Diverse Rotations and Crop Resilience – Soil Health at Work

Bill Deen

November 28, 2017

OMAFRA Soil Heath Research Forum

Guelph, Ontario

Putting Soil Health First

A Climate

Ontario

Towar

Production roundup

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Everybody's talking 'bout: soil health

Sustained yields under intensive farming may be masking some of the soil health issues.

Attend any agricultural conference these days and the odds are there will be a presentation about soil health, why it's important, and the various ways to achieve it. It's a term that has become part of farming's vocabulary very much like sustainability.

But, like sustainability, it can mean different things to different people. Everyone seems to have a different definition. So, how does a producer know he or she's on the right track? What are the indicators?

To borrow a line from the late John Lennon: "Everybody's talking 'bout aggregation, infiltration, respiration, sequestration. All I am saying is: how do I know?"

We put the question to some of those in the Ontario industry who are most involved in the day-to-day delivery of the soil health message. Here's what they had to say:

Kinburn-based independent CCA Paul Sullivan says his soil health awareness was triggered years ago by presentations at farm meetings: talks by researchers and extension staffers like Bill Deen, Adam Hayes, and Anne Verhallen about the benefits of rotation, cover crops, reduced tillage etc.

He now realizes he deals with soil health every day when assessing crops or taking soil samples. "I look at soil much differently than five years ago," he says. It's not just about the physical characteristics but the biological activity. "If the biology is active, then we will likely have better health."

It results in something that many refer to as "mellow" soils. But what does that really mean? "I have a hard time explaining it ... but, just like soil biology or soil health, as advisors we should try and do a better job explaining terms," Sullivan says.

Dale Cowan, senior agronomist with AGRIS and Wanstead Co-op, sits as the CCA rep on the Soil Health Working Group. That group has developed a definition that encompasses the physical, chemical, and biological factors that work together in a healthy soil to "support plant growth without becoming degraded or otherwise harming the environment."

But Cowan says there's more to it than merely defining soil health. It's about setting goals for your operation, defining the problems that are holding back productivity, and then deciding to make the investment and the necessary changes.

"Will I invest the time to identify one or two things I need to do?" he says. "Then gather the information, make a plan, determine the measurement metric, implement, evaluate, take responsibility for the plan and its outcome, modify and attempt to perfect it."

"Why would we think soil health would be, or should be, easy?"

STILL, FARMERS would like to measure the year-in, year-out progress they're making.

Bryan Cook, a CCA with Cropland Consulting, offers a simple checklist: "Healthy soil is a lot of visible worm middens, no ponding water after an inch of rain in October, no brown snow in the winter months, and no visible signs of erosion in spring."

"If growers can check off all the above, management is trending positive for soil management."

For Jerry Winnicki, a CCA with Clark Agriservice at Wellandport, there are clear signs:

> **"Give producers more credit. They know what is best for them, or they will not be producing long."**

• Walk over a field in the spring after a winter wheat or a forage crop was worked under as compared to one with a long-term soybean history. The difference is unbelievable – a sponge versus cement.

• Watch where the seagulls fly when two fields are being prepared for seeding side by side – one field from a dairy farm and the other from a long term soybean field. Simply amazing

• Watch the difference in crop growth as you cross an old headland, especially in a dry year. This effect can last for 15 years or more!

"I did a random sample of organic matter comparisons between fencerows and field conditions last fall and found that levels were 25 per cent lower in the field compared to the fencerow."

Those organic matter levels do tell a story, he says. "I have never discussed organic matter as much with growers as this year and the differences they saw with emergence, plant growth and final yields."

Sullivan looks at it in a similar way. For him, a productive soil is one that's "easy to probe, even if it is very wet. It doesn't smear and the soil core breaks apart quite well when mixed up. Water gets away and doesn't pond or stand in areas."

"It smells like soil should, not putrid like you get where there is residue not broken down."

"There will be signs of soil organisms like millipedes and particularly earthworms and earthworm middens. If we find part of a worm in the soil sample core, that's a great indicator."

Those are visual indicators but Sullivan also believes "it would be useful to work towards some fast, meaningful lab tests that would allow us to measure levels and then track them. We just need to know what the numbers will mean."

IF YOU want tests, take comfort in knowing that researchers are working on it. There's the "Cornell Test" that's also being evaluated by OMAFRA and the University of Guelph. The problem is that it continues to adapt as our understanding grows, says OMAFRA soil management specialist Anne Verhallen.

Independent CCA Peter Johnson mentions the Haney test, which gives a visual indication of soil respiration, which should be correlated to biological activity. But, he adds, "what that means is still unknown."

There are tests you can do for aggregation and infiltration; many of them have been around for years. They can be found on the OMAFRA website or the Agronomy Handbook. Verhallen says. More detailed tests can be found on the USDA's Soil Health Test website.

But, perhaps the best clues can be found in the long-term rotation and tillage trials being done by University of Guelph's Dr. Bill Deen and Dave Hooker. "You can pretty much predict soil health based on rotation, followed by organic additions (maybe), then tillage, and then other factors," Johnson says.

If you want proof, leave a zero nitrogen strip and see how it performs in a "healthy" versus an abused field, Verhallen says, adding that, in Dr. Hooker's trials, the zero-N strips "shone where soil health is better."

A diverse rotation and the use of cover crops and underseedings are seen as beneficial to soil health.

On the other hand, soil health improvements don't always show up in the weigh wagon. Johnson offers the example of his own farm - a strict three-crop rotation, with red clover, and in no-till since 1988. That should qualify as "healthy" under most definitions, he says.

But this is where it becomes perplexing. "I have worked for most of my farming career to achieve this "healthier" soil," Johnson says, suggesting that these efforts should have paid off in terms of yield in a stress year like 2016. "I should win, right? Are my corn yields higher? No! In fact, I'm pretty sure that some of my high-input, intensive neighbours outyielded me."

"So what am I missing in this picture? Why hasn't my better management, better soil health made me king of the yield hill?"

There are other realities, he suggests. Soil type, resistant weeds blowing in on the wind. The bottom line, Johnson says, "don't lose any sleep over soil health tests. Get an aerial picture of the growing crop. Look at the colour of the soil, especially if fall tillage is done. Take a bottle of vinegar to the knolls and see if it fizzes when you pour some on the soil to show that high pH subsoil is at the surface. Look for middens."

"I think we get lost trying to measure something that is nearly impossible to measure and miss the simple visual clues."

