The Prairie Soil Carbon Balance Project at 21: Key Learnings

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with SSCA

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Learnings

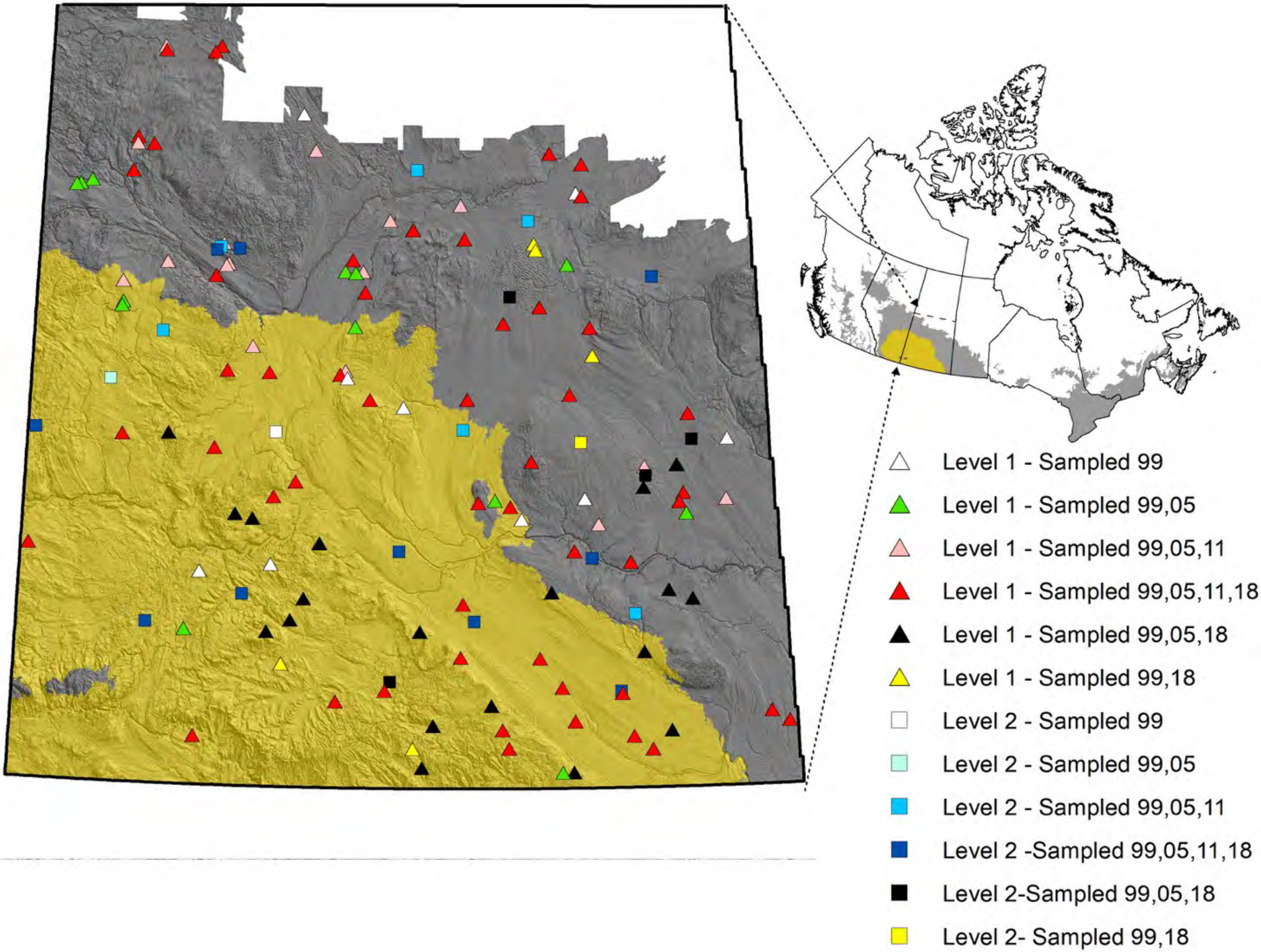
1. Soil organic carbon (SOC) increases with conservation cropping (direct seeding, crop diversity, and little fallow)
2. SOC increased most for soil with low initial SOC
3. SOC is variable in space and time
4. Soil organic carbon is sequestered in relatively stable forms in a healthier soil
5. Measurements are needed
6. Measurement based offset protocols need careful consideration

Prairie Soil Carbon Balance Project – Build Knowledge about SOC change on farmland

- Measure SOC change on network of fields converted to low disturbance direct seeding in 1997 throughout the Province of Saskatchewan
  - Measure in fall 1996 (139 fields), fall 1999 (137 fields), fall 2005 (121 fields), fall 2011(83 fields), spring 2018 (90 fields) on benchmark microsites
  - Number of fields in network decreased over time due to cooperator withdrawal and/or fundamental change in management (e.g. grass pasture)
- Collaborative project between
  - SSCA and Agriculture and Agri-Food Canada (AAFC) continually
  - GEMCO (GHG industrial emitters) and AAFC funding for 1996 & 99 samplings
  - AAFC funding for 2005 sampling
  - AAFC and Saskatchewan Pulse Growers resources for 2011 sampling
  - AAFC, University of Saskatchewan, SSCA, Saskatchewan Agricultural Development Fund, Checkoff-funded commodity groups for 2018

Prairie Soil Carbon Balance Project Objectives

- Can we determine SOC change for land that underwent conversion to direct seeding in 1997?
  - SOC change for individual fields?
  - SOC change for groupings of fields? What are differences between groupings?
  - How deep do we need to sample?
  - Do results from small research plots match what occurs on commercial farm fields?


Level 1 - Sampled 99
Level 1 - Sampled 99,05
Level 1 - Sampled 99,05,11
Level 1 - Sampled 99,05,11,18
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Level 2 - Sampled 99
Level 2 - Sampled 99,05
Level 2 - Sampled 99,05,11
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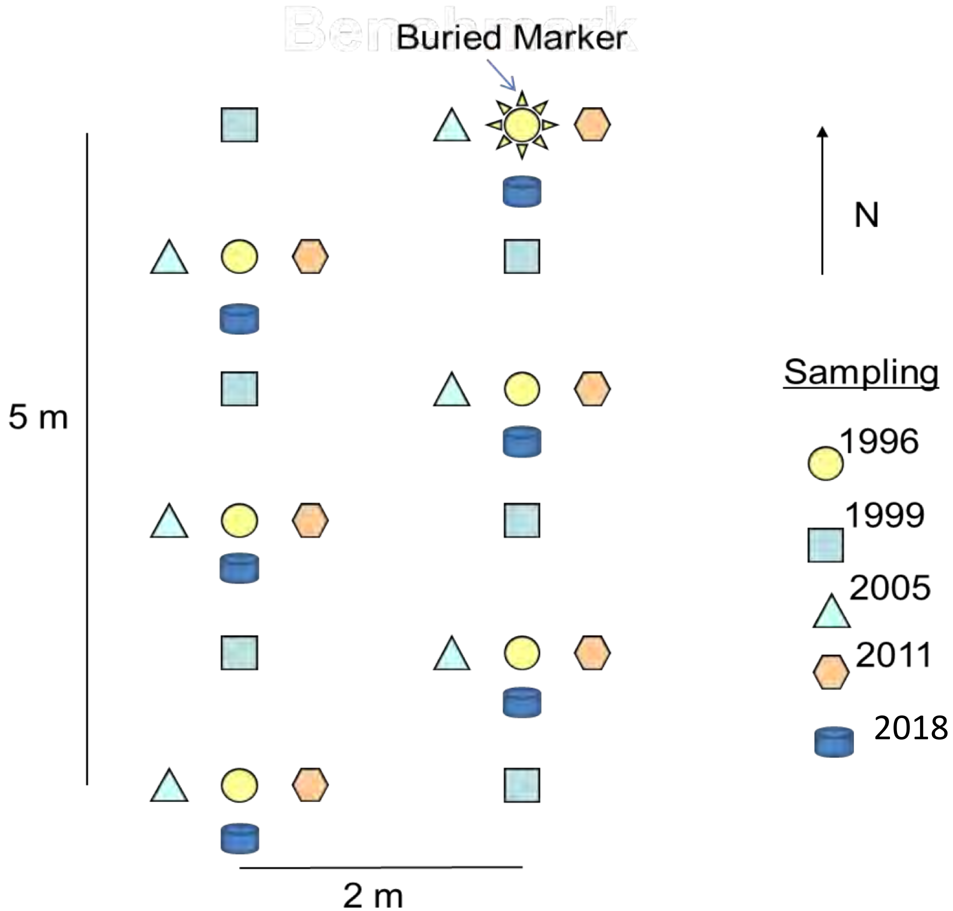
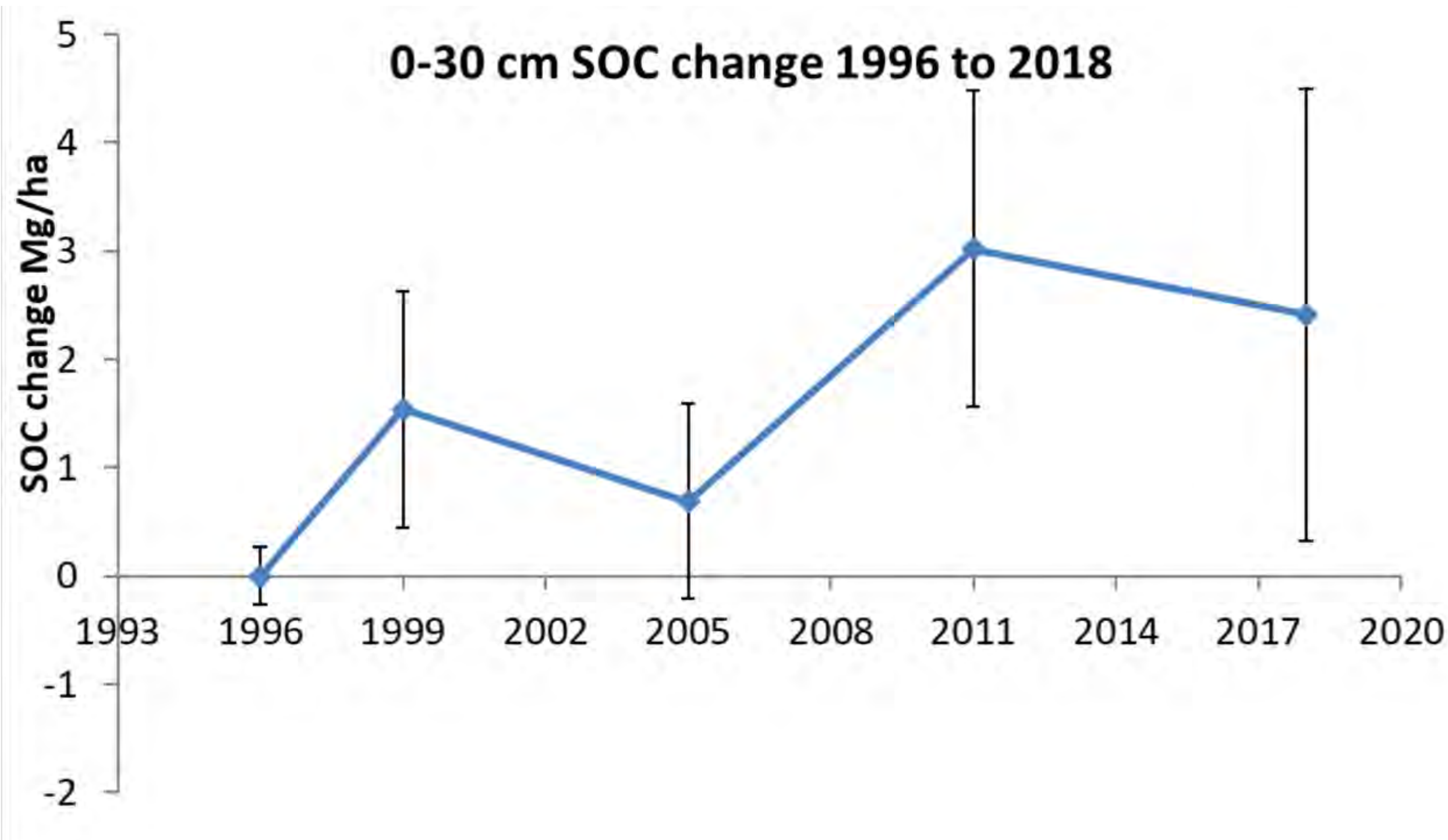
Level 2-Sampled 99,05,18
Level 2- Sampled 99,18

