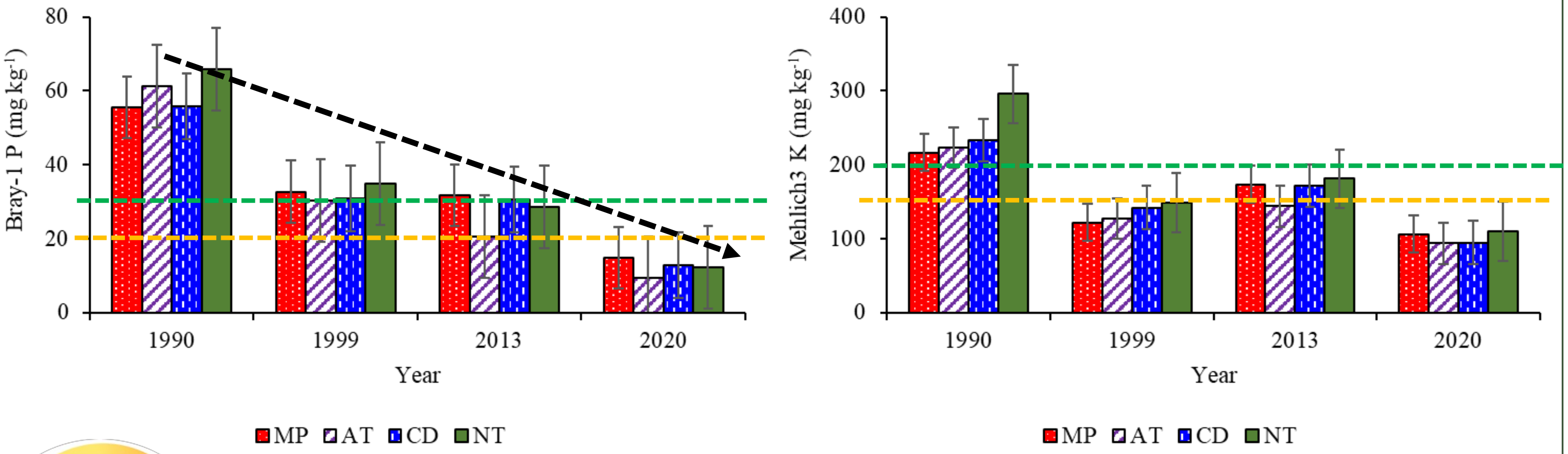


Alternate tillage (AT) = lack of SOM buildup!
Q: How would AT for NT + CD work?!

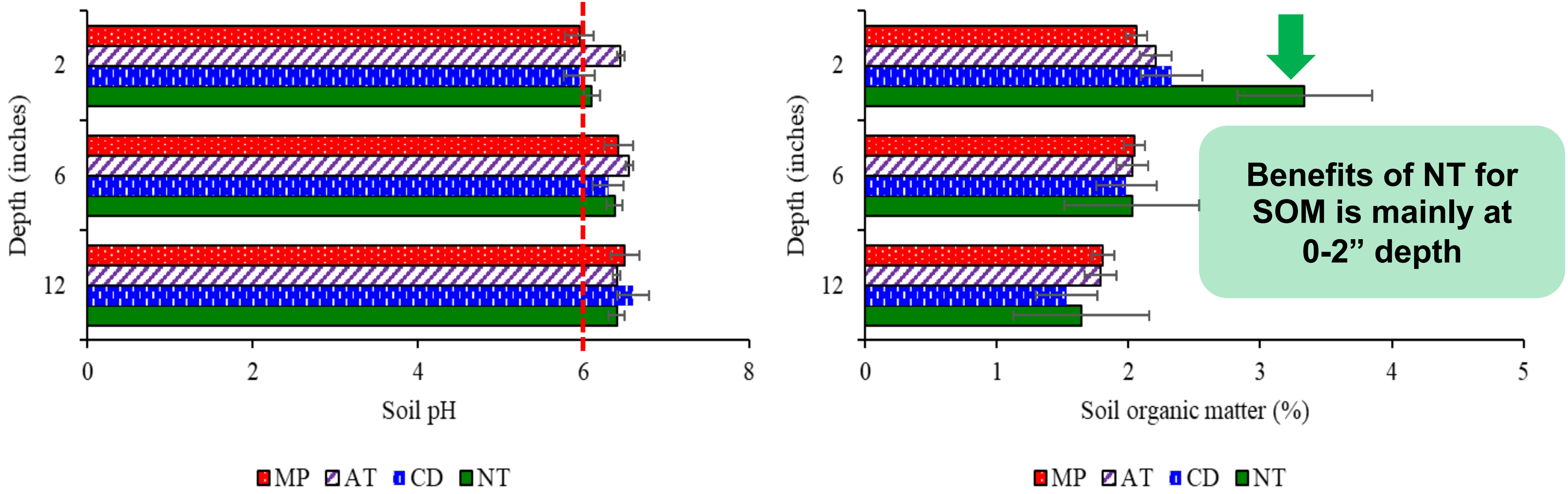


Soil P and K trends (1990-2020)

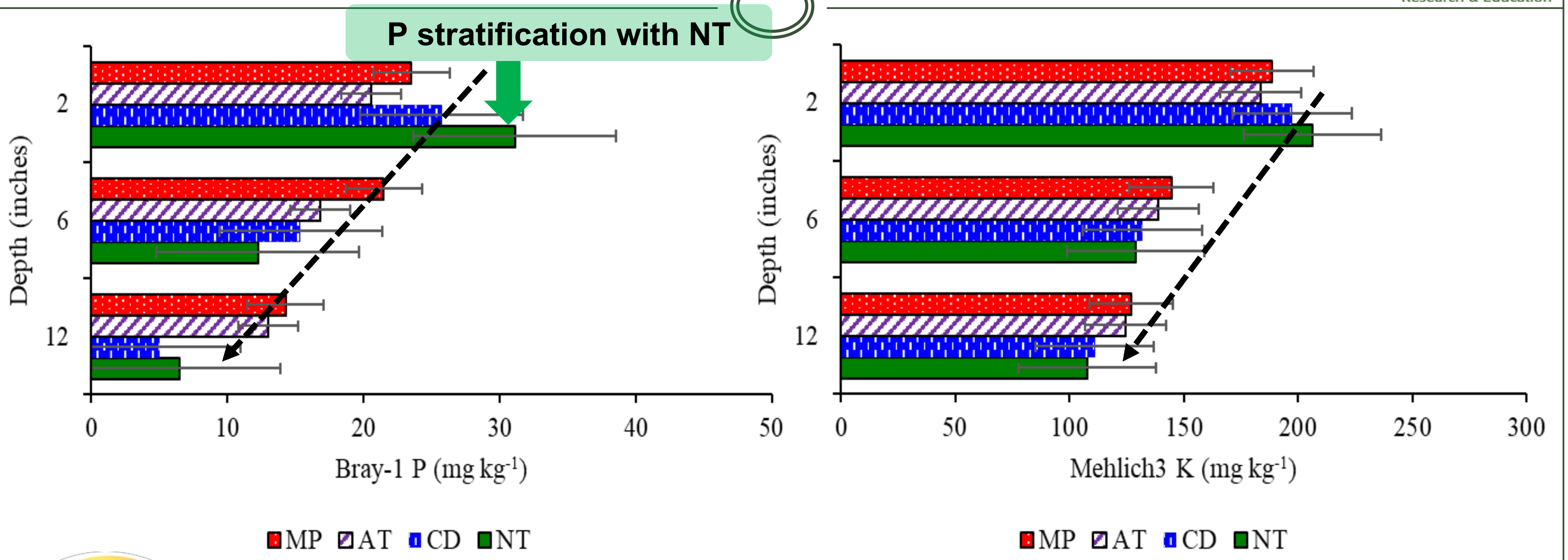
At current NPK practice, P & K levels are dropped to a point that need buildup + maintenance



Soil pH and SOM by depth (2018)



Soil P and K by depth (2018)



Soil Sulfur by depth (2018)

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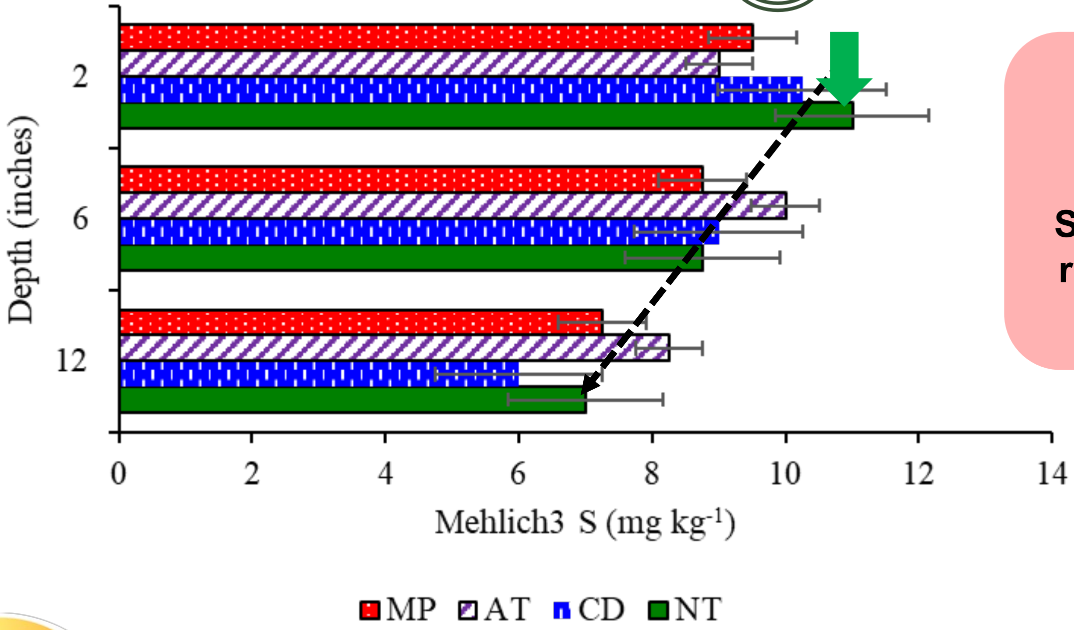