THEN THERE'S the challenge of taking a long term view in an industry that often with the current year in mind. "They don't want to lose money."

Whattam takes a different view. "I don't think it is the right way to farm to just grow beans after beans to claim you made the most per acre at the coffee shop. I think soil health will suffer for it and the chickens will come home to roost, whether they deal with it or pass it on to the next renter/owner to deal with."

"It's not all about yield," Verhallen concurs, citing savings in nitrogen and other inputs in a healthy soil. "It's the long game. It's about being good stewards and leaving a legacy."

MacEwen AgriCentre CCA Clare Kinlin disagrees. "I personally struggle with losing significant money for today to benefit tomorrow."

"If I went to the bank and told them I could not pay my mortgage this month because I am investing it for my retirement, I am fairly confident I would need a new place to live."

"Give producers more credit. They know what is best for them, or they will not be producing long."

SO, MAYBE in this quest for soil health we're losing sight of what's really important? Production is what drives producers to embrace soil health, says Kinlin. "We continue to try and make the poor soils better but economics drive it."

Independent CCA Pat Lynch makes a similar point. When you consider that a "healthy" soil may still be challenged by white mould or resistant weeds, you have to accept the fact that "a healthy soil may not be a profitable soil. And ultimately that is what it is about. We must be able to grow crops profitably."

"We have too many chasing the "healthy soil" concept and ignoring some of the basics of crop production," Lynch adds.

"I am afraid that meetings this winter will spend a lot of time talking about soil health

> **"We have too many chasing the "healthy soil" concept and ignoring some of the basics of crop production."**

and miss the opportunity to learn about soil fertility, why you have to use 20 gallons of water when post spraying, how to get a good seedbed, why and how to plant early, and when to spray weeds."

"Soil health is a bit like beauty. It is in the eye of the beholder."

Even a diehard soil health supporter like Verhallen admits she "can't totally argue with Pat."

She concedes that modern hybrids, with their greater stress tolerance, and intensive management, have been able to mask soil issues.

On the other hand, she adds that "soil health does pay; it really does."

There are savings. Brown reminds us that a soil with good microbial diversity and organic matter may be able "to protect the crop from diseases and may not need a fungicide and it may have improved infiltration and water-holding capacity *so that tiles won't need to be split to improve drainage or irrigation won't be considered as one of the next technologies.*"

Analyzing these contributions from an economic perspective isn't easy, but these efforts are underway. Brown mentions a recently harvested side-by-side replicated comparison of cover crop cum after wheat, with and without organic amendments.

That site averaged 1.5 dry tons more (almost double) than cum with no amendments, she says.

"And when forage quality was evaluated using today's milk value, the feed value was more than double for the cover crop oats with amendments ... over $2,000/acre for oats with amendment."

"Impressive, but one site - one year."

But, as Whattam points out, there are also costs, like changing from one tillage system to another. It raises a host of questions. For one thing, she says, there may be short term losses due to the learning curve.

"How many years should a major system change be in place before you decide it is working or not? How many years do you use a new piece of tillage or planting equipment before you decide if it was the right investment? Can you cause more harm than good by changing systems too often?"

"I have more questions than answers sometimes."

IT'S A clash of priorities that can baffle even the most experienced agronomist. Some, like Maizex Seeds lead agronomist Greg Stewart, take a philosophical approach.

"I had a phase in life were it was all about soil compaction never more than 15 psi, then a phase were it was all about aggregate stability and then a phase where it was all about 30 per cent residue cover. Now it seems to me that genetic gains are going up faster than soil health is going down, so I have mostly stopped worrying."

St. Marys-area CCA and Dupont Pioneer seed dealer Russ Barker does worry and think about the ramifications of continuing society on a production-oriented path.

"I may not be right ... don't exactly what soil health is the full be, but I can sure tell you what it is not. It is not fundamentally that for the last 25 years, farm had a history of 50 per cent or more soybeans grown in the rotation."

"I'll bet these same farms have been profitable for the owners. Who am I to say that this is wrong?"

"But when I walk on these soils in the spring I get an uneasy feeling. They are hard and crunchy compared to farms with a more diversified rotation, which are softer and mellower."

"We can make a seedbed in these parts out of hard and crunchy. It takes more time and tool to do it and it is dry."

"At the end of the day, the seed and brain force is the part that bothers me. It makes me the wrong thing to do. Soils are chock full of living beings. It is right to use brute force to mold them into a definition that is based on economics alone? Some would argue yes."

"I can respect that opinion. I just don't agree with it."