Benchmark Microsite

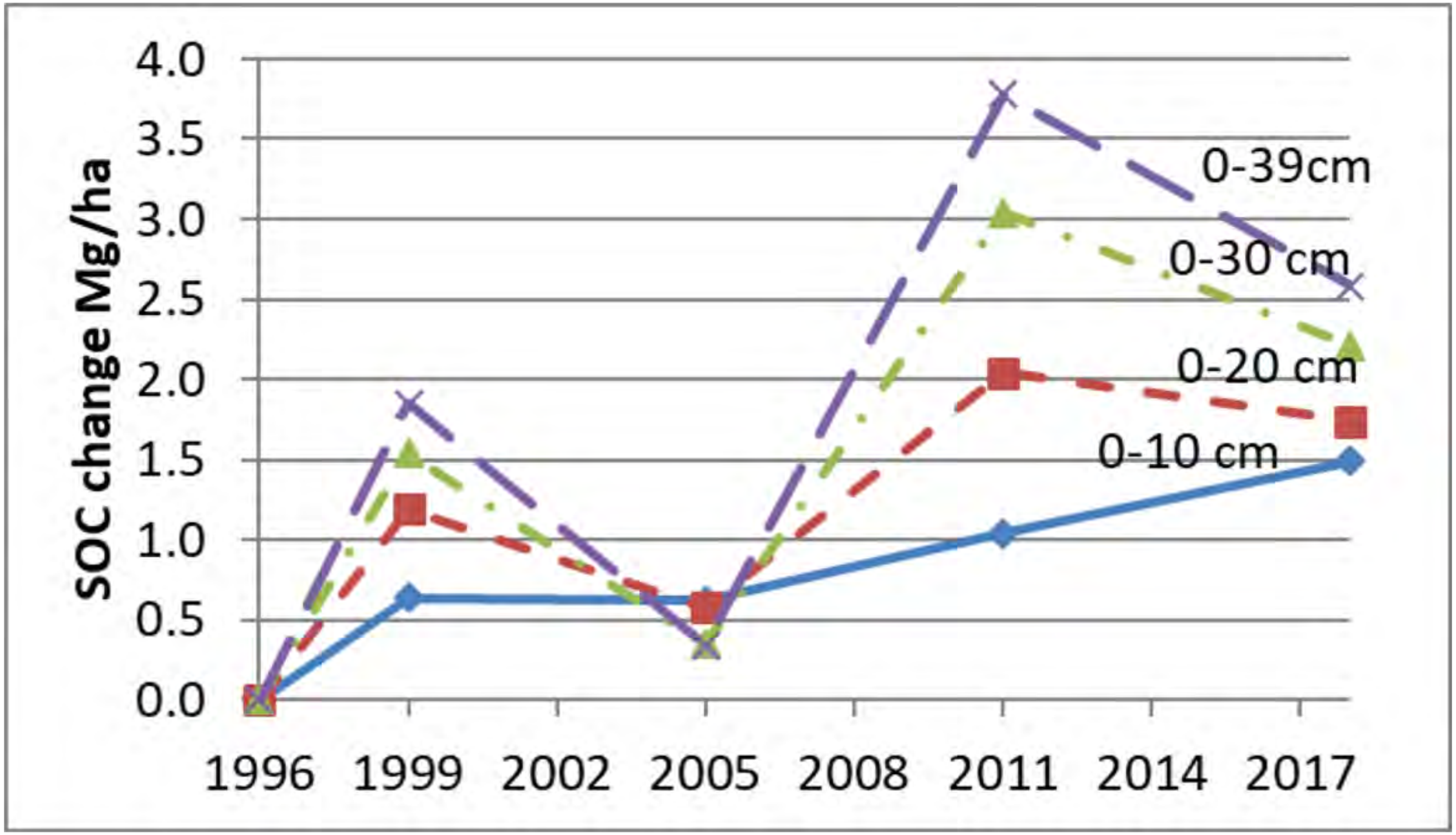


1. Soil organic carbon (SOC) increases with conservation cropping

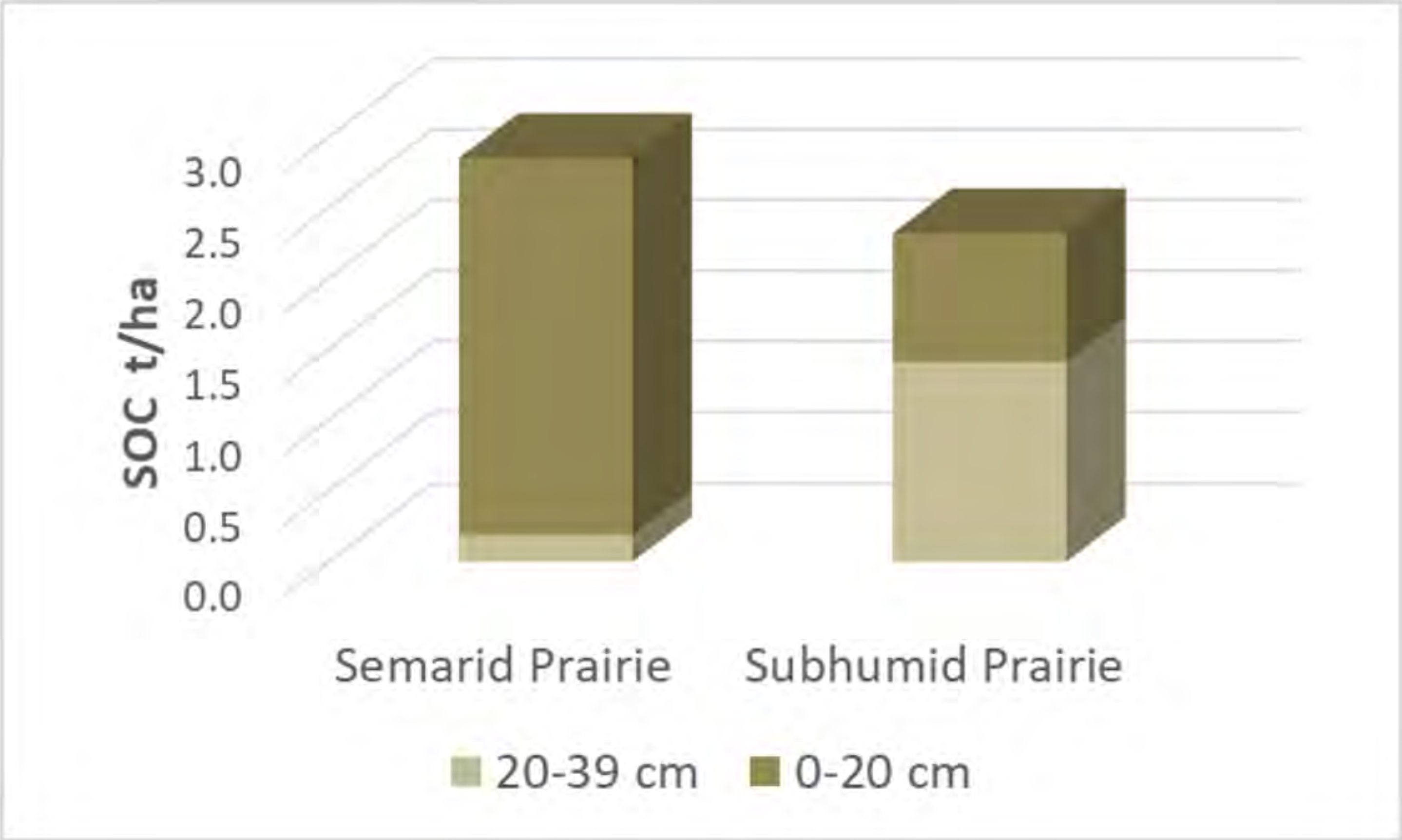
SOC Increase



SOC Increase to Depth

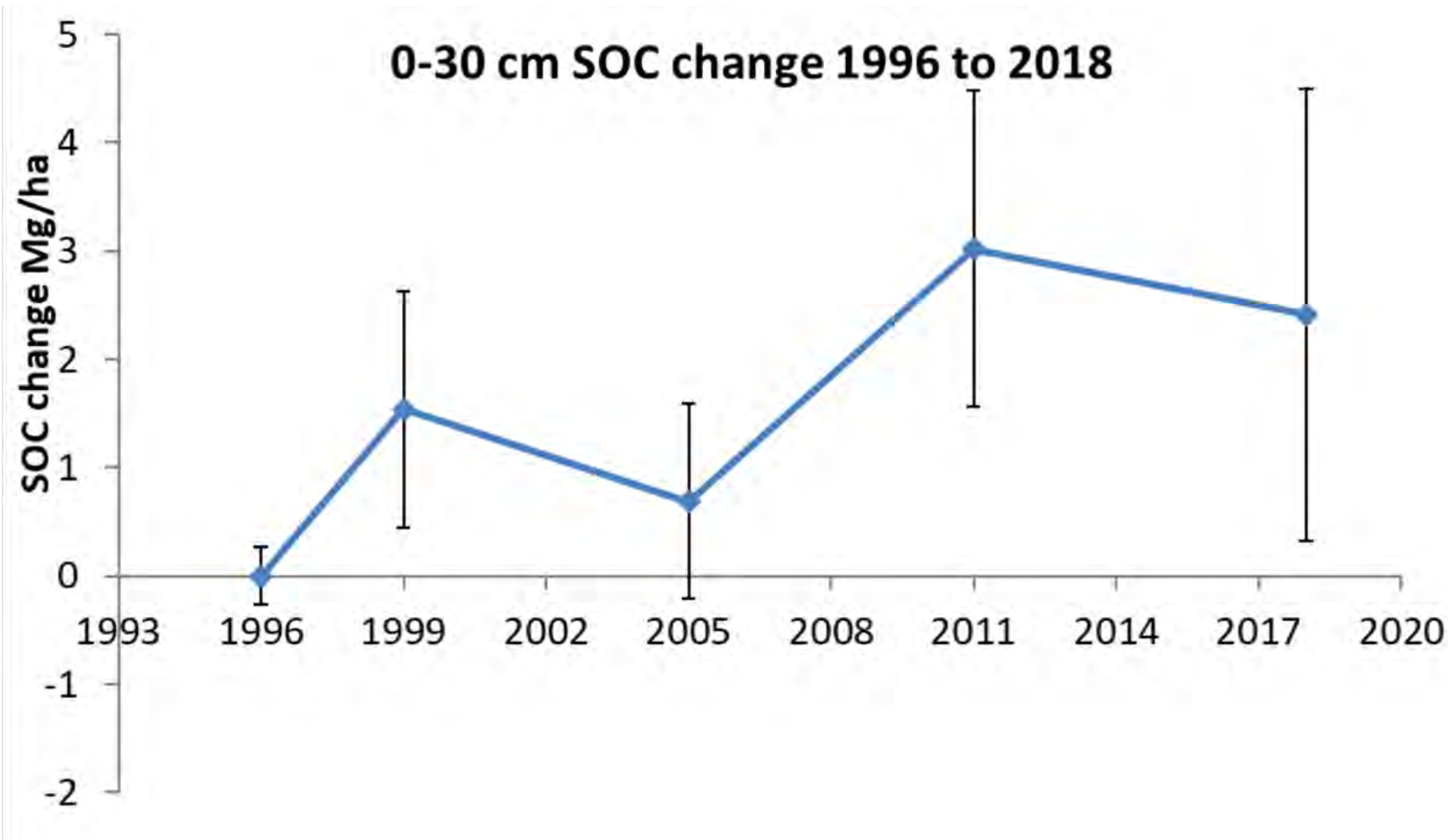