Optimum Mehlich3 S is > 22 lbs/acre (>11 mg kg^{-1})

Sulfur was below the optimum range regardless of the tillage treatment

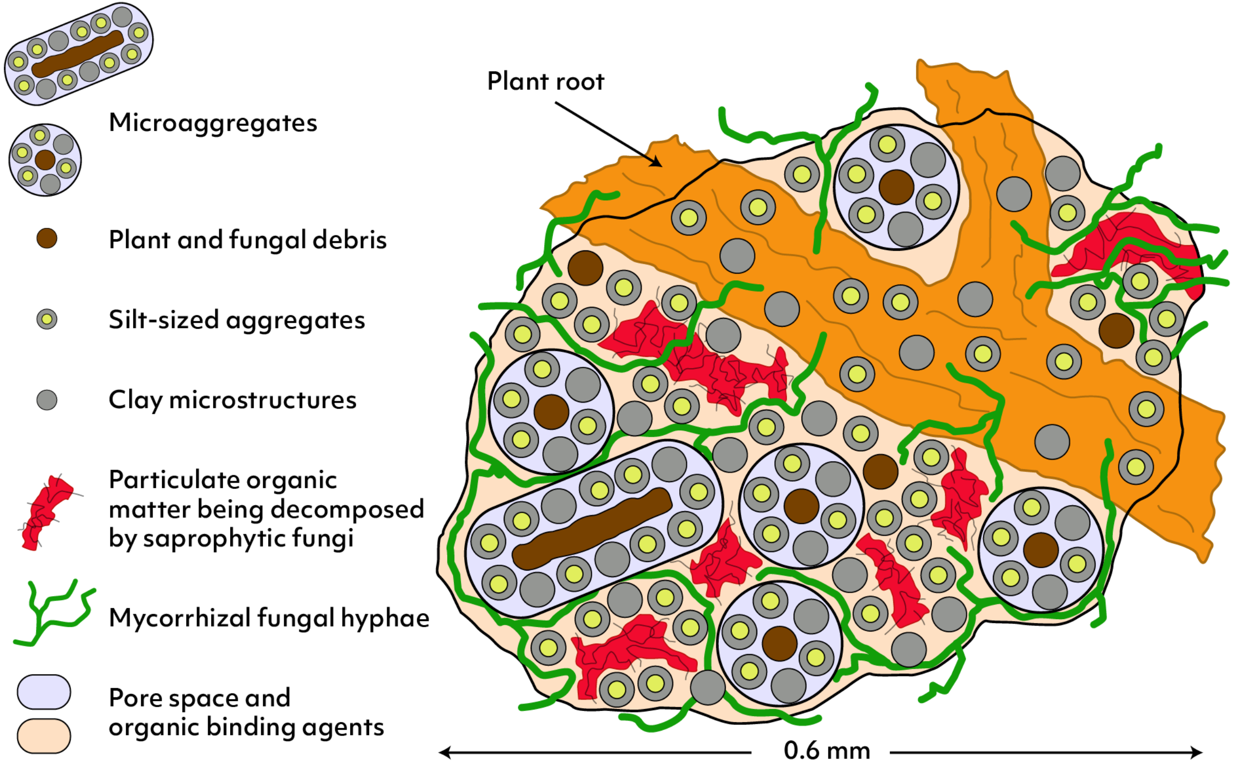
2.a What changes in soil **chemical** properties occur after 50 years?

1. Soil pH was mainly stable due to periodic liming.
2. Soil organic matter was increased from 1970-1990 and then stayed high in NT; benefits are only at 0-2"; **NT is not enough**!
3. Soil P & K, regardless of tillage, have decreased over time to a point that indicates a need for build up and maintenance.
4. Soil P showed clear stratification with NT but no effect on corn and soybean yield.
5. Sulfur levels for all tillage practices were below the optimum range.

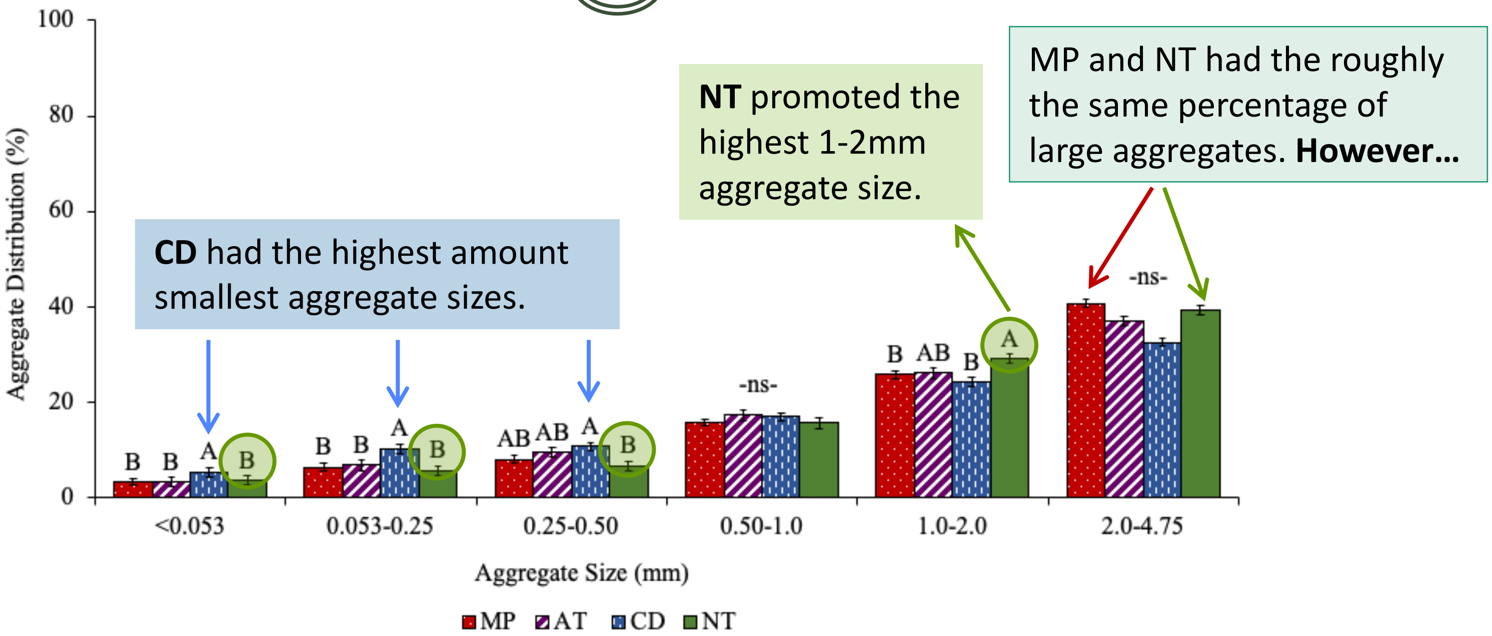
2.b What changes in soil **physical** properties occur after 50 years?

CONCEPTUAL DIAGRAM OF A MACROAGGREGATE

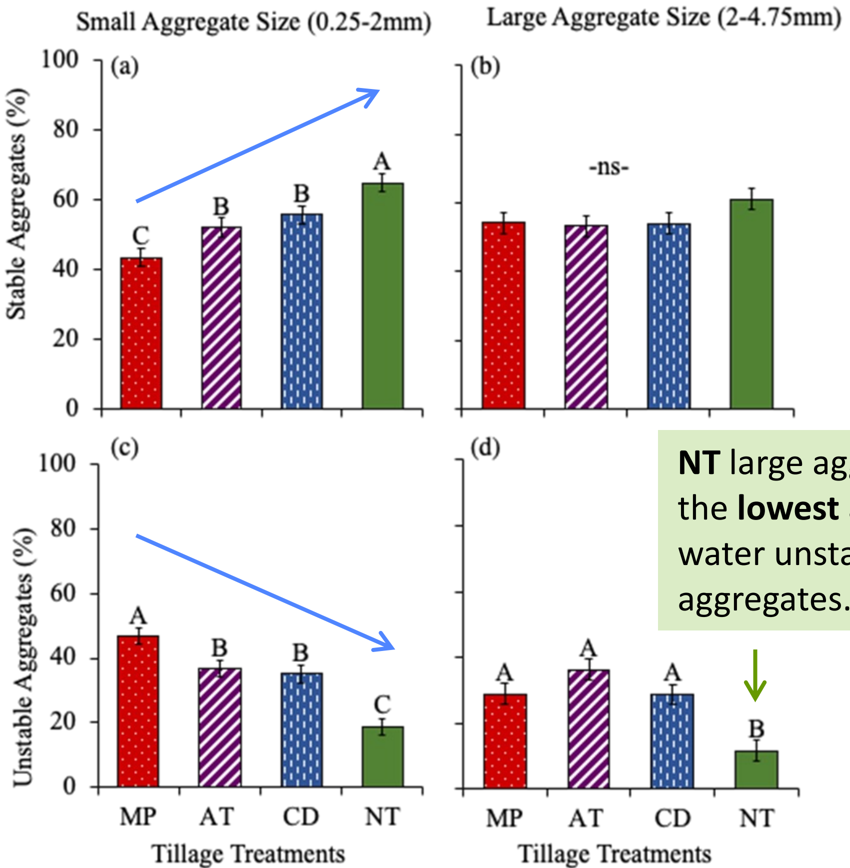
From Jastrow and Miller, 1998, in *Soil Processes and the Carbon Cycle*, CRC Press.