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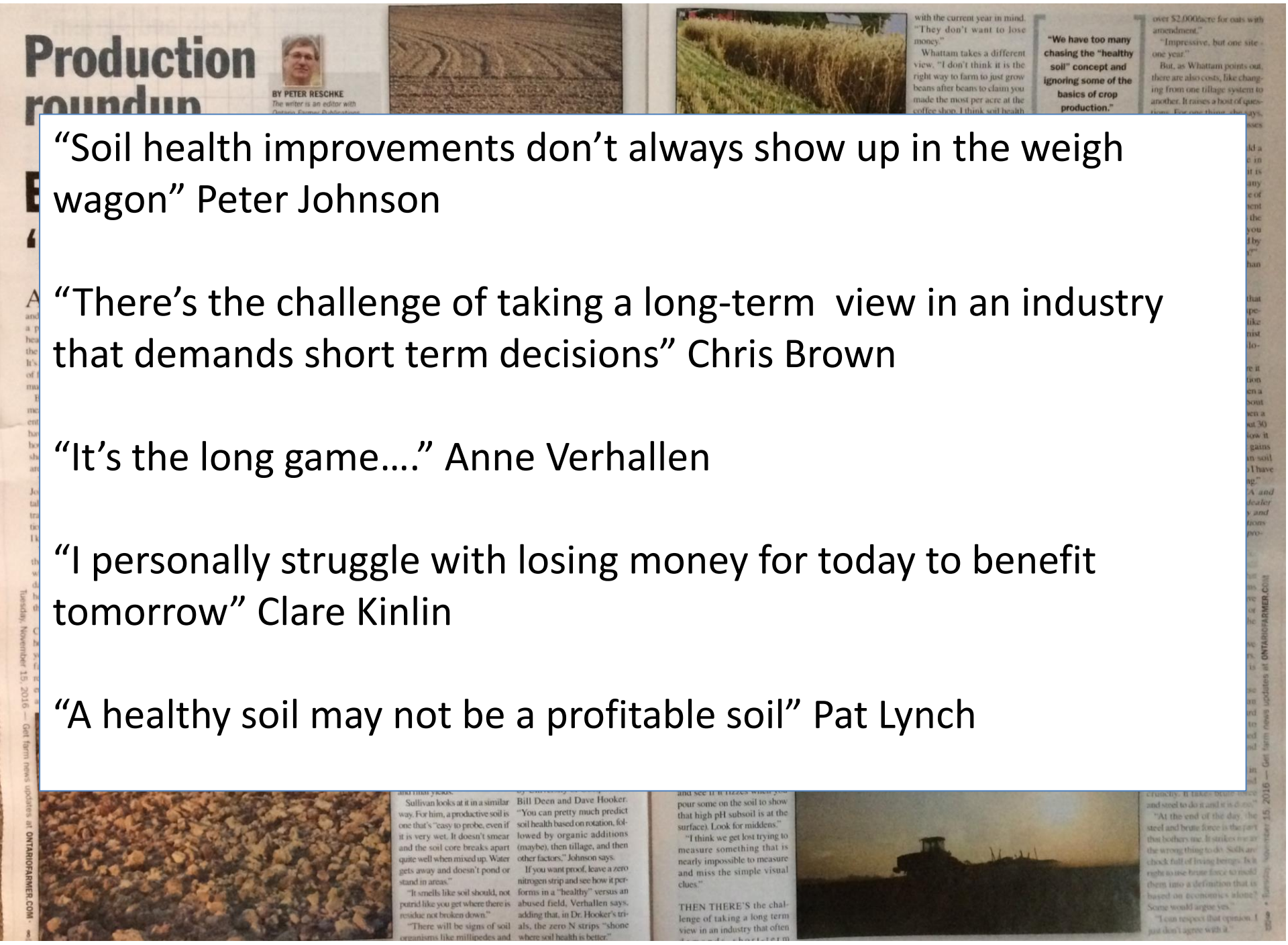
2016

Ontario



"Soil health improvements don't always show up in the weigh wagon" Peter Johnson

"There's the challenge of taking a long-term view in an industry that demands short term decisions" Chris Brown

"It's the long game…." Anne Verhallen

"I personally struggle with losing money for today to benefit tomorrow" Clare Kinlin

"A healthy soil may not be a profitable soil" Pat Lynch

Production/profit of soil health BMPs

Tillage system: frequent intensive ⟷ no-till

Rotation: simple ⟷ complex

Cover crops: no cover ⟷ single species ⟷ complex mixes

Inputs: intensive use of synthetic inputs ⟷ organic

Amendments: residue removal ⟷ manure/compost addition

Soil compaction avoidance: none ⟷ extensive

Impact of BMPs on soil health

Tillage system: frequent intensive → no-till

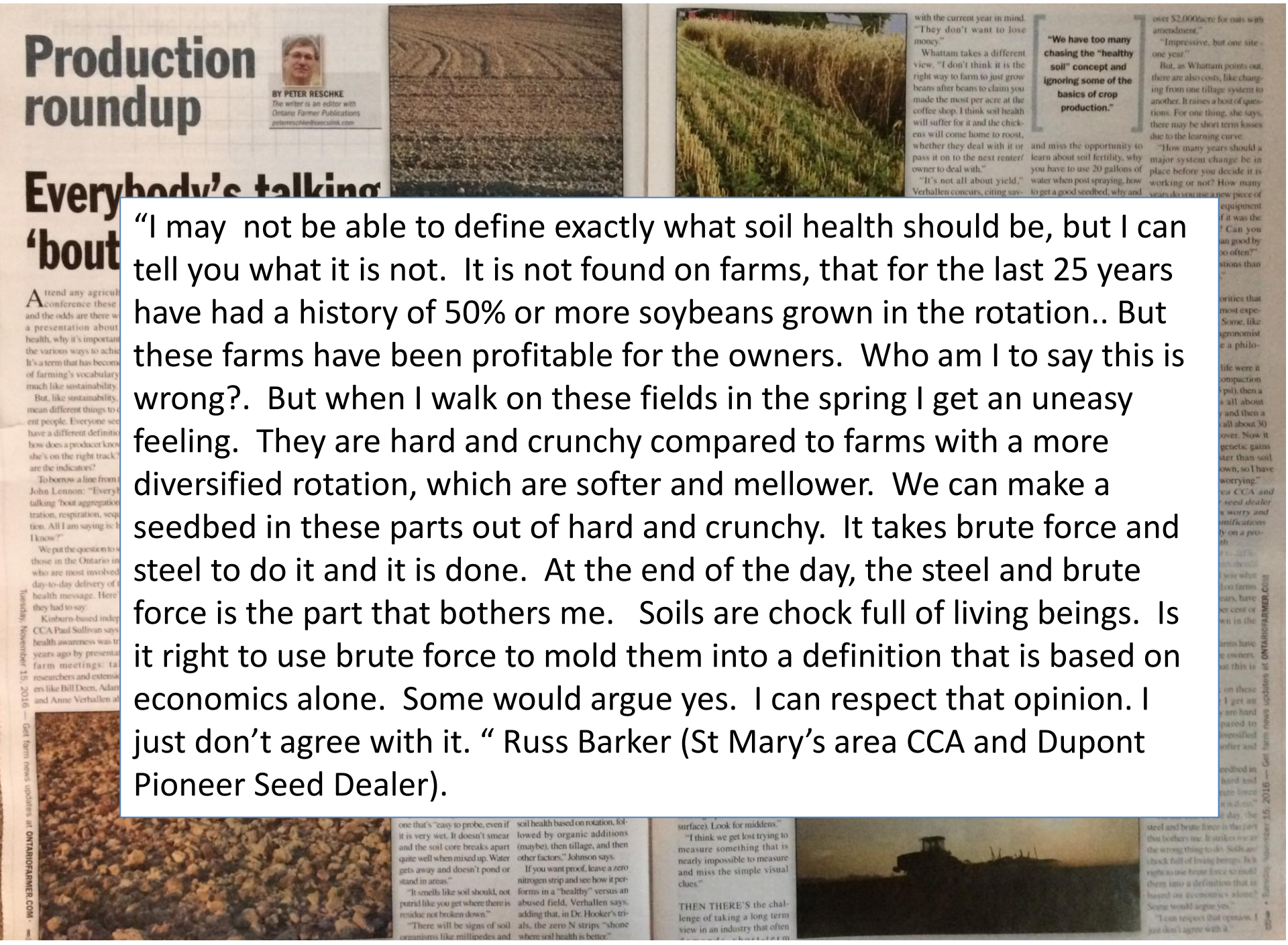
Rotation: simple → complex
- → Enables reduced/no-till
- → Provides cover crop niche
- → Reduces residue removal impact
- → Reduces risk of compaction
- → Reduces input use