Semiarid Prairie (Brown and Dark Brown Soil Zones) vs Subhumid Prairie (Black, Dark Gray, and Gray soil zones)

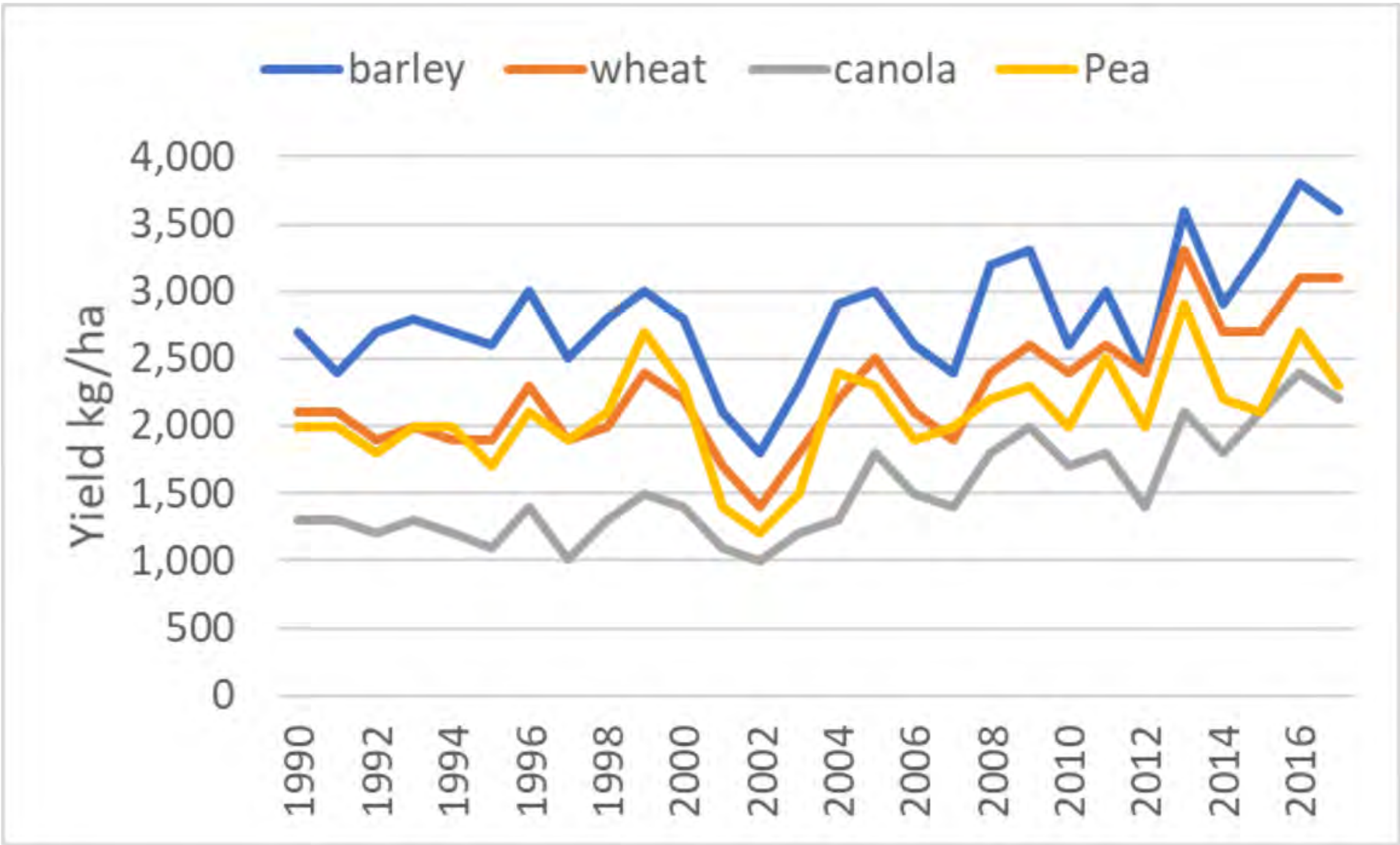


More SOC increase in semiarid prairie zones and all change in upper cm
Lower SOC increase in subhumid prairie zones and change throughout 40 cm