Tillage effect on dry aggregate size distribution (%)

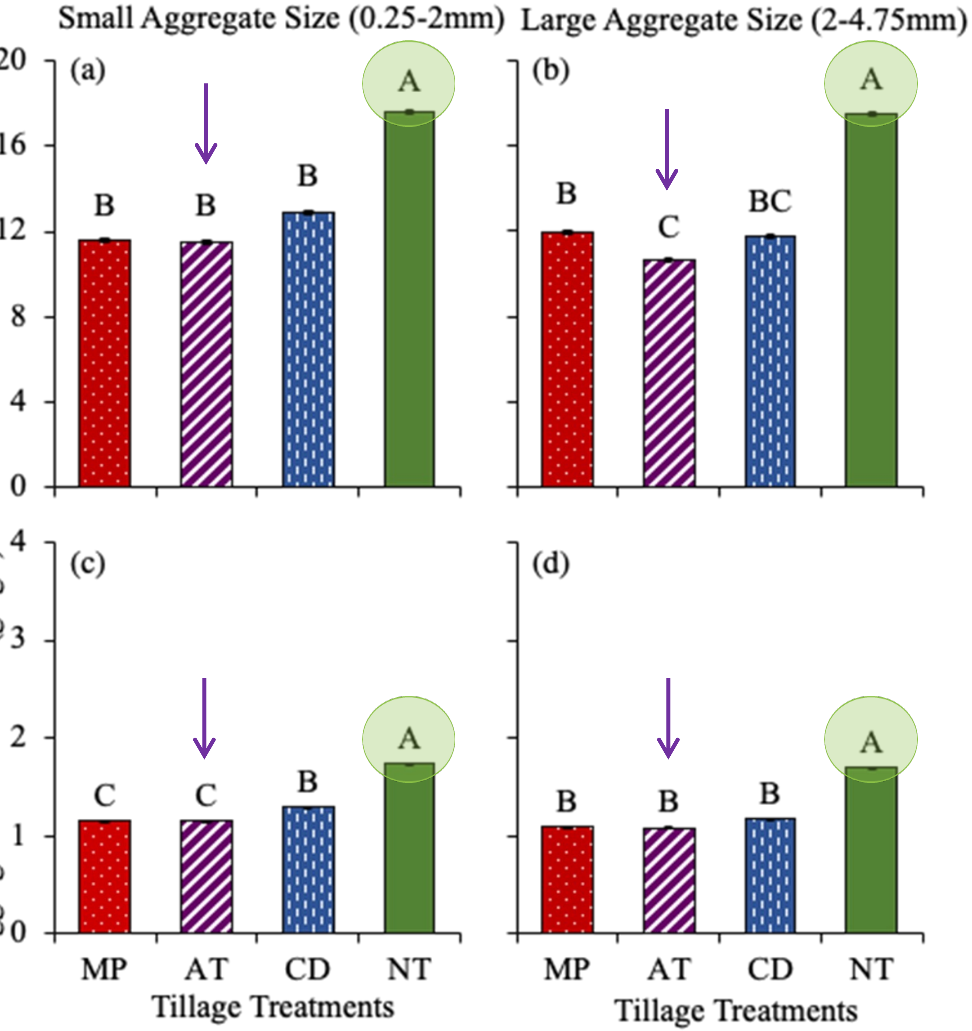


Tillage effect on percent water stable, (a) small and (b) large aggregate sizes in addition to percent water unstable (c) small and (d) large aggregate sizes



A **reduction** in tillage increased **water stable** aggregates in **small** aggregate size.

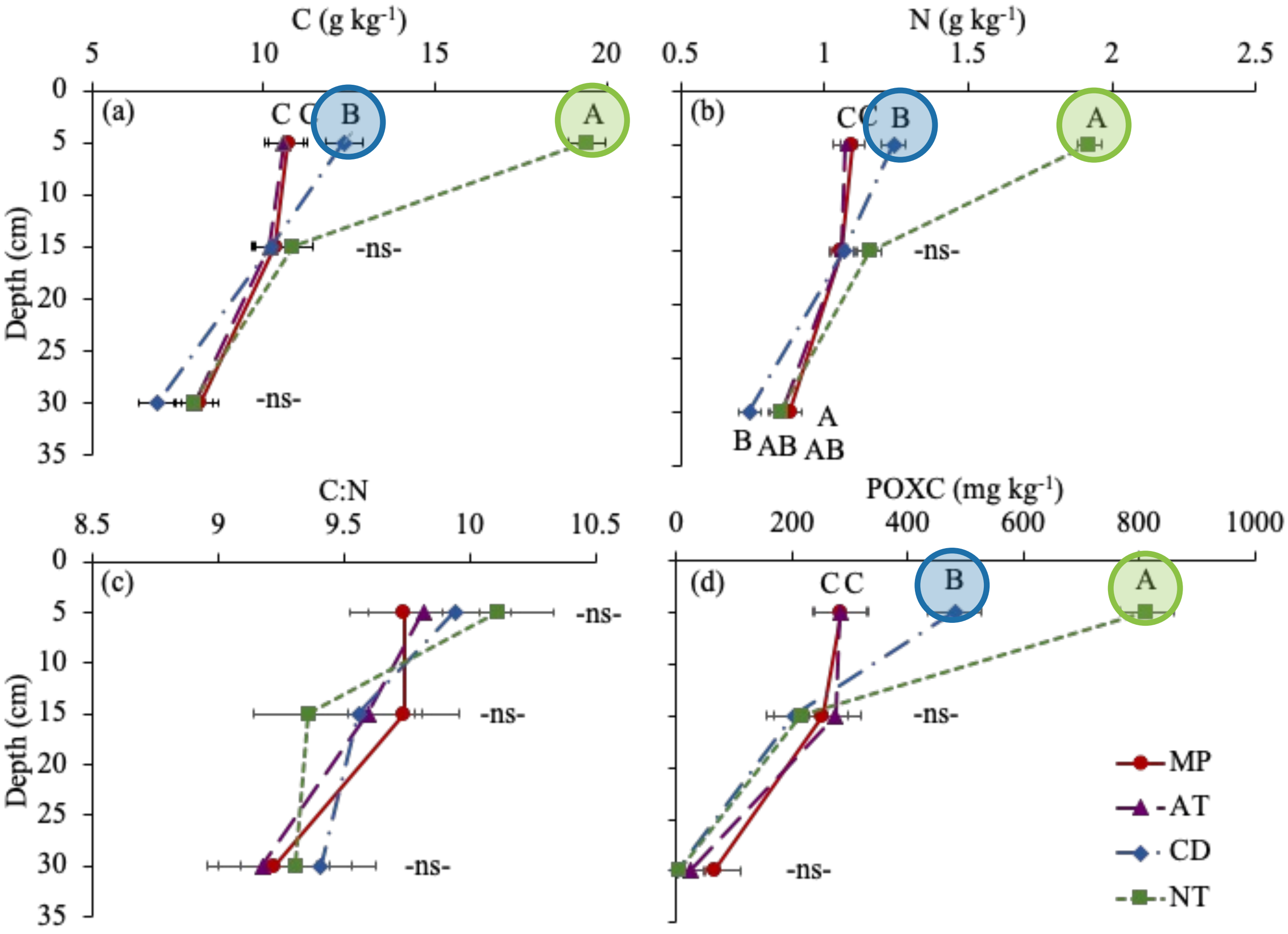
NT large aggregates had the **lowest** amount of water unstable aggregates.



Tillage effect on dry, (a) small and (b) large aggregate associated C (%) in addition to dry, (c) small and (d) large aggregate associated N (%)

NT dramatically increased aggregate associated C and N.

AT reduced the aggregate stored C and N that would have been build through continuous NT.