Cover crops: no cover → single species → complex mixes

Inputs: intensive use of synthetic inputs → X organic

Amendments: residue removal … → manure/compost addition

Soil compaction avoidance: none → extensive



Production roundup

BY PETER RESCHKE
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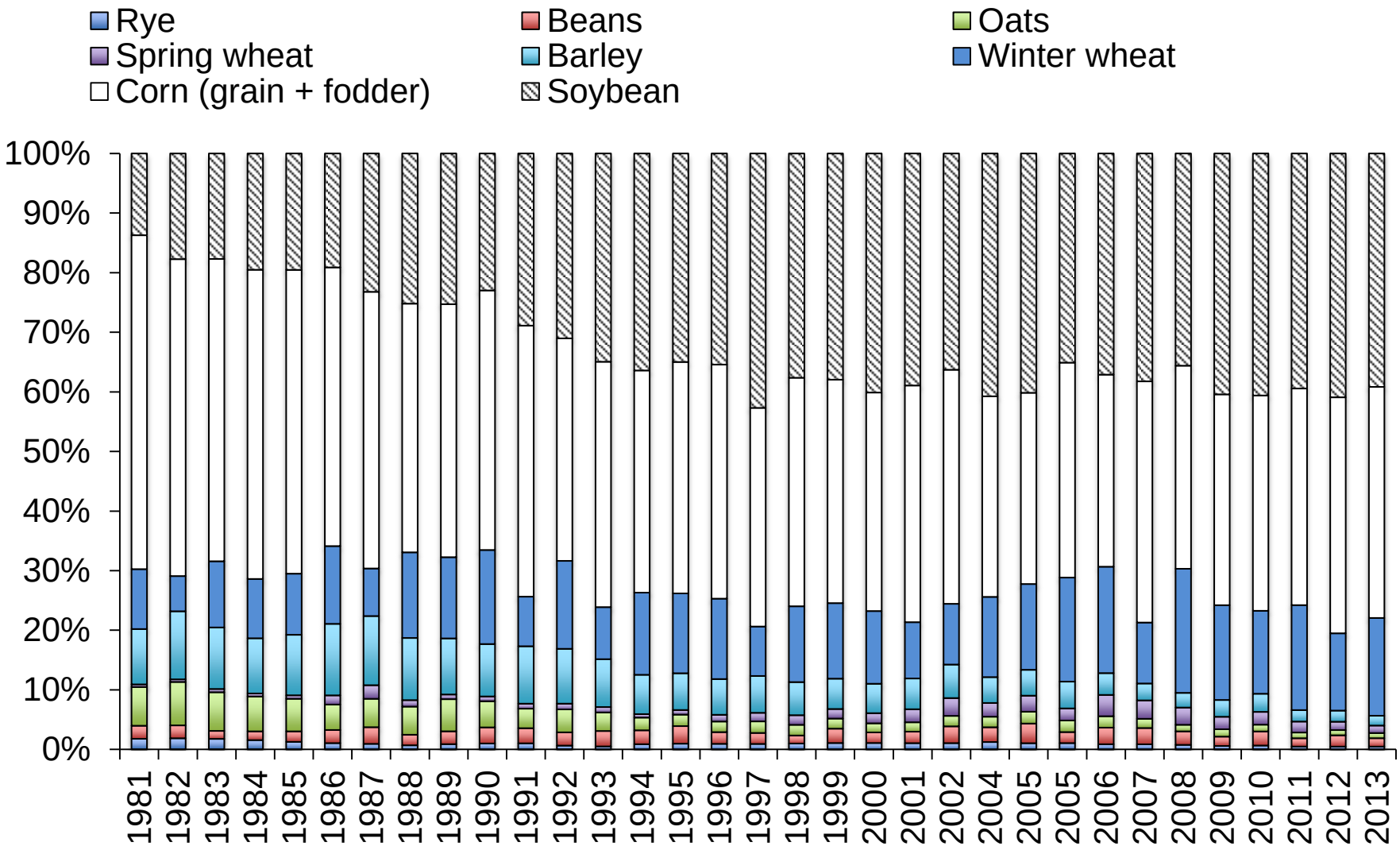
Everybody's talking 'bout

"We have too many chasing the "healthy soil" concept and ignoring some of the basics of crop production."

"I may not be able to define exactly what soil health should be, but I can tell you what it is not. It is not found on farms, that for the last 25 years have had a history of 50% or more soybeans grown in the rotation.. But these farms have been profitable for the owners. Who am I to say this is wrong?. But when I walk on these fields in the spring I get an uneasy feeling. They are hard and crunchy compared to farms with a more diversified rotation, which are softer and mellower. We can make a seedbed in these parts out of hard and crunchy. It takes brute force and steel to do it and it is done. At the end of the day, the steel and brute force is the part that bothers me. Soils are chock full of living beings. Is it right to use brute force to mold them into a definition that is based on economics alone. Some would argue yes. I can respect that opinion. I just don't agree with it. " Russ Barker (St Mary's area CCA and Dupont Pioneer Seed Dealer).