SOC Increase

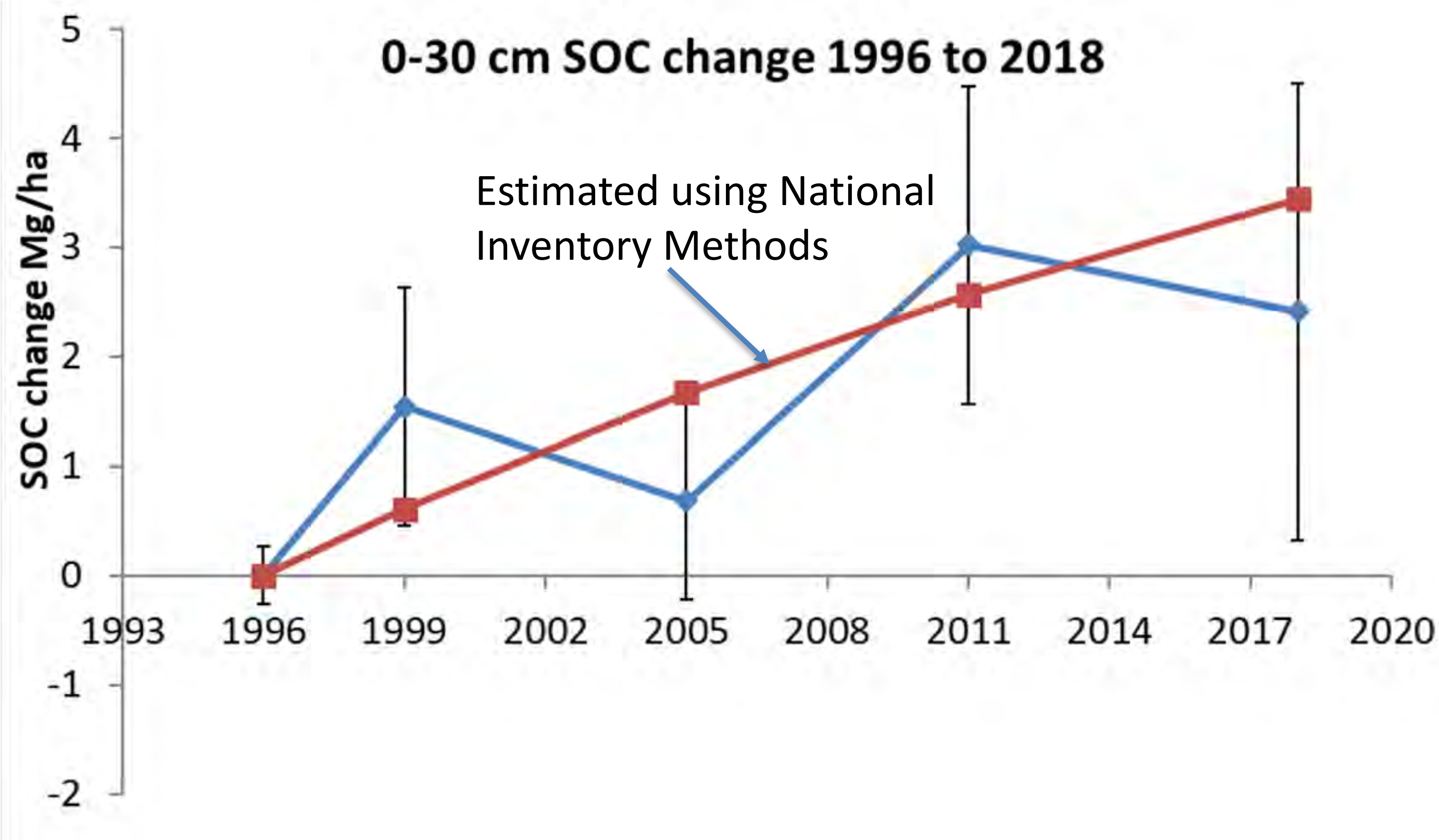


Low yields in 2001-2003 causing SOC reduction for 2005 ?



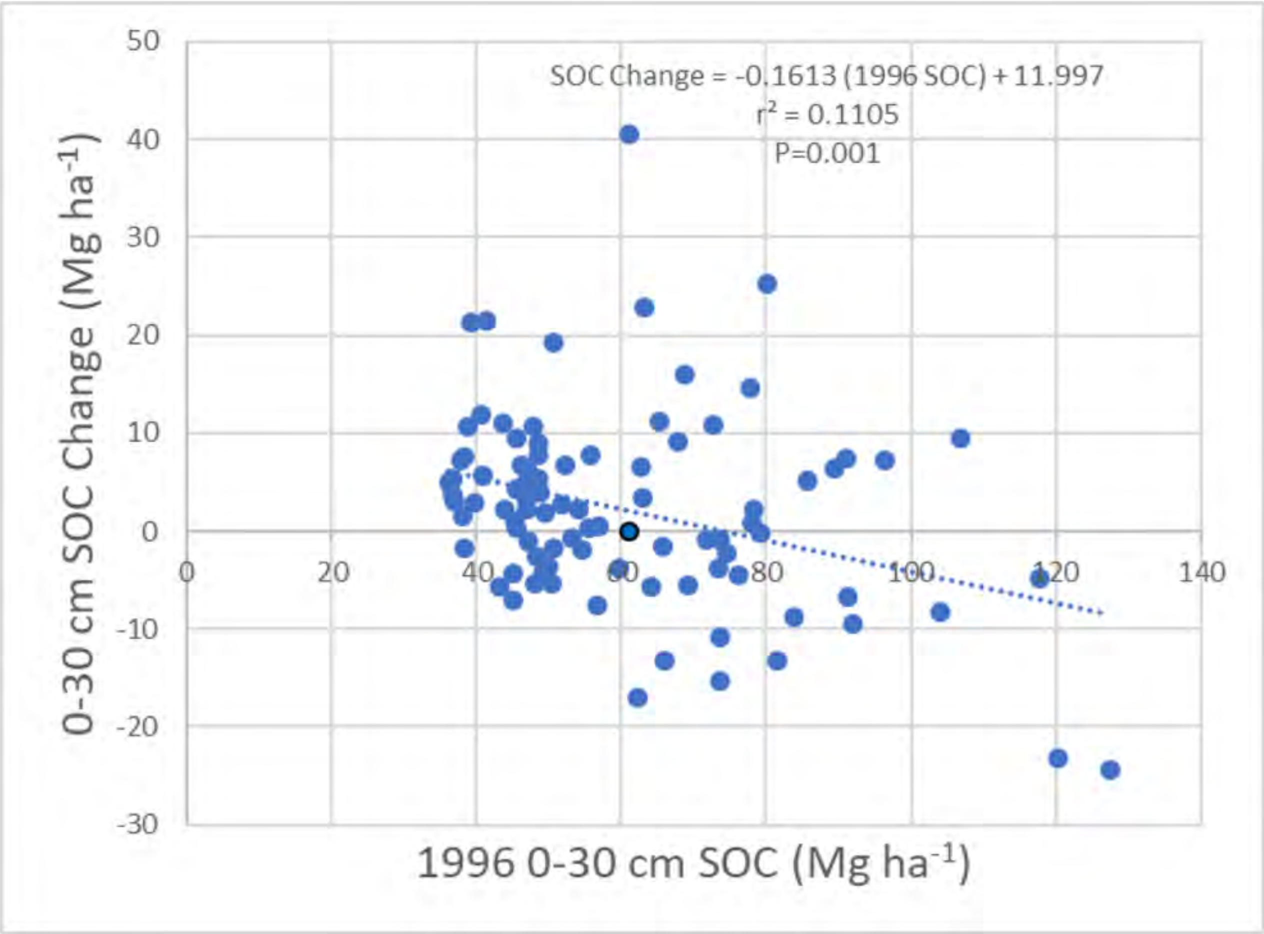
Average Saskatchewan crop yields (Statistics Canada)

SOC change was expected



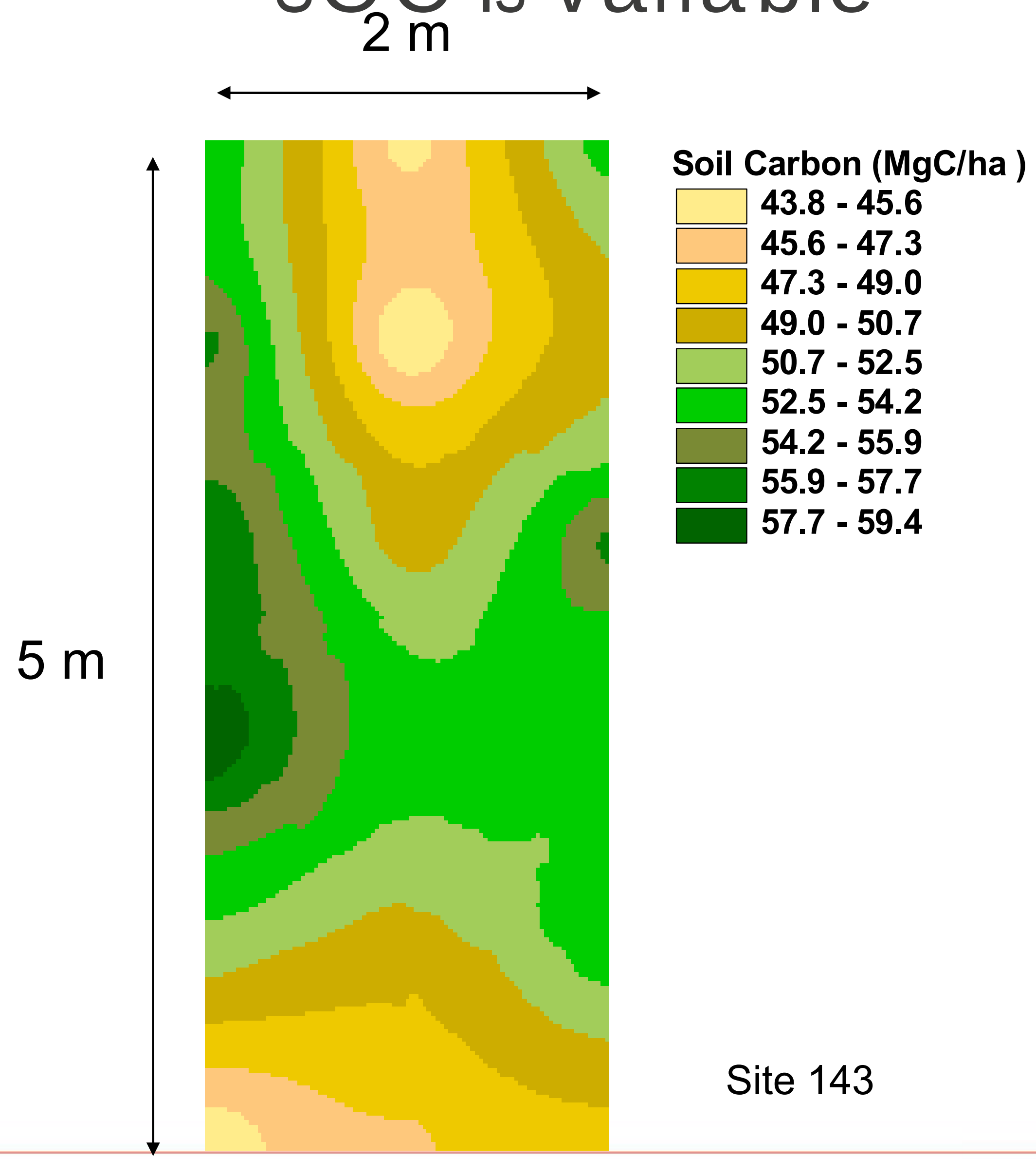

2. SOC increased most for soil with low initial SOC

SOC increased for soil with low initial SOC and decreased for soils with high initial SOC (true for all depths)