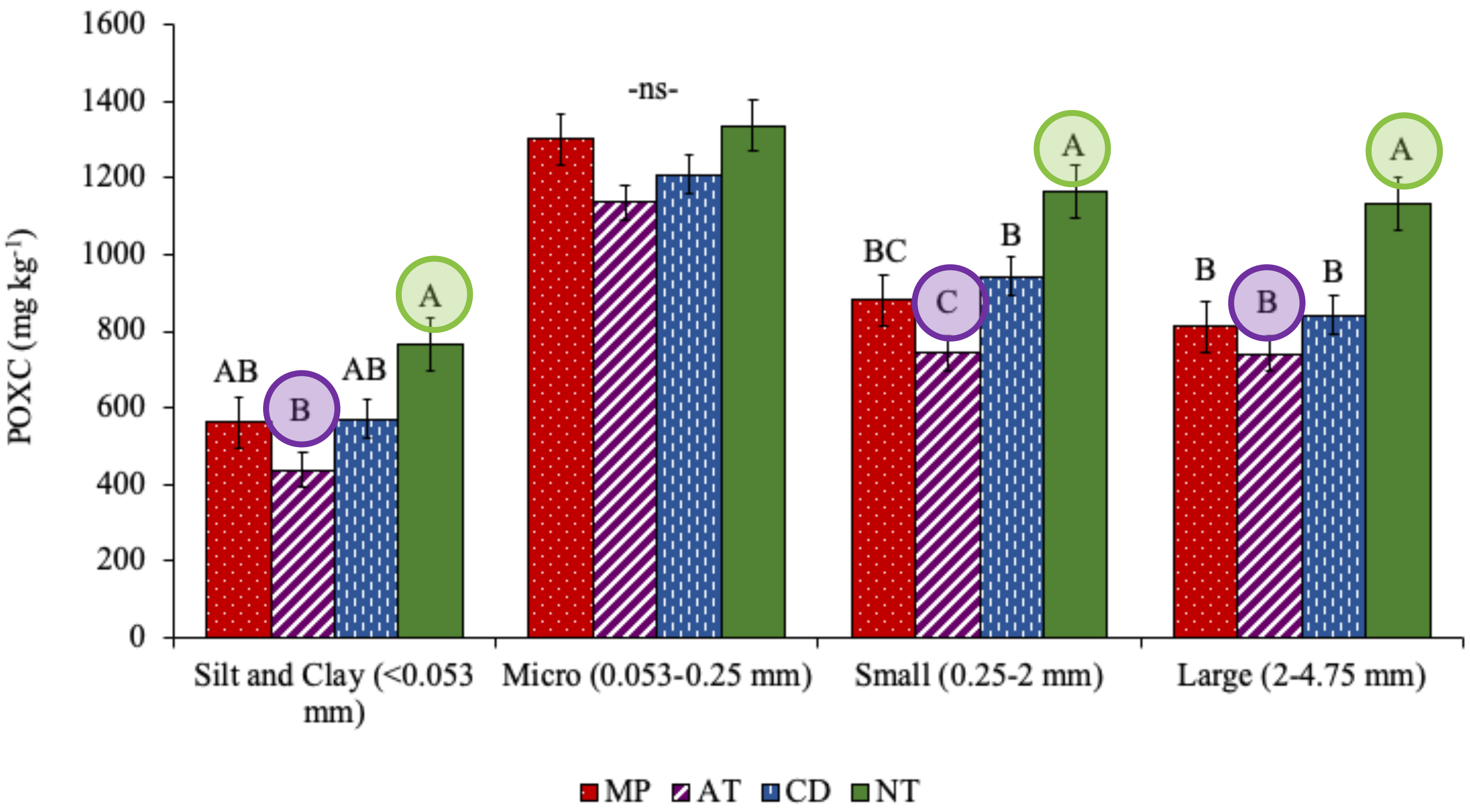


Tillage effect on soil (a) C, (b) N, (c) C:N and (d) POXC by soil depths of 0-5, 5-15, and 15-30 cm

C, N, and POXC were all dramatically increased by **NT**, but limited to the top of the soil profile.

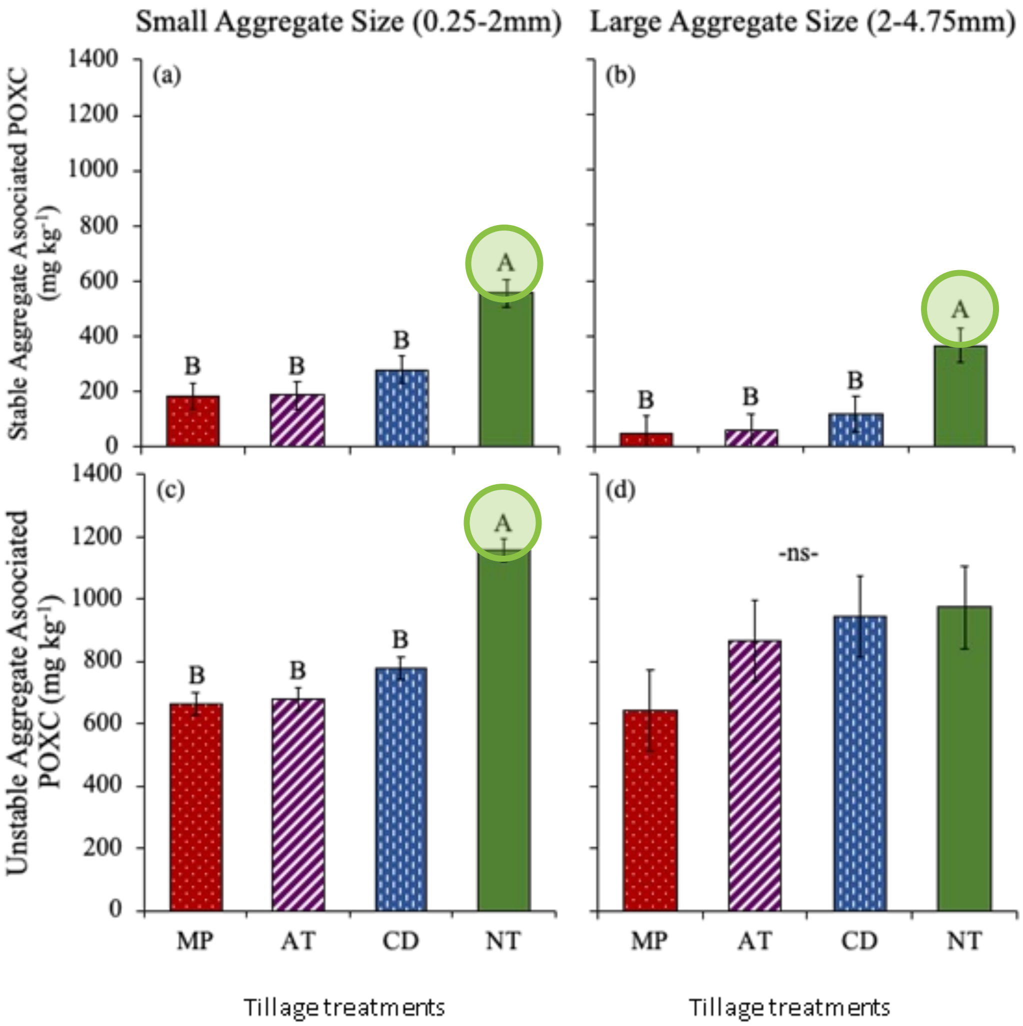
CD increased soil C, N, and POXC as well.

Tillage effect on dry aggregate associated POXC (mg kg^{-1})



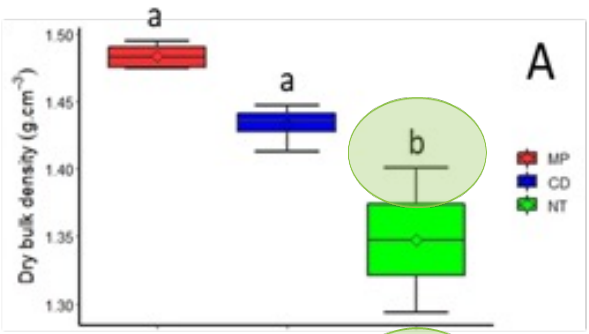
POXC increased in almost every aggregate size in **NT**.

Tillage effect on water stable (a) small and (b) large aggregate associated POXC (mg kg-1) in addition to water unstable (c) small and (d) large aggregate associated POXC (mg kg-1)

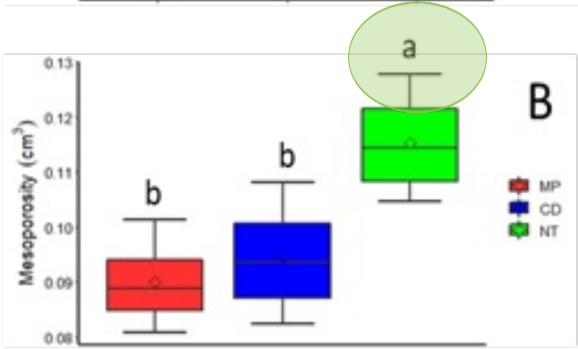


NT had the highest amount of POXC.

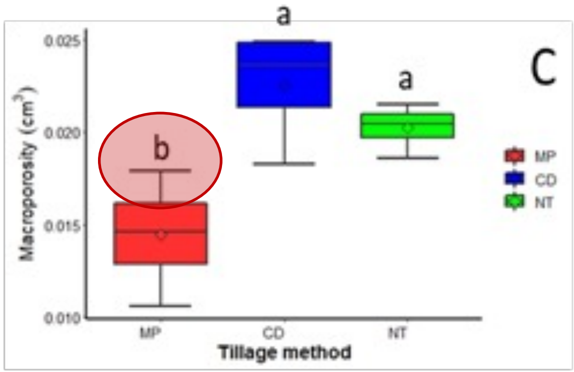
Unstable aggregates had more than 2x the amount of POXC than stable aggregates.



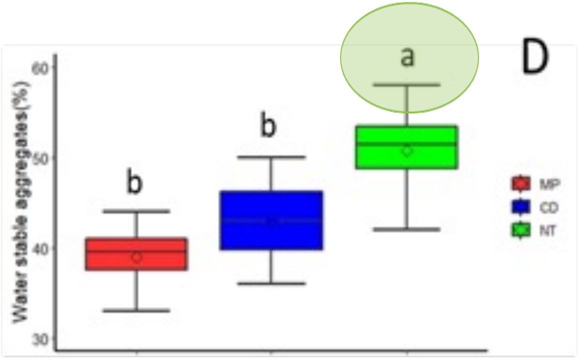
NT DBD was 9% lower than MP or CD.