% harvested area, Ontario, 1981-2013

(Ontario Ministry of Agriculture, Food and Rural Affairs, Field statistics 2014)



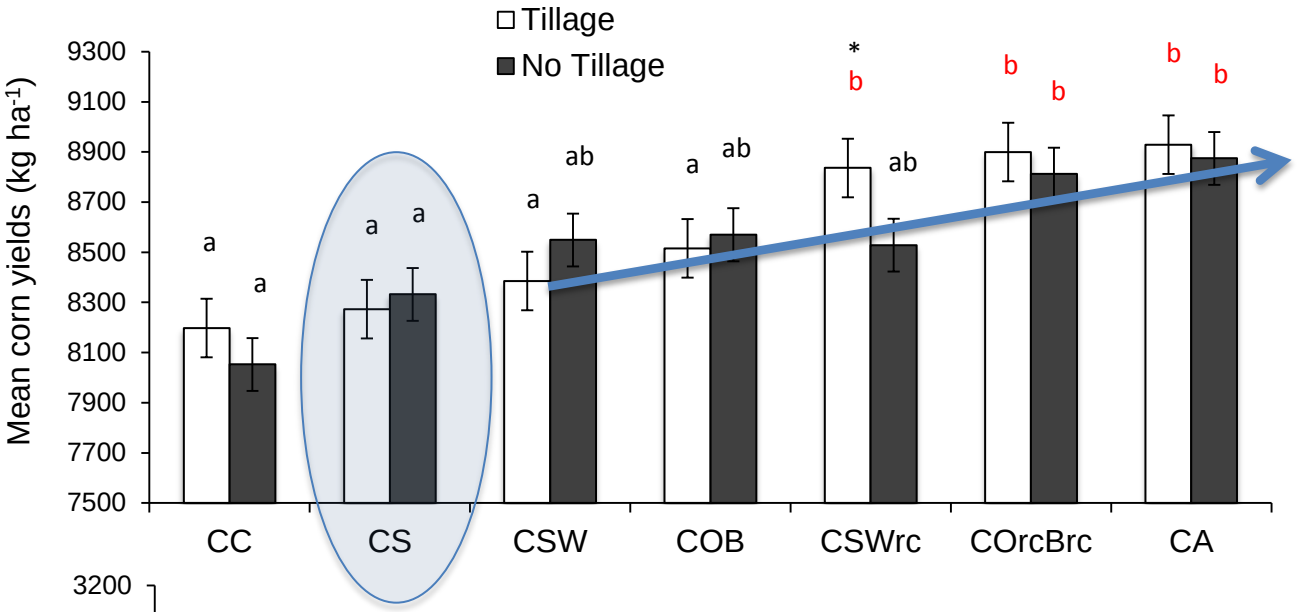
Gaudin A *et al.*, PLOS one (2014) DOI 10.1371/journal.pone.0113261

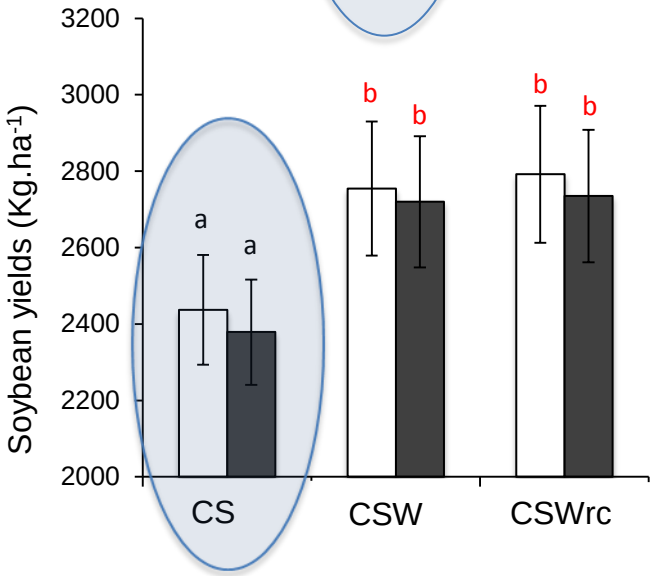
Corn/soybean rotation is associated with

- Reduced yield and greater yield instability
- Lowest soil organic matter/poorest soil structure
- Increased nitrogen requirement
- Reduced input use efficiency
- Increased GHG emission
- Reduced success of no-till/reduced till
- Reduced opportunity to incorporate cover crops
- Reduced opportunity for sustainable biomass removal

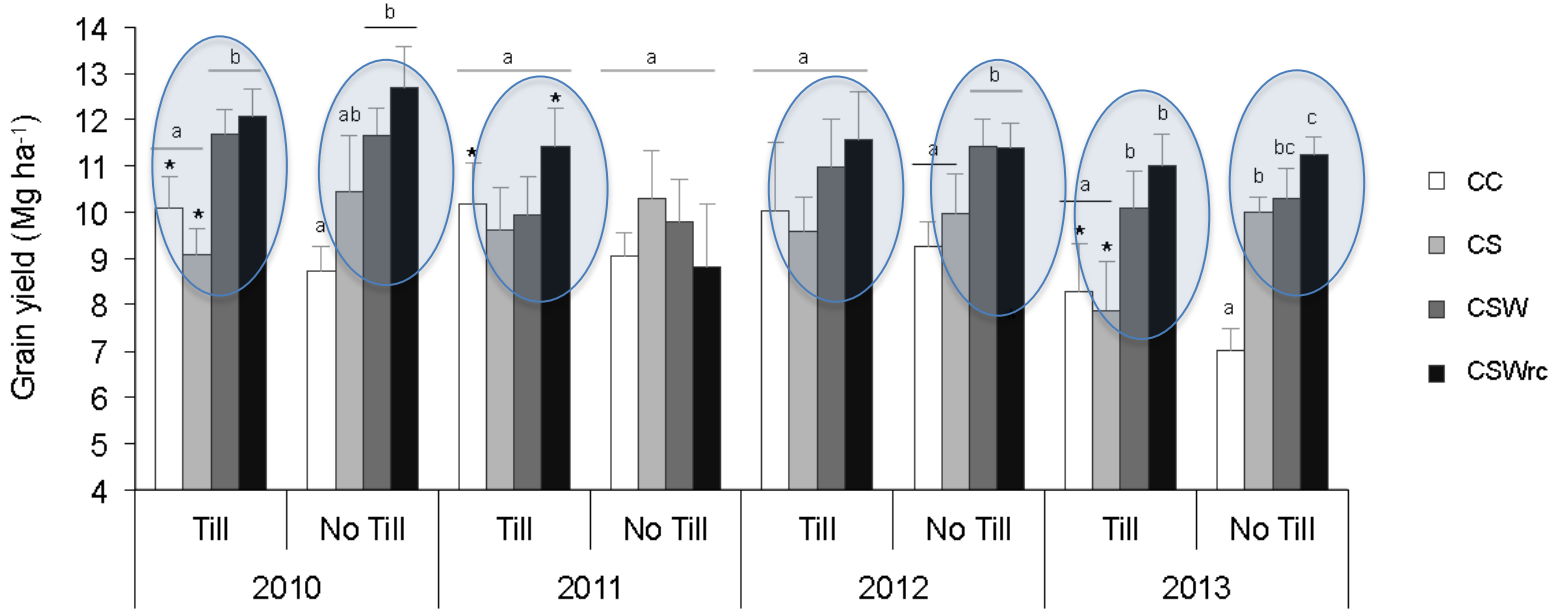
Meyer-Aurich et al, 2006a; Meyer-Aurich et al 2006b; Sanscartier et al, 2013; Munkholm et al, 2012; Munkholm et al, 2013; Muellera et al, 2009; Gaudin et al, 2013; Gaudin et al. 2014; Gaudin et al. 2015, Kludze et al. 2013.; Van Eerd et al.. 2014