3. SOC has a high variability in space that adds to variability to measured SOC changes with time

SOC is variable



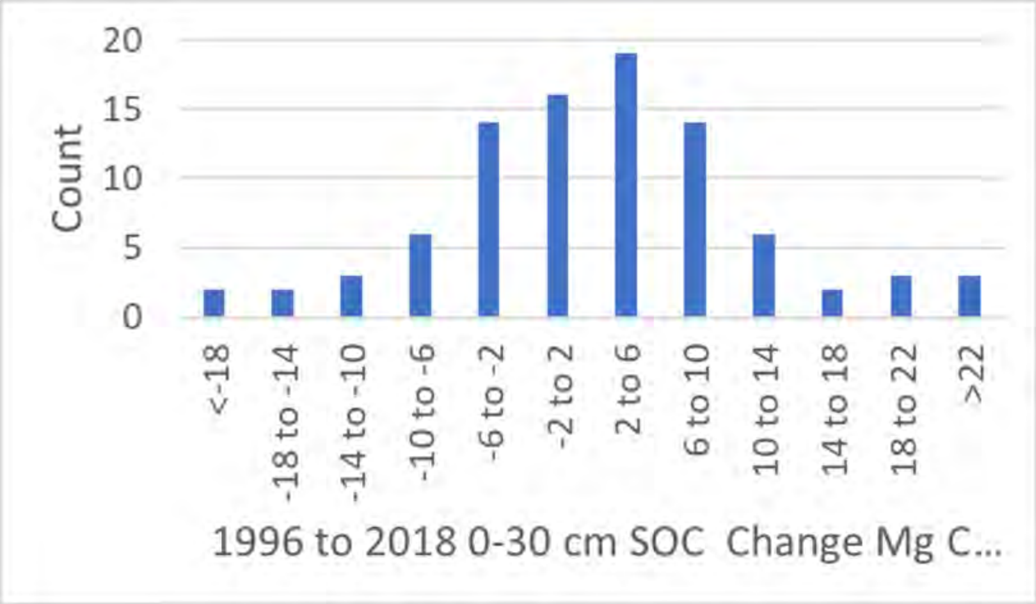
Site 143

PSCB

- Large SOC variability over short distances was unexpected
- Interaction with new management practice (conservation cropping) and SOC level within a benchmark so SOC response complicated
  - Not like a blanket increase used to evaluate method initially (uniform input of coal dust)
- Need 30+ benchmark to detect significant change statistically

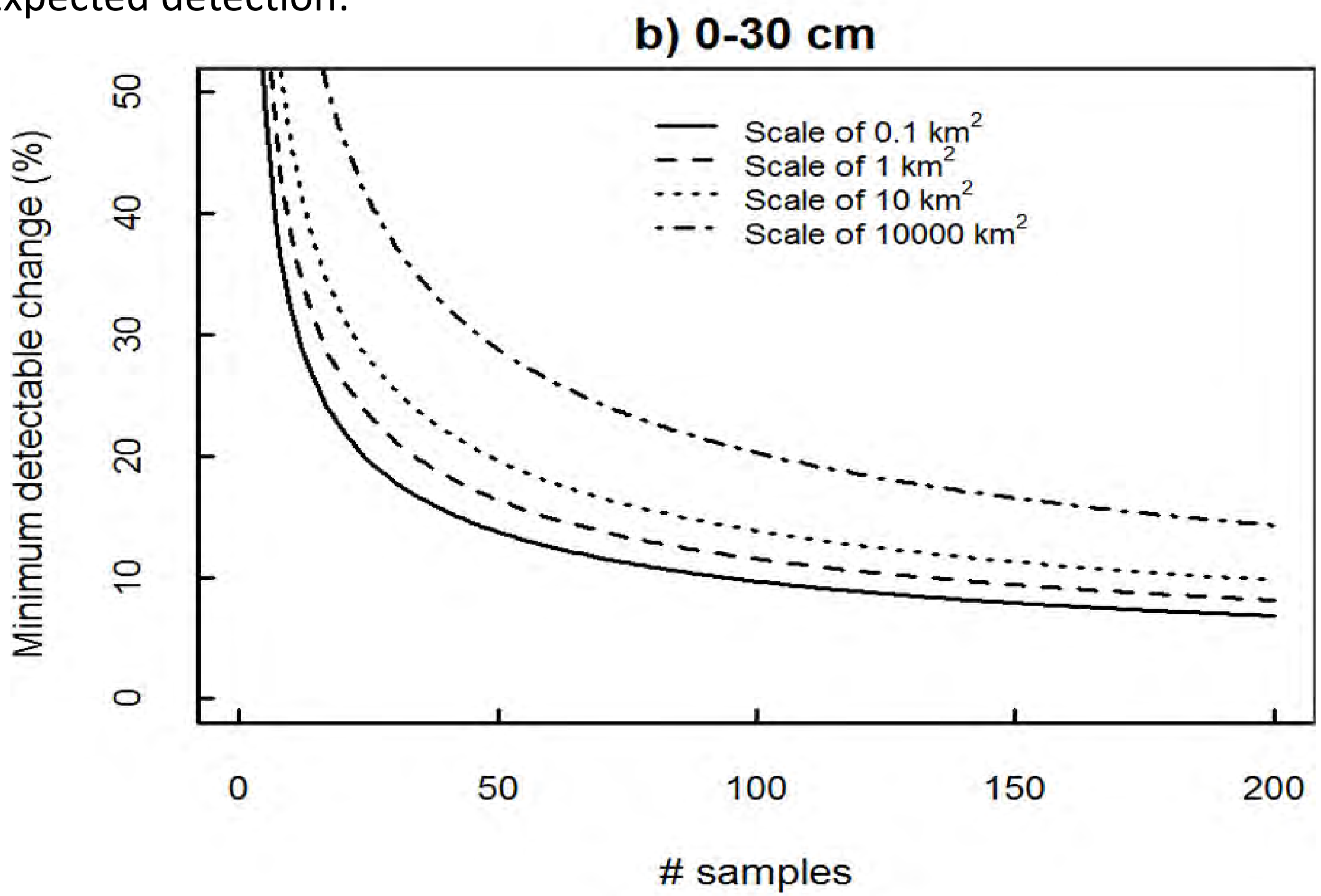
Variability

- Can't resample the exact same soil so that the spatial variability adds to the variability of the measurement even with small spatial offset.
- Chance of SOC of in the specific sample core produced some large differences between measured SOC values over time.
- Overall pattern of observed value conforms to normal distribution so no rationale to drop unrealistic increases or decreases just because they don't look right. (It is what it is)



Benchmarks were able to detect changes of about 5% of total carbon with < 100 samples and so better than non-stratified random sampling

Expected detection:



Source: Maillard et al. 2016. Agric. Ecosys. Environ. 236:268-276

Can we measure SOC change on individual field?

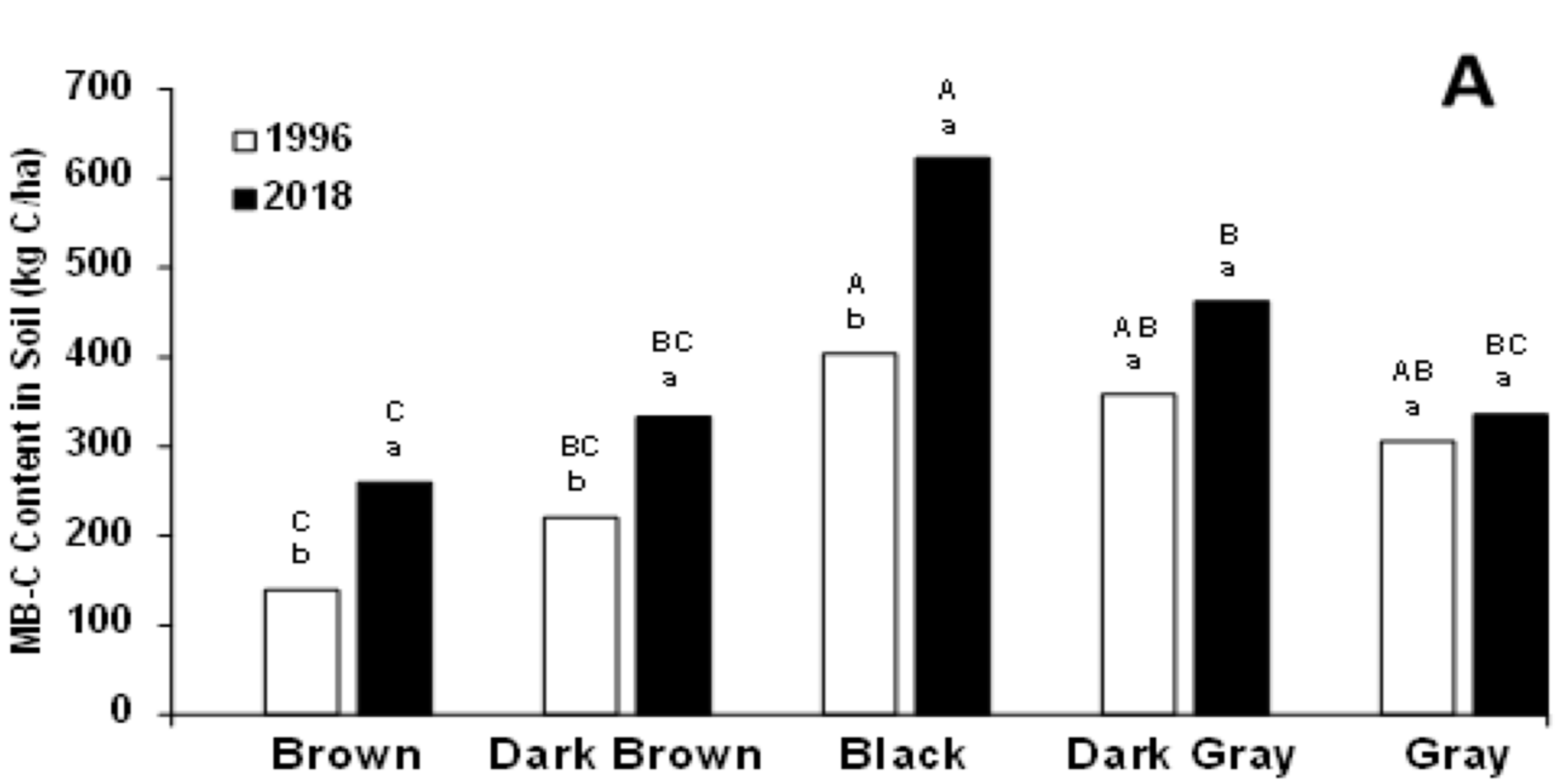
- In practice – *NO*!
- Measurements of change for individual benchmark microsite cannot be interpreted meaningfully, sometimes large ups and downs
- Grouping of benchmarks provides interpretable measurements
  - SOC is so variable spatially that, using this method based on slightly offset soil sampling, it requires at least about *30* benchmarks to have reliable (interpretable, comparable) averages
  - The best (unbiased) value for each benchmark in the group is the average for all benchmarks in the group
- Therefore it would costly to measure SOC change on single field as it would require about 30 benchmarks on that field