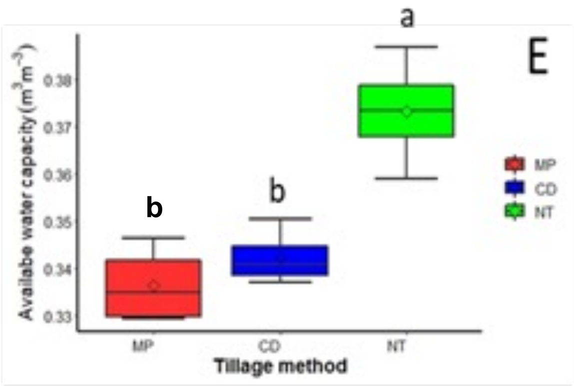
NT was the only treatment causing high meso-porosity.



MP disrupted soil aggregation.

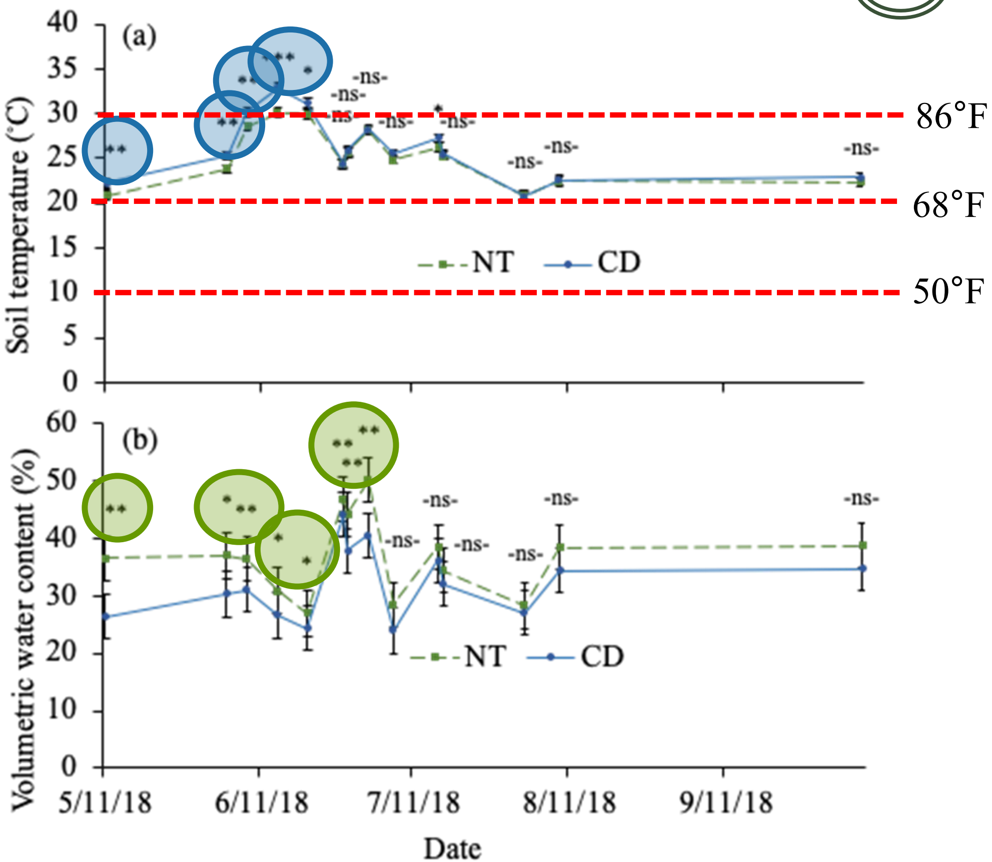


Tillage intensity decreased WSA.



NT increased AWC, reflected in macro- and meso-porosities.

Tillage effect on (a) soil temperature (°C) and (b) volumetric water content (%)



CD had drier and warmer soils early in the season.

NT had cooler and more moist soils early in the season.

Soil matric potential and saturated hydraulic conductivity (SHC)

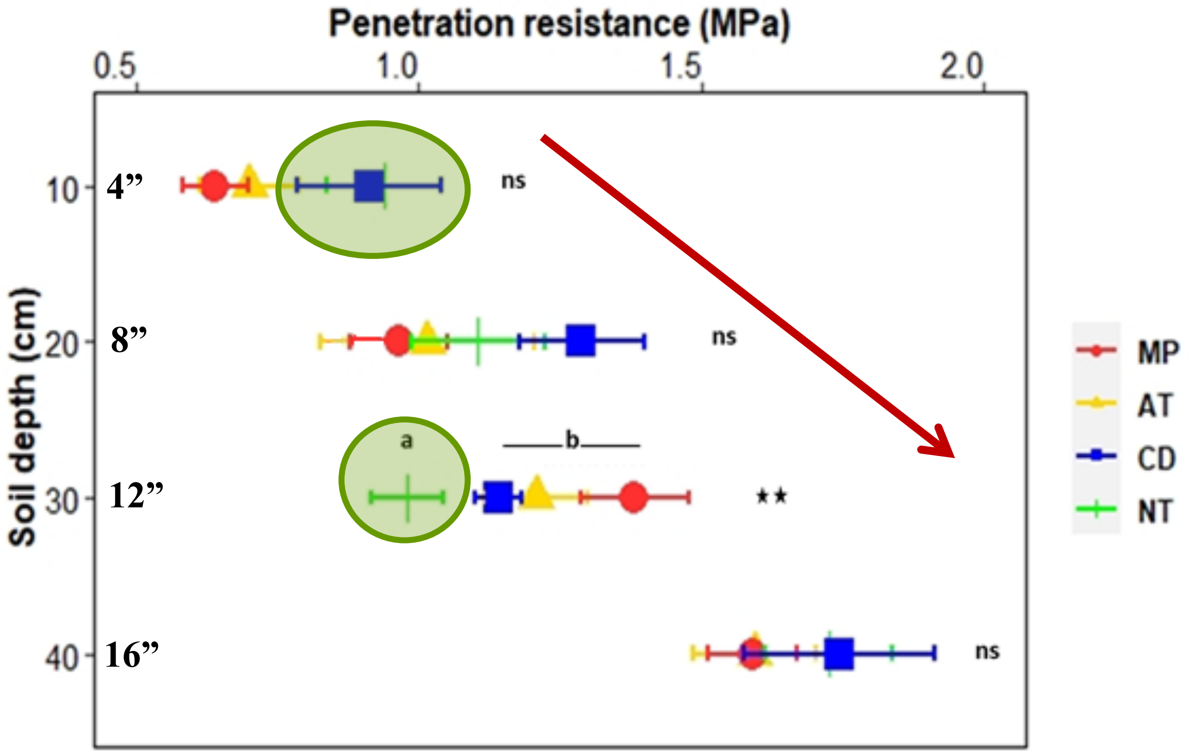
	Matric potential of water (kPa)							
Tillage system	0	-0.30	-33	-10	-1500	IAWHC	RAWHC	SHC
			Soil water (m^3m^{-3})					$cm.h^{-1}$
MP	0.442 b	0.428 b	0.338	0.574	0.097	0.240	0.476	14.65 ab
CD	0.449 b	0.427 b	0.333	0.559	0.090	0.242	0.469	26.70 a
NT	0.481a	0.460 a	0.345	0.586	0.102	0.243	0.484	2.97b
CV (%)	5.02	4.87	2.98	5.30	16.34	4.40	3.91	85.32
p-value	0.03	0.03	0.27	0.42	0.48	0.84	0.47	0.04

Tillage methods include moldboard plow (MP); 2-yr no-till and 1 yr MP (AT); chisel-disk (CD); and no-till (NT). Intact Available Water Holding Capacity (IAWHC) and Repacked Available Water Holding Capacity (RAWHC).

Intensity of yearly tillage did not change water retention.

Higher water retention in **NT** could be explained by higher pore volume.

Tillage effect on soil compaction



Penetration resistance followed an increasing trend with soil depth.

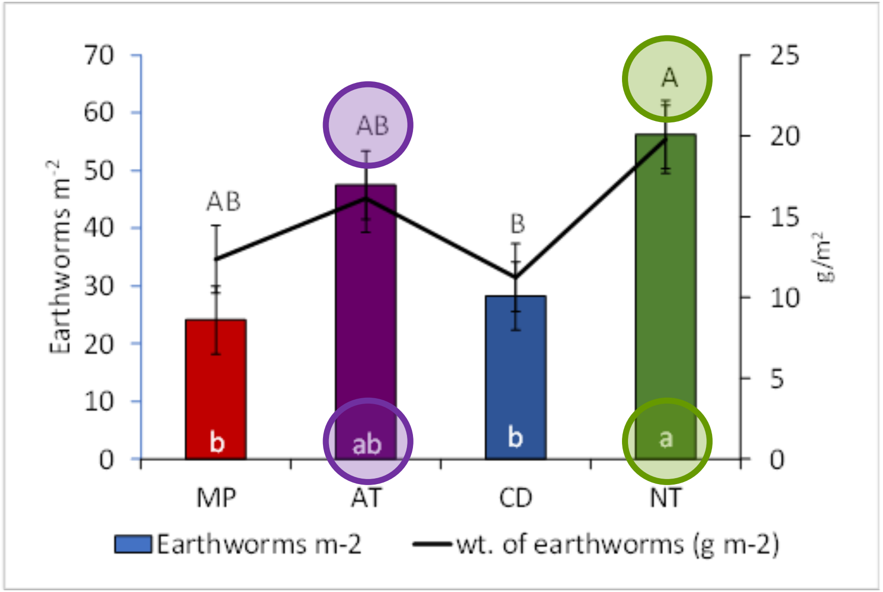
NT and **CD** resulted in the highest surface compaction, but NT had the lowest subsurface compaction.