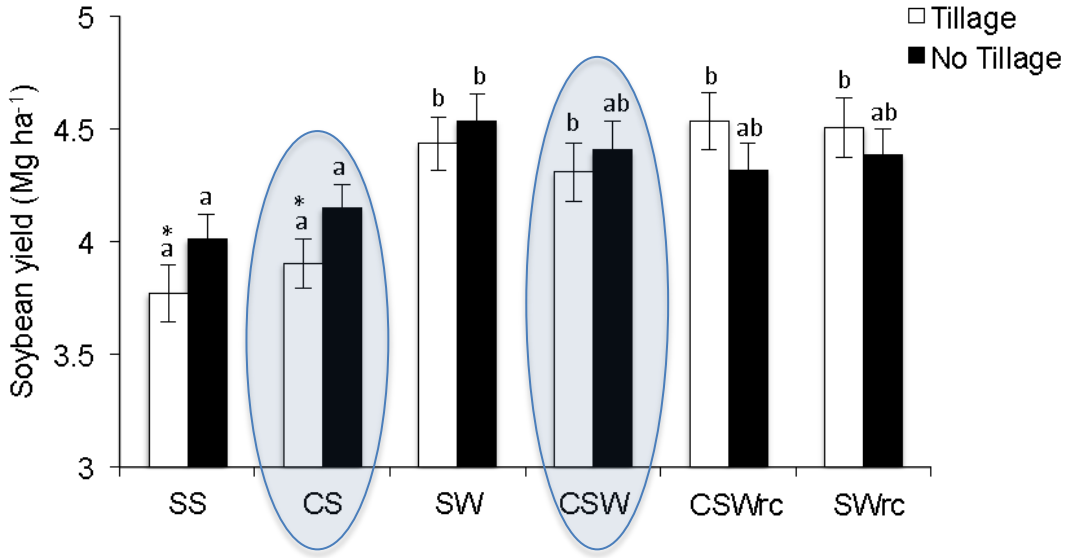
Rotation complexity effect on corn and soybean yield: Elora 1982-2012





Rotation complexity effect on corn and soybean yield: Ridgetown 2010-2013





Gaudin A *et al.*, Agriculture, Ecosystem and Environment (2015), 210:1-10

PLOS ONE

RESEARCH ARTICLE

Increasing Crop Diversity Mitigates Weather Variations and Improves Yield Stability

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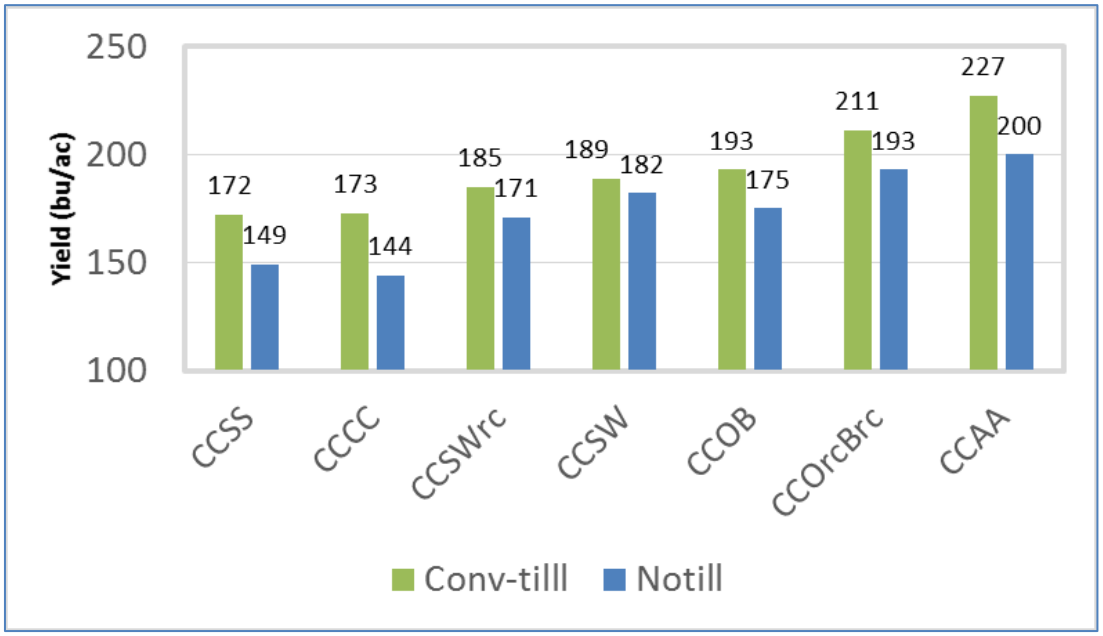
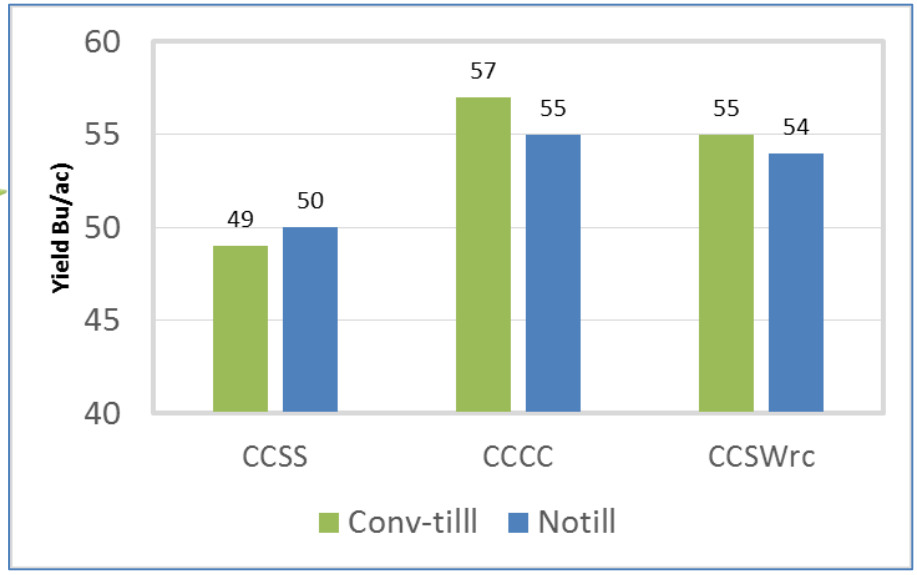
Cropping sequence diversification provides a systems approach to reduce yield variations and improve resilience to multiple environmental stresses. Yield advantages of more diverse crop rotations and their synergistic effects with reduced tillage are well documented, but few studies have quantified the impact of these management practices on yields and their stability when soil moisture is limiting or in excess. Using yield and weather data obtained from a 31-year long term rotation and tillage trial in Ontario, we tested whether crop rotation diversity is associated with greater yield stability when abnormal weather conditions occur. We used parametric and non-parametric approaches to quantify the impact of rotation diversity (monocrop, 2-crops, 3- crops without or with one or two legume cover crops) and tillage (conventional or reduced till- age) on yield probabilities and the benefits of crop diversity under different soil moisture and temperature scenarios. Although the magnitude of rotation benefits varied with crops, weather patterns and tillage, **yield stability significantly increased when corn and soybean were integrated into more diverse rotations**. Introducing small grains into short corn-soybean rotation was enough to provide substantial benefits on long-term soybean yields and their stability while the effects on corn were mostly associated with the temporal niche provided by small grains for underseeded red clover or alfalfa. **Crop diversification strategies increased the probability of harnessing favorable growing conditions while decreasing the risk of crop failure. In hot and dry years, diversification of corn-soybean rotations and reduced tillage increased yield by7%and 22%for corn and soybean respectively.** Given the additional advantages associated with cropping system diversification, such a strategy provides a more comprehensive approach to lowering yield variability and improving the resilience of cropping systems to multiple environmental stresses.