4. Soil organic carbon is sequestered in relatively stable forms in a healthier soil

Semiarid Prairie

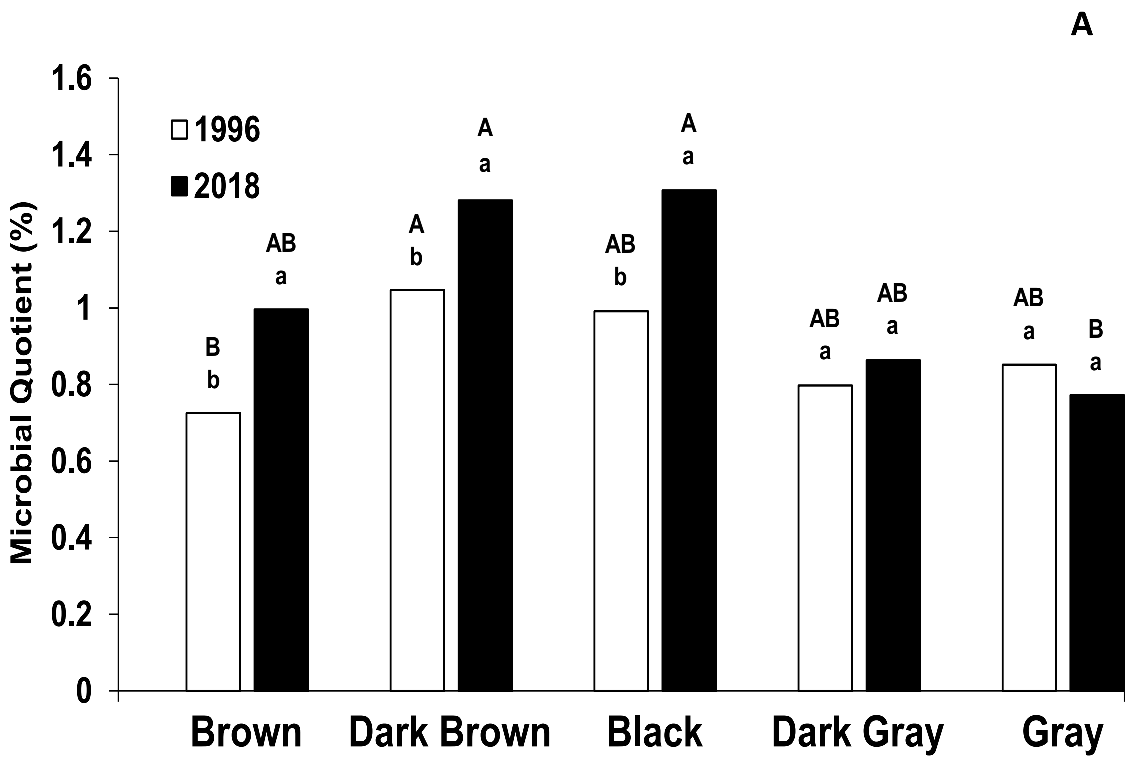
Subhumid Prairie

Microbial Biomass Carbon Increased

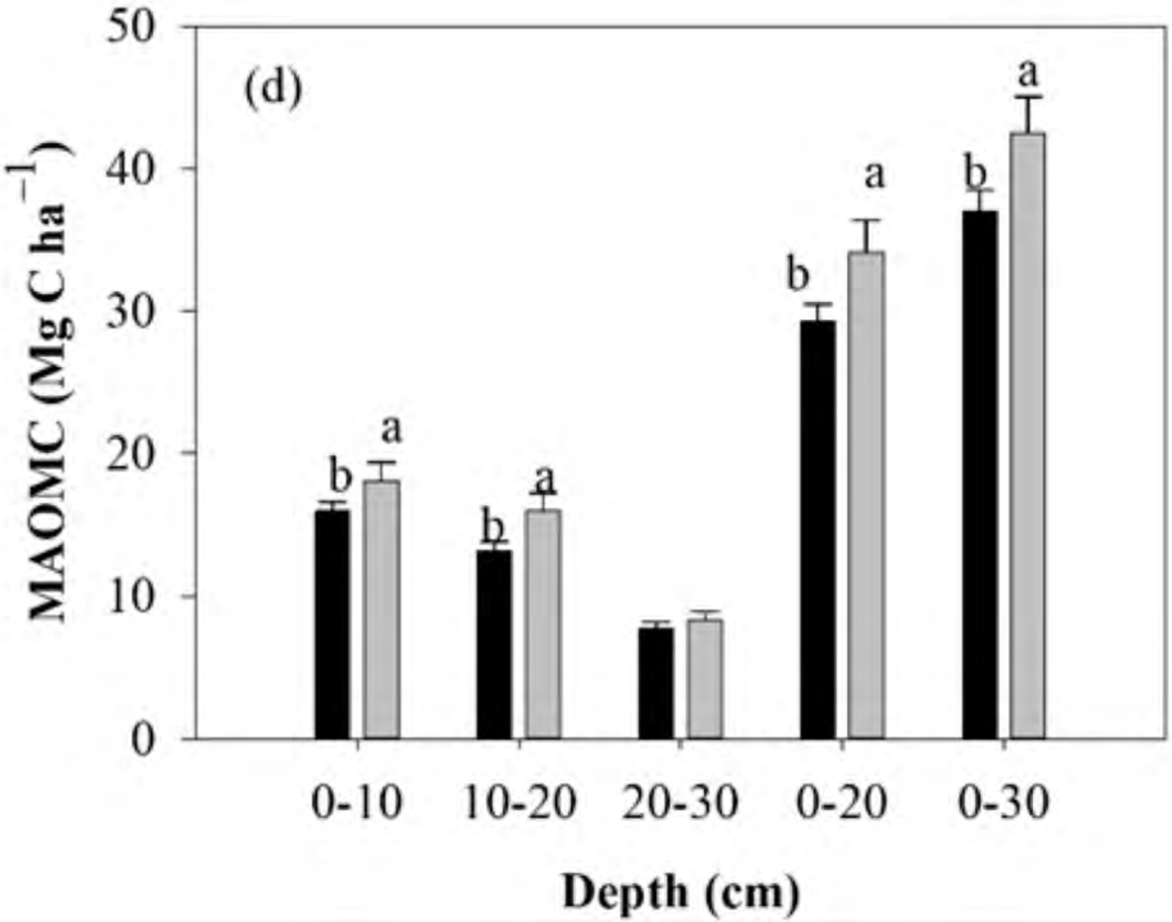


% of SOC respired per unit of soil Microbes Increased (Healthy soil)

More active microbes but not excessively consuming SOC (Stable C)



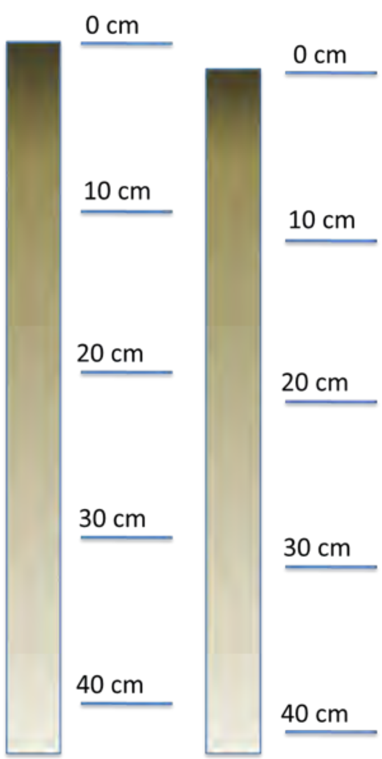
Most SOC is soil mineral associated organic matter C (MAOMC = stable C)