2.b What changes in soil **physical** properties occur after 50 years?

1. NT had consistently low soil penetration resistance at the plow depth (12 in. depth) and no other compaction differences.
2. Compared to other tillage treatments, NT also had higher mean weight diameter, lower bulk density, higher soil porosity, water stable aggregates, and available water capacity.
3. Continued to build C and POXC after 50 years, but benefits were limited to the upper soil profile.
4. If using alternate tillage (AT), most of the above-mentioned benefits will be lost.

2.c What changes in soil **biological** properties occur after 50 years?

Earthworm abundance and biomass



NT approximately **doubled** earthworm abundance and total biomass compared to yearly tillage practices (MP and CD).

AT did have an improvement of earthworm biomass and abundance, but not as great as NT.

Earthworm ecotypes

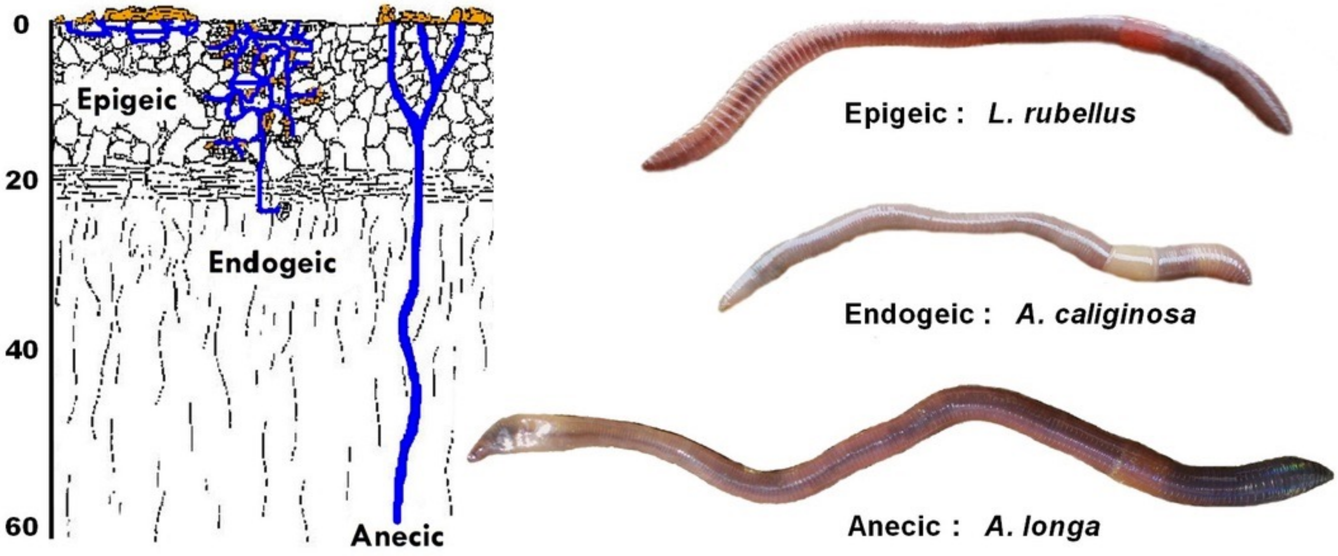


Diagram courtesy of the Science Learning Hub. Figure adapted from Fraser and Boag, photos of earthworms copyright Ross Gray.

Earthworm ecotype percentages in years 50 and 51

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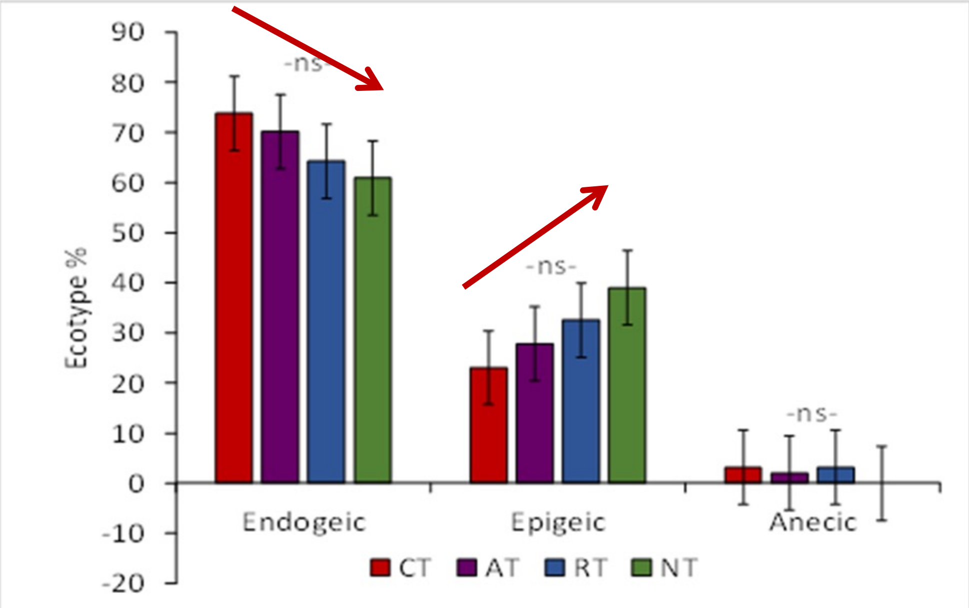
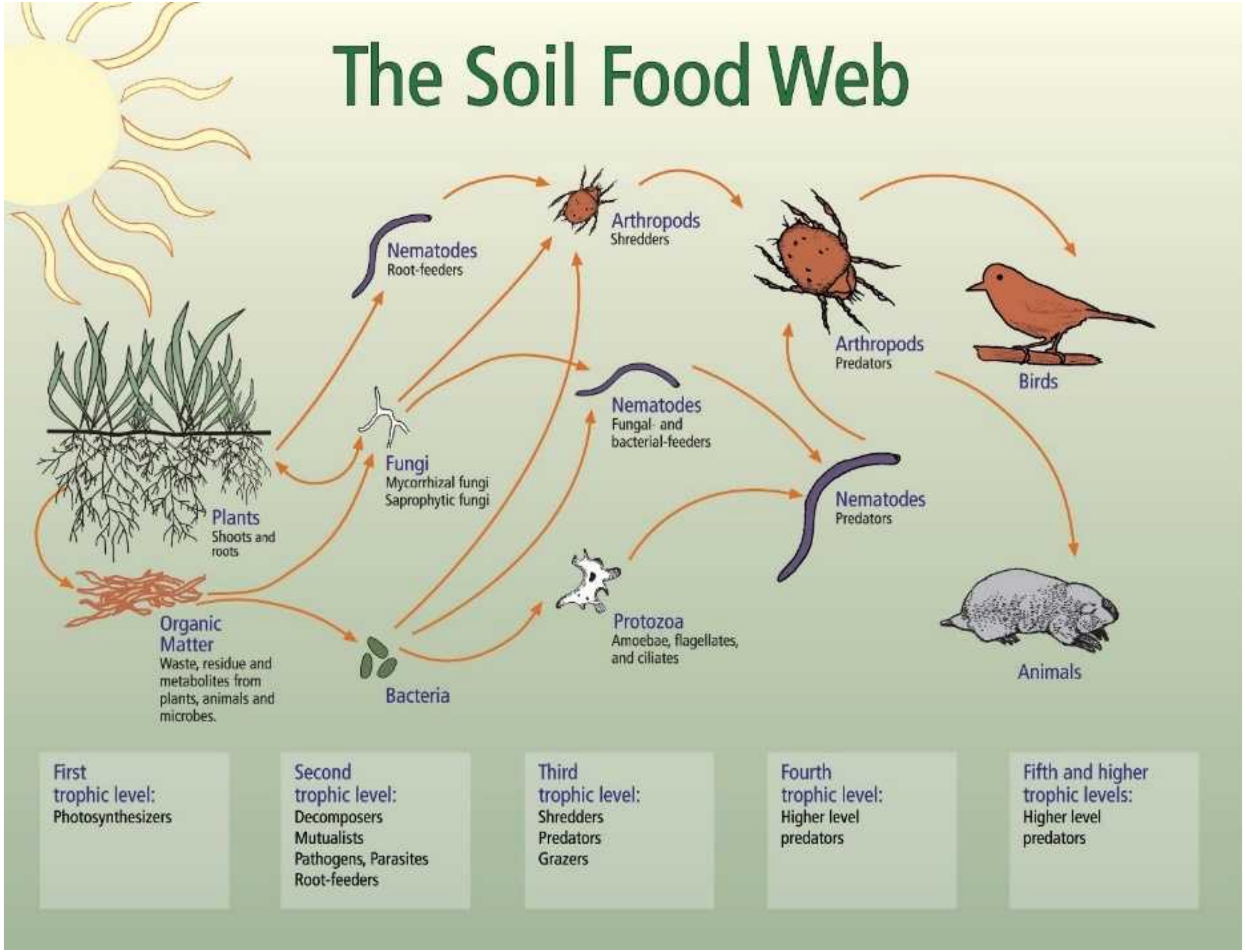


Although not significant, as **tillage intensity increases**, endogeic earthworms **decrease** and epigeic earthworms **increase**.

What are free-living nematodes?


The Soil Food Web
Nematodes
Root-feeders
Arthropods
Shredders
Arthropods
Predators
Birds
Fungi
Mycorrhizal fungi
Saprophytic fungi
Nematodes
Fungal- and
bacterial-feeders
Nematodes
Predators
Plants
Shoots and
roots
Organic
Matter
Waste, residue and
metabolites from
plants, animals and
microbes.
Bacteria
Protozoa
Amoebae, flagellates,
and ciliates
Animals
First
trophic level:
Photosynthesizers
Second
trophic level:
Decomposers
Mutualists
Pathogens, Parasites
Root-feeders
Third
trophic level:
Shredders
Predators
Grazers
Fourth
trophic level:
Higher level
predators
Fifth and higher
trophic levels:
Higher level
predators

Tillage effect on nematode soil indices.