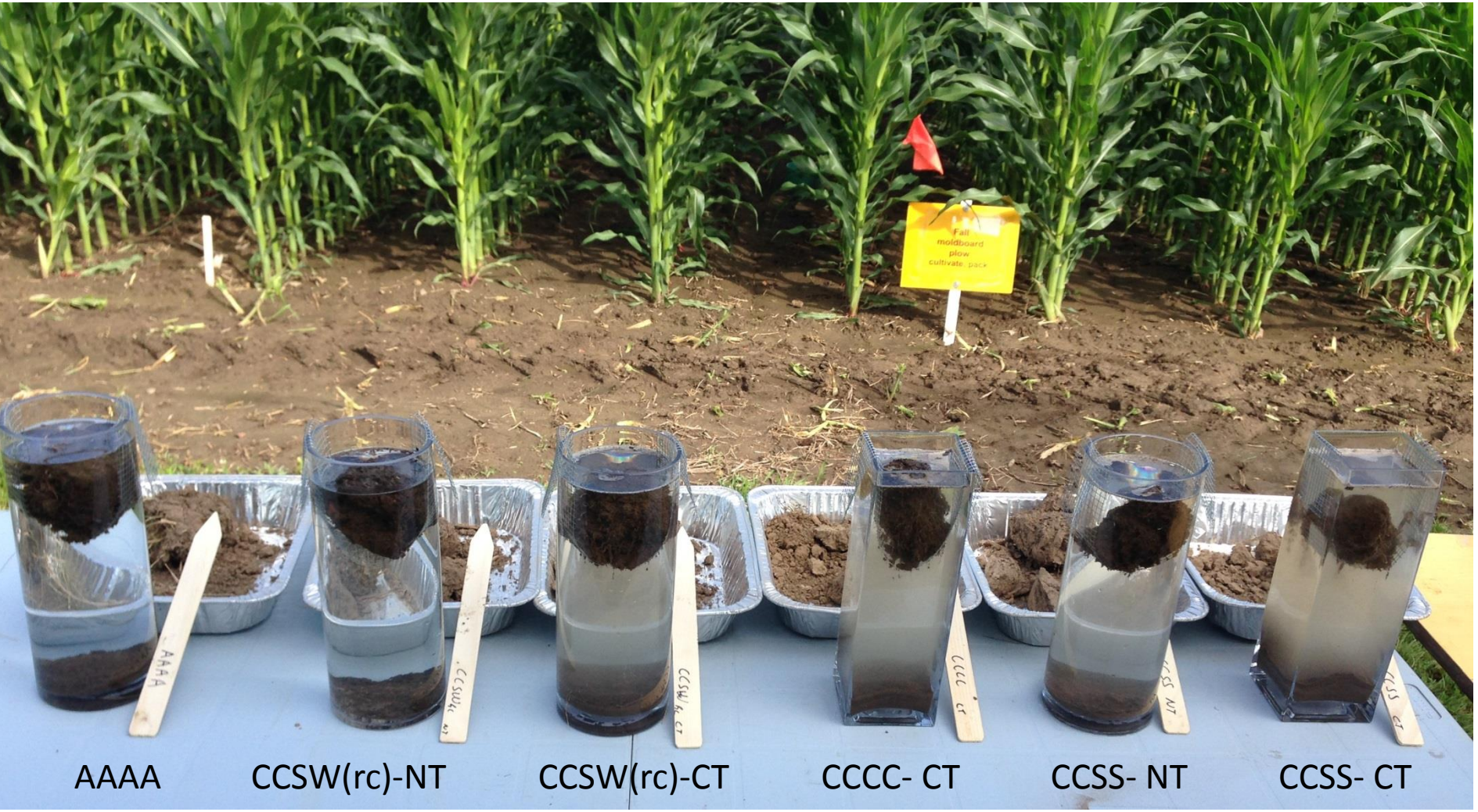
Corn and soybean yield: Elora rotation trial, 2016