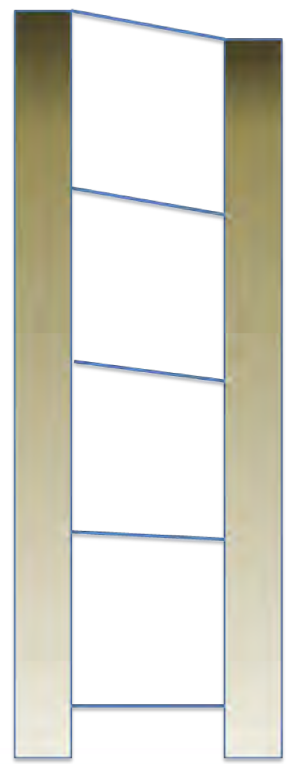
5. Measurements are needed

Soil Bulk Density is Critical

- 2018: increase in soil bulk density but no increase in SOC concentration
  - Average bulk density in 1996 was 1.455 t/m^3 but was 1.483 t/m^3 in 2018 (significant)
  - Average SOC concentration was1.373% in 1996 and 1.372% in 2018 (not significant)

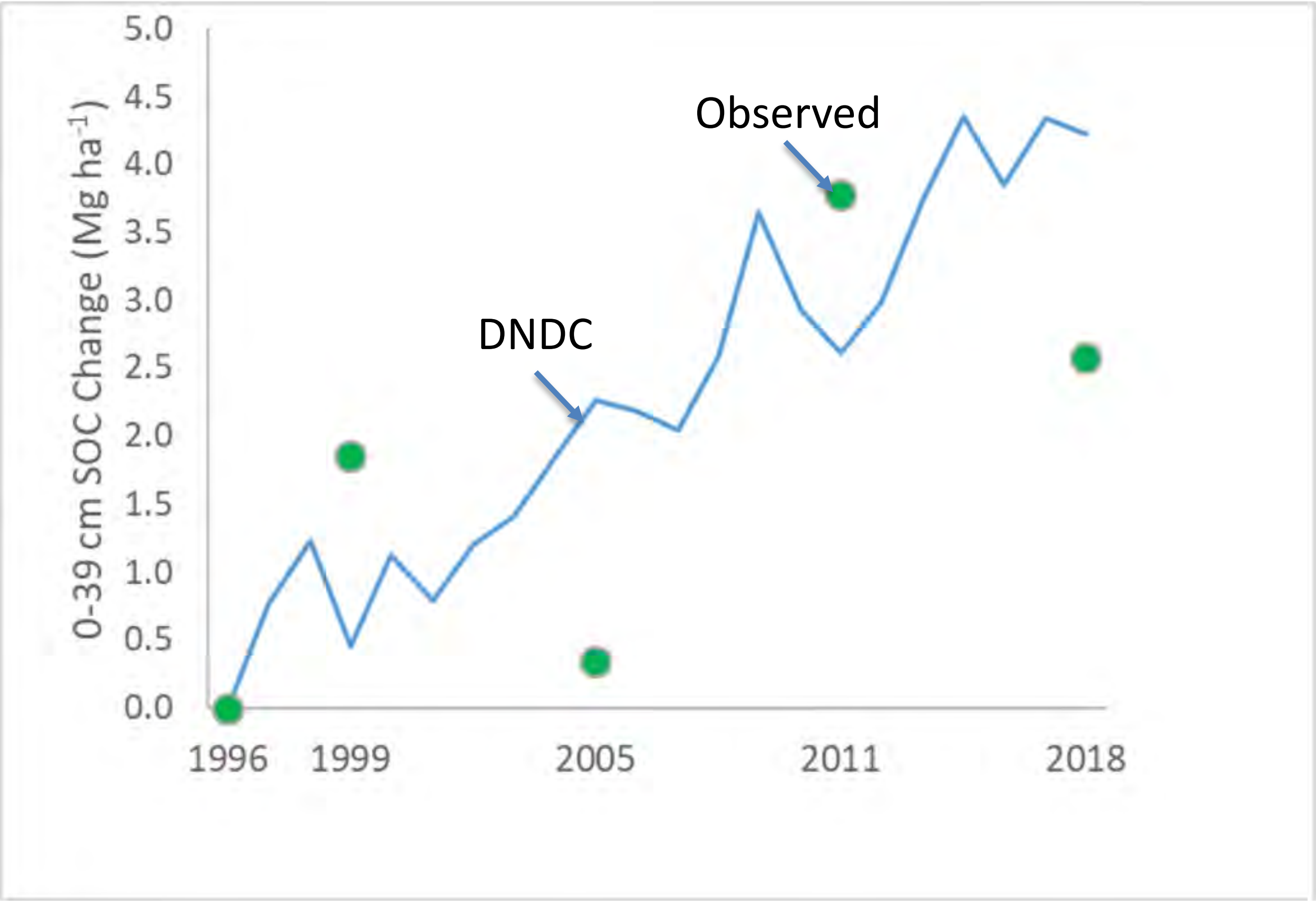


Denser soil means each increment would contain more soil with lower SOC concentration if SOC concentration was not changing.

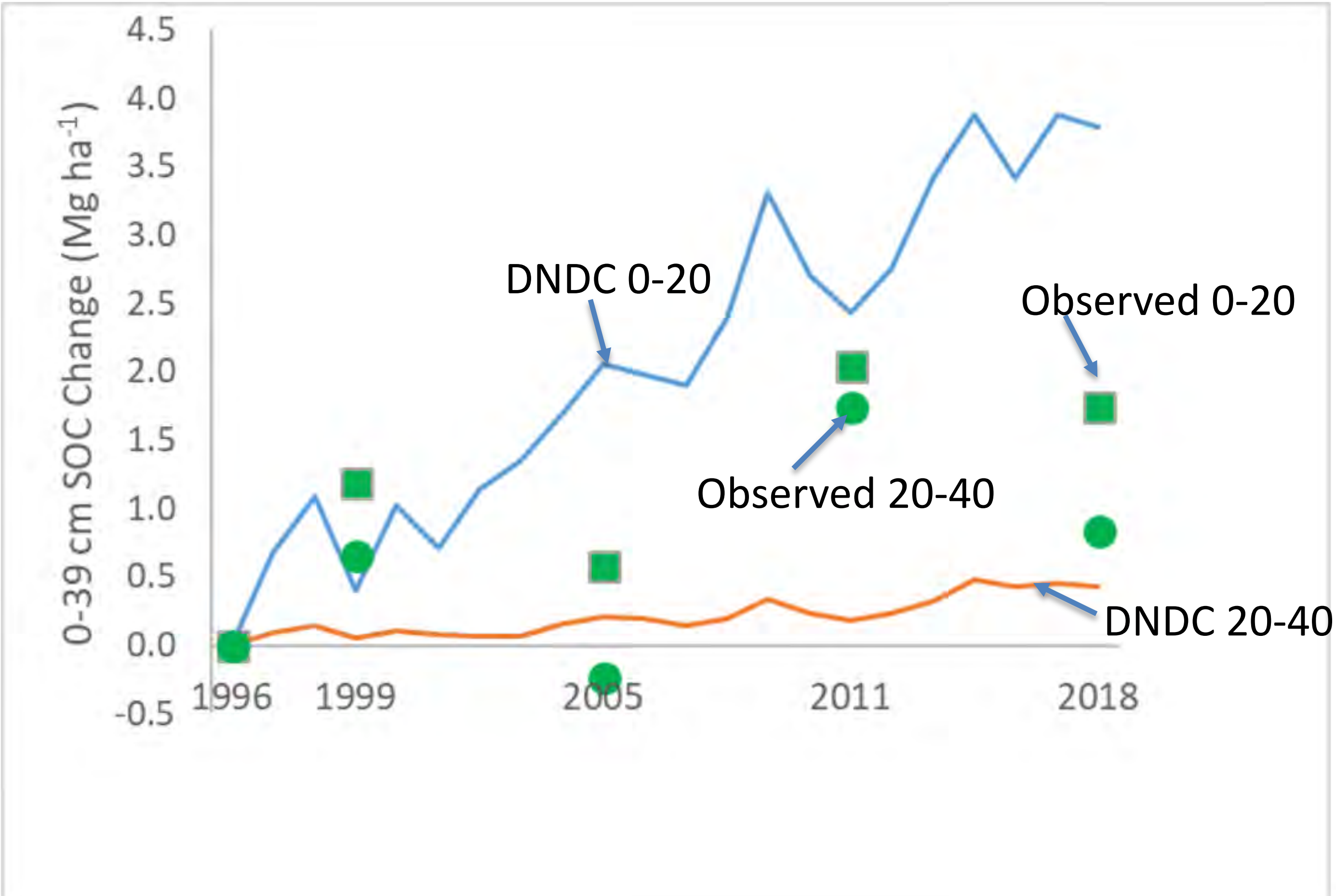


- Expressing on basis of mass equivalence corrects for effect of different bulk densities and both profiles are expressed on same basis.
- Therefore, higher bulk density and same SOC concentration means more SOC total on mass basis
- ***But means extra care and more expensive equipment to sample to measure bulk density accurately***

Comparison with model DNDC (0-40 cm)



Comparison with model DNDC by depth (overestimating surface SOC and underestimating lower SOC)



6. Measured-based offset protocols need careful consideration

Press release March 18, 2019

First soil carbon credits could unlock millions of offset supply in Australia

The Clean Energy Regulator issued offsets to a soil carbon project, a global first that could unlock millions more carbon credits from Australia's project pipeline.