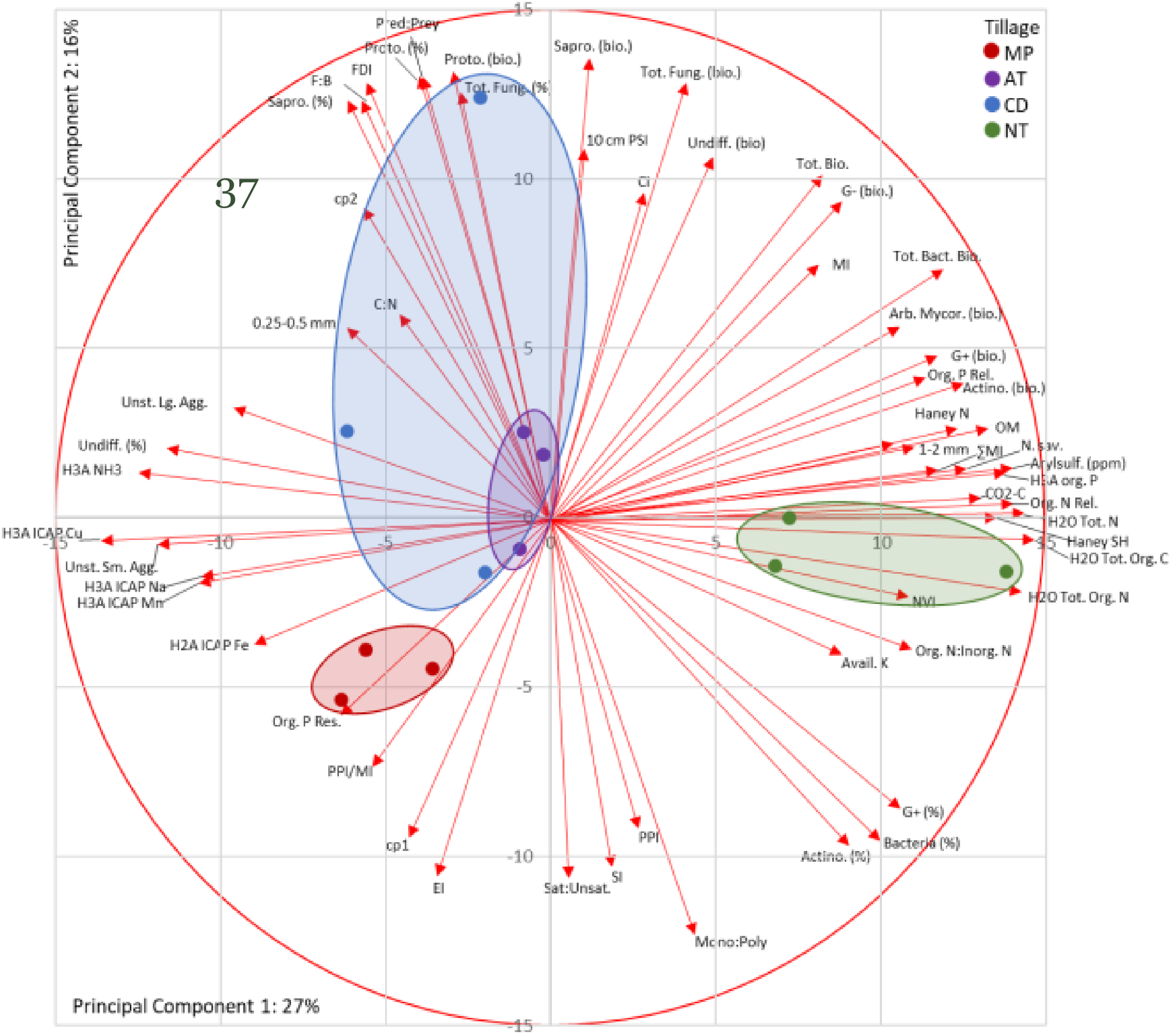
Indices	MP	AT	CD	NT	p-value	df	F-value	SE
MI	1.78	2.35	2.33	2.51	0.10	3	3.2	0.18
MI (2-5)	2.21	2.48	2.52	2.77	0.08	3	3.72	0.13
ΣMI	2.40 b	2.61 ab	2.56 ab	2.68 a	0.04	3	4.91	0.06
PPI	2.80	2.74	2.70	2.80	0.87	3	0.23	0.11
PPI/MI	1.66	1.19	1.17	1.12	0.20	3	1.92	0.18
EI	77.9	55.5	56.1	62.1	0.22	3	1.78	7.81
SI	86.8 a	74 b	77.1 ab	83.8 ab	0.03	3	4.48	2.77
CI	16.2	71.8	52.3	44.2	0.11	3	3.01	14.3

NT encouraged higher trophic level to flourish (high Maturity indices); indicating that despite fertilization, there was a stable soil system developed and a lack of short-term enrichment.

Additionally, frequency of tillage disturbance was irrelevant to nematode trophic level.

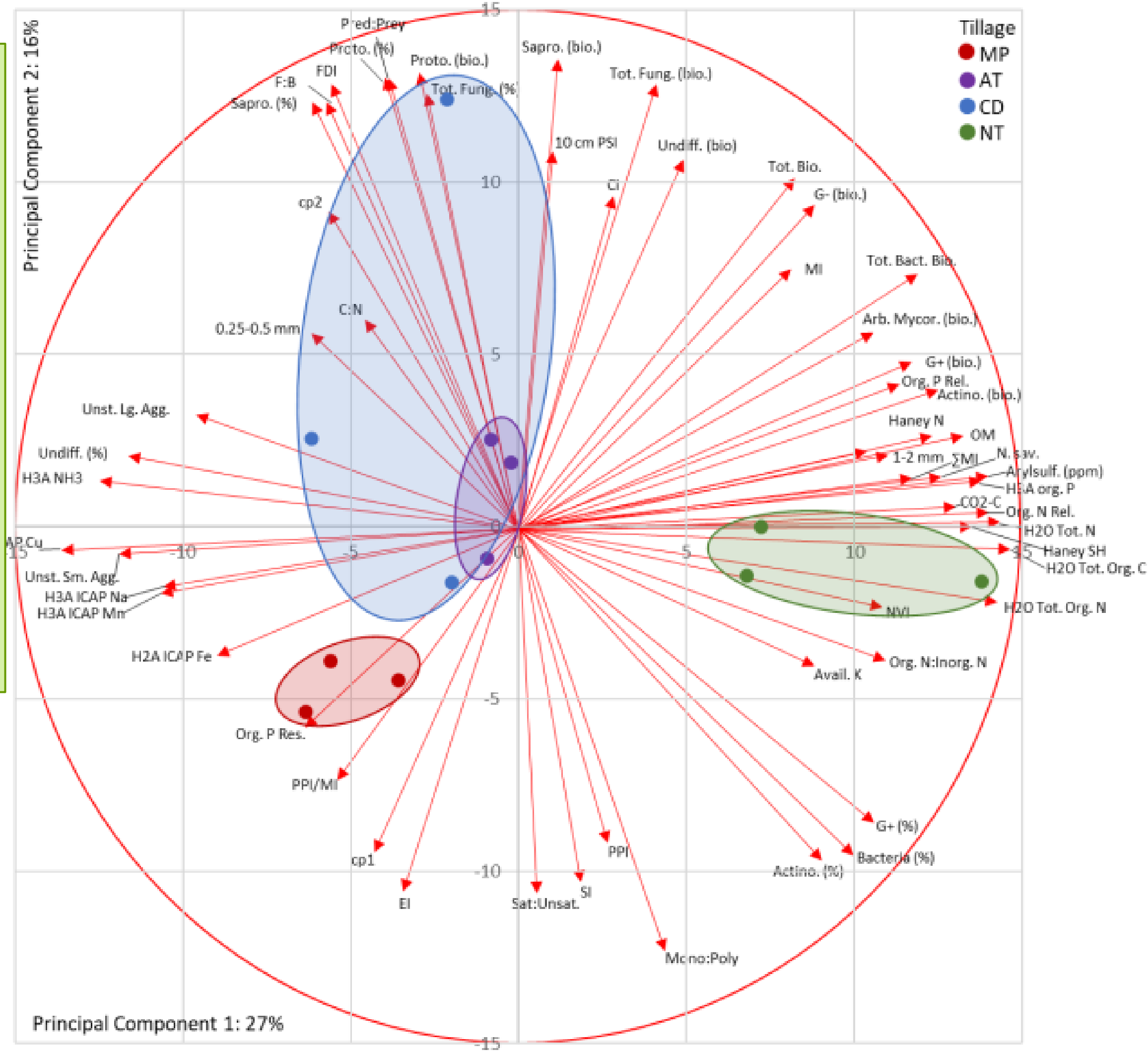
Rows are tillage averages of: **MI**-maturity index**; MI (2-5)**-maturity index 2-5**; ΣMI**-summed maturity index**; PPI**-plant parasitic index**; PPI/MI**-plant parasitic index to maturity index ratio**; EI**-enrichment index**; SI**-structure index**; CI**-channel index**.** Tillage methods include moldboard plow (MP); 2-yr no-till and 1 yr MP (AT); chisel-disk (CD); and no-till (NT). Different letters indicate significance at <0.1.