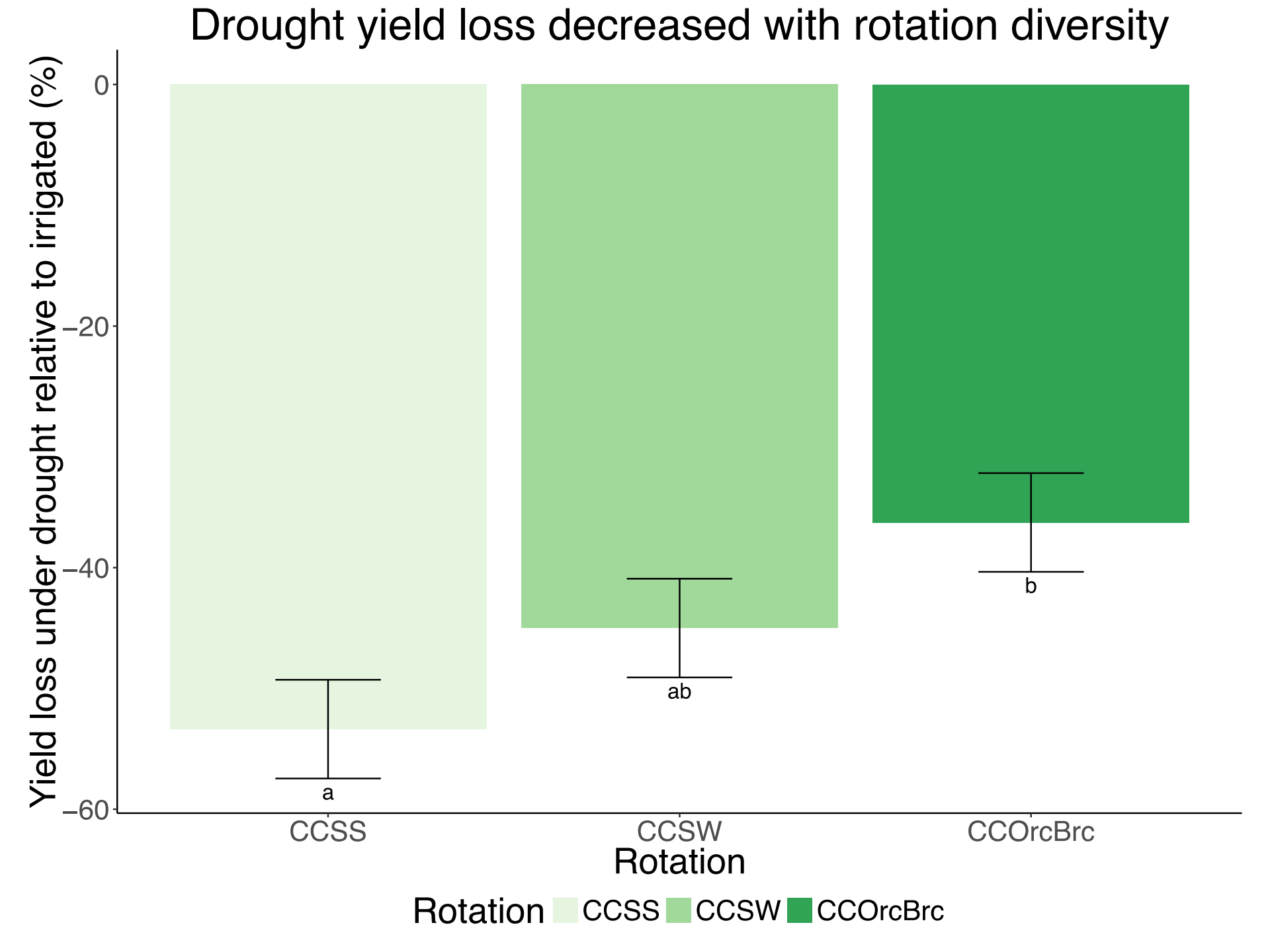
2016 precipitation

May - 42 mm
June – 36 mm
July 1-13 – 11mm
July 14-24 – 23mm
July 25-31 – 37 mm
August - 146mm
Sept – 64 mm


Fall
moldboard
plow
cultivate, pack
AAAA
CCSW(rc)-NT
CCSW(rc)-CT
CCCC- CT
CCSS- NT
CCSS- CT

Elora Long-term Rotation
Drought Resilience trial - 2016

- 3 rotations selected
  Corn – Corn – Soy - Soy
  Corn – Corn – Soy - Wheat
  Corn – Corn - Oats(red clover) –Barley(red clover)
- Tillage
  Till (moldboard), no-till (conservation tillage 1980-2002, no-till 2002-present)
- Water treatments (Summer 2016)
  Simulated drought, ambient rainfall (control), irrigated (control)
- Objectives: Quantify rotation interaction with moisture and study the mechanisms underlying drought resilience


Drought yield loss decreased with rotation diversity
Yield loss under drought relative to irrigated (%)
0
−20
−40
−60
a
ab
b
CCSS
CCSW
CCOrcBrc
Rotation
Rotation
CCSS
CCSW
CCOrcBrc

Economic Justification for Wheat in Rotation

- 4 %increase in corn yield: 7 bu/ac @ $4.50/bu = $32/ac
- 12 % increase in soy yield: 5.5 bu/ac @ $12.50/bu = $69/ac
- Increased drought tolerance/yield stability = ??
- Reduction in N requirement: 26.4 lb/ac @$0.55/lb = $14/ac
- Cover crop N (eg red clover): 50 lb/ac @$0.55/lb = $27/ac
- Reduced tillage requirement = ??
- Ability to sustainably sell crop residue = ??
- Other eg. herbicide resistance management = ??
- **Added profit attributed to wheat** **>$143/ac**

- Wheat straw sale (1.2 t/ac net value in winrow $.03/lb) $79/ac
- Double crop forage (2-3 t/ac net value in winrow $??/lb) ??

Benefit of BMP's for production/profit

Tillage system: frequent intensive ⟷ no-till

Rotation: simple ⟷ complex

Cover crops: no cover ⟷ single species ⟷ complex mixes

Inputs: intensive use of synthetic inputs ⟷ organic

Amendments: residue removal ⟷ manure/compost addition

Soil compaction avoidance: none ⟷ extensive

Benefit of BMP's for soil health in a **corn/soybean** system

Tillage system: frequent intensive → no-till

Rotation: simple → complex
- → Enables reduced/no-till
- → Provides cover crop niche
- → Reduces residue removal impact
- → Reduces risk of compaction
- → Reduces input use

Cover crops: no cover → single species → complex mixes

Inputs: intensive use of synthetic inputs → X

Amendments: Residue removal ... → manure/compost addition

Soil compaction avoidance: none → extensive

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