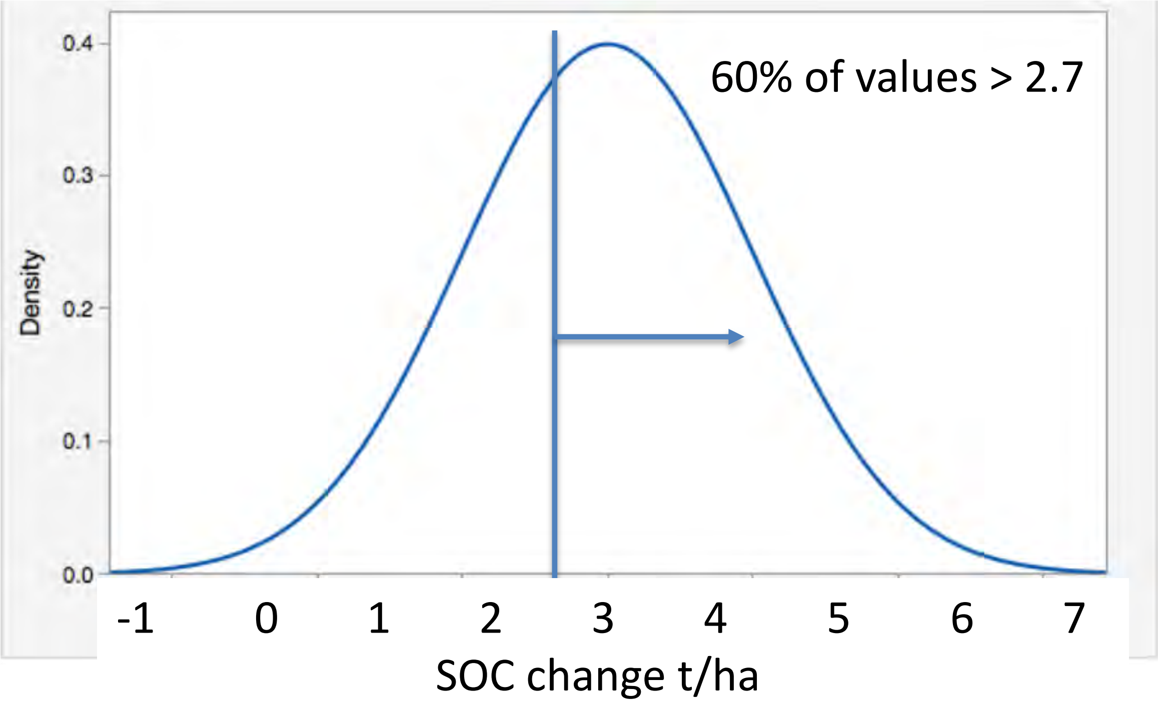
The regulator issued 406 Australian Carbon Credit Units (ACCUs) to the Victoria-based Grounds Keeping Carbon Project, owned by developers Corporate Carbon and farmers Niels and Maria Olsen.

The project combines cultivation, mulching, aeration, and mixed species seeding to improve grazing systems and build soil carbon, the owners said in a press release.

Australian SOC offset protocol

- First working protocol in a regulated market with actual measured SOC change for individual properties.
- Only specific practices allowed, mostly pasture improvements.
- Baseline is the initial SOC but other GHG emissions (N_2O, CH_4) as difference between with and without project (only partly measurement based).
- Change discounted to the SOC amount with 60% probability of exceeding set SOC change
  - Arbitrary, no scientific precedent.
  - Produces an increasing discount as uncertainty of measurement increases so rewards care and precision.
  - Measured decrease would become a greater loss due to discount.
  - (50% of SOC increase is placed in a buffer that can be recovered after three measurements (minimum 1 yr apart and maximum 5 yr) without a loss of SOC.
- Treats all measured change as real so, for integrity, it also promises $ charges for any credited loss although mechanism for that is not clear

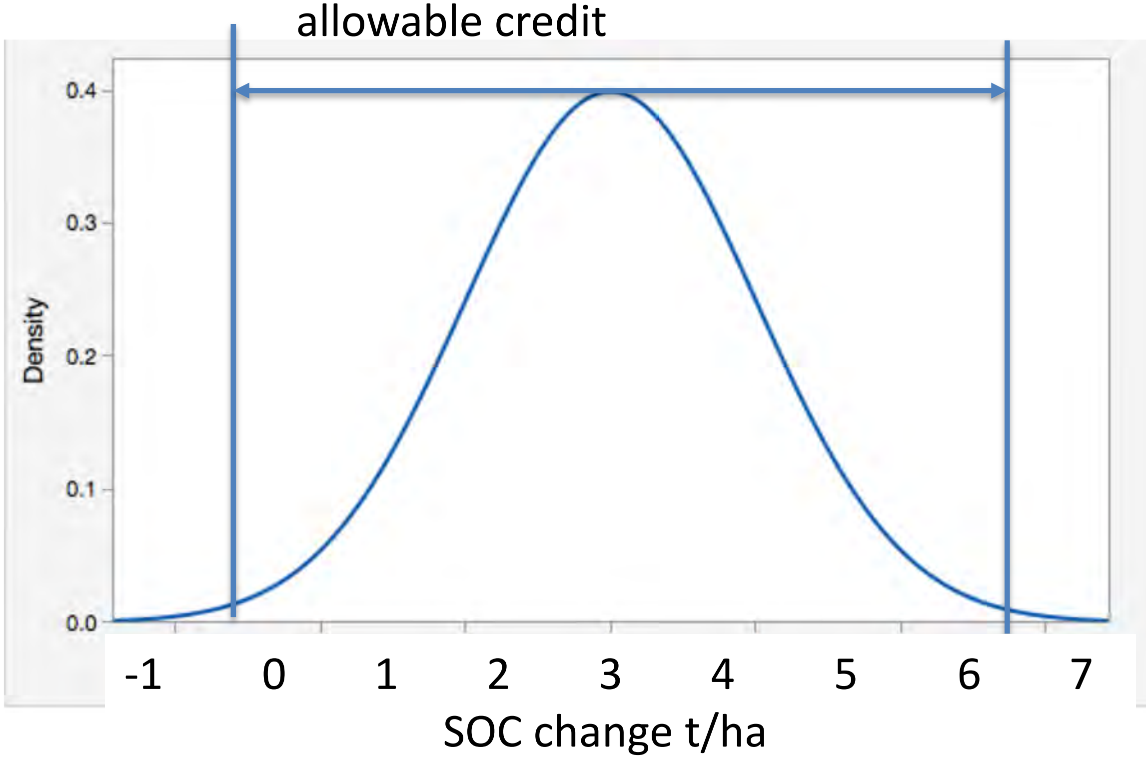
Discount is the value that 60% of expected values exceed



Hypothetical example, C credit = 2.7 t C/ha

Classical statistics such as is based on confidence limits.

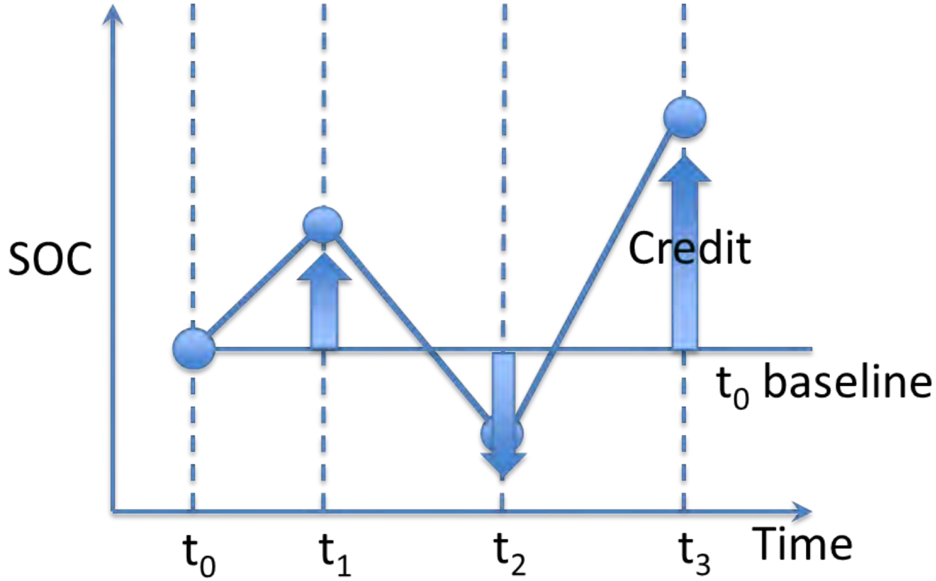
No allowable SOC credit if confidence limits encompass zero change, otherwise, mean is the allowable credit



Hypothetical example, no allowable C credit since confidence limits include zero change

Australian Protocol

- Compares SOC change to a baseline of the initial SOC
  - Captures what atmosphere experienced as soil CO_2 removals or emissions since initial SOC measured
  - *Not consistent with Saskatchewan or Federal Government principles that requires only accounting for additional SOC changes that would not have occurred otherwise.*



Any drop or gain in SOC from changes to land management changes before the baseline year or due to weather or after the baseline year will be included in the reported C change for the Australian protocol

Australian Soil Carbon Offset Protocol for Saskatchewan?

- PSCB sampling protocol would not meet Australian protocol
  - Paired sampling over time, that is basis of PSCB, is explicitly not allowed
    - (PSCB had different objective and did not deal with the objective of upscaling to larger area that is the focus of Australian protocol)
- Nevertheless, the 1999 results with the 23 level 2 sites, with 3 benchmarks for fields, provides an indication of how the Australian protocol would perform in Saskatchewan (3 samples per uniform paddock would be probably fairly typical under the Aust. protocol)

Performance Indication from PSCB for Australian Protocol Saskatchewan

- There 23 level 2 fields with 3 microsites included in 1999
  - Minimum measured SOC change = loss of 4.8 t C/ha
  - Maximum measured SOC change = gain of 13.5 t C/ha
- Individual field basis:
  - Classical statistics say no change in a field was significantly different from zero so all considered to have zero SOC change
  - Australian Protocol says:
    - credited minimum change is loss of 6.8 t C/ha
    - credited maximum change is gain of 10.4 t C/ha
    - 13 fields had credited gain of SOC with average of 4.3 t C/ha, each field claims its own value (initial payment for 50% as rest put into buffer)
    - 10 fields had credited loss of SOC (of which 2 of those actually had measured increase)
- Aggregated (grouped) field basis:
  - Classical statistics say average change for group is 2.3 t C/ha that is significantly different from zero with 95% confidence
  - Australian Protocol says that credited mean change for group is 1.0 t C/ha and