Soil nematode communities are represented in each point. Clusters are grouped by color.

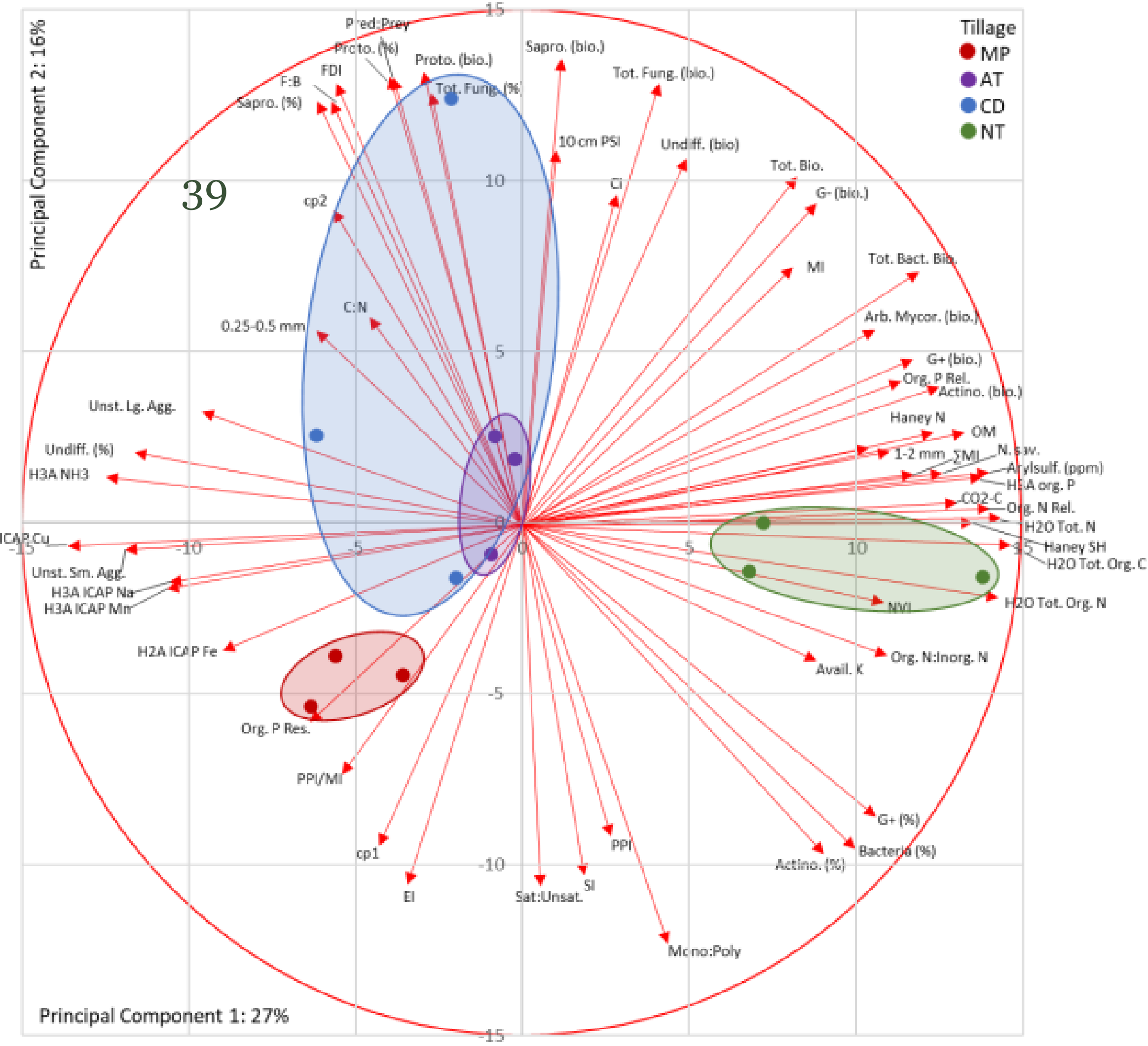


NT was positively associated with higher:

- Organic Matter
- Soil respiration
- Haney Soil Health test
- Water extracted org. C
- Soil N (N savings, organic N release, Haney N, Org:Inorg N, water extracted total N and organic N)
- P availability
- Aggregate sizes (1-2mm)
- Nematode Σmaturity Index (stable soil ecosystem)
- Arylsulfatase

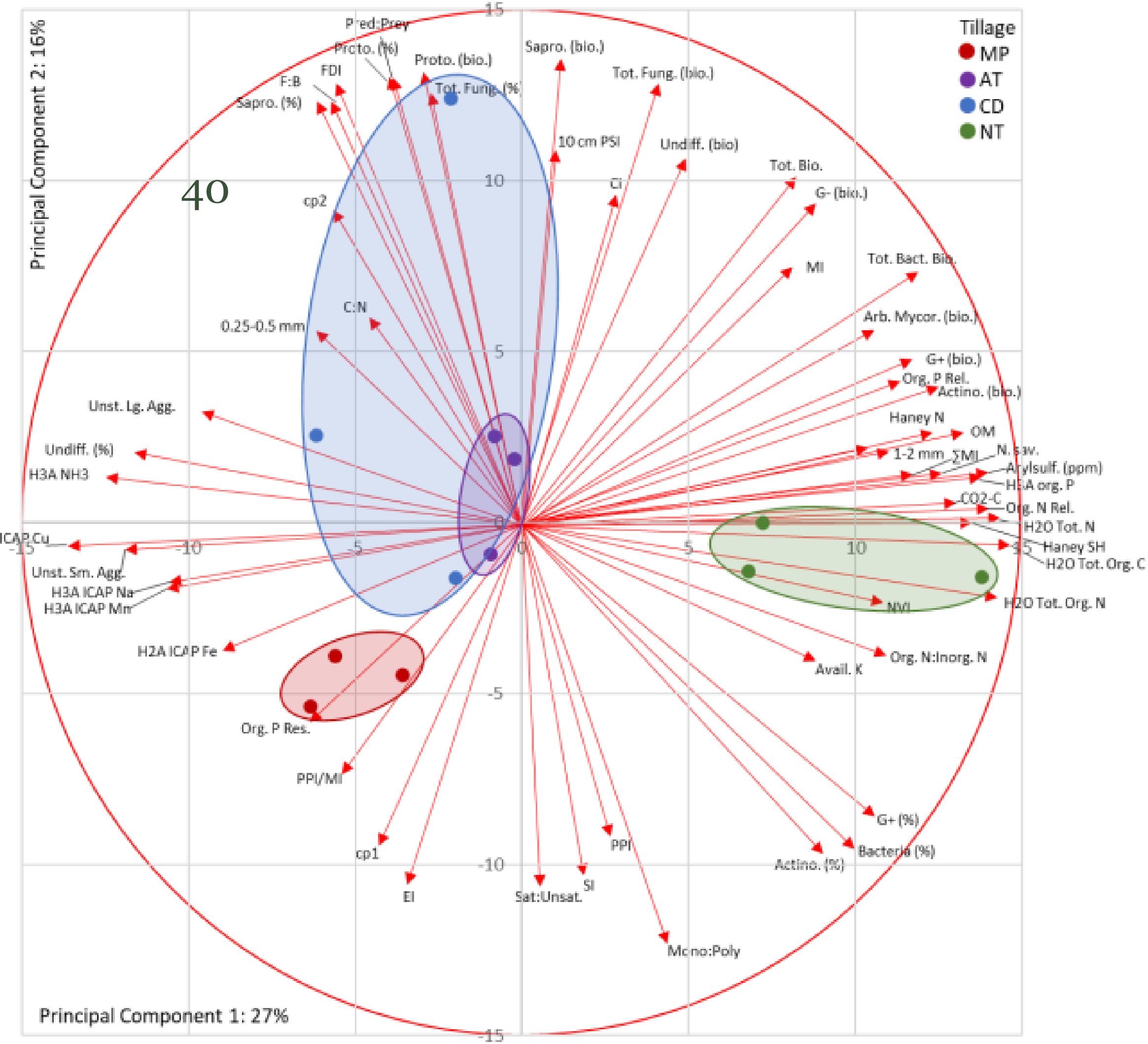


MP was located on the opposite end of PC1 compared to **NT**. It was more lightly associated with Organic P Residue, more Plant Parasitic nematodes, and **negatively associated with NT attributes.**



CD was more closely related to:

- Soil fungal populations
- Protozoa populations
- Fungal feeding nematodes (cp2)



2.c What changes in soil **biological** properties occur after 50 years?

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1. NT had developed the populations skewed towards higher nematode trophic levels.
2. NT and MP had developed separate nematode communities, including NT having a higher ΣMI, indicating a state of succession and stability of a soil system, measuring setbacks in succession by disturbance and the resulting enrichment effects, reflected in a lower MI.
3. Tillage effects outweighed seasonal effects on soil nematode community structure.
4. AT did not lose most biological benefits that it had built compared to NT (earthworms, nematode communities) unlike the physical benefits that were lost.

Summary

1. NT, at optimum fertility, is competitive to other tillage systems and could even increase soybean yields.
2. NT soil organic matter benefit is limited to 0-2” of soil depth. Integrated practices are needed to build soil organic matter beyond 0-2”.
3. NT over a long period improves soil structure and water holding capacity and offers protection for carbon within aggregates.
4. NT improves soil biological properties including earthworms and nematode community.

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Questions?

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GNC19-292

"What soil ecosystem services and economic benefits does 50 years of no-till provide in contrast to other tillage practices in Southern Illinois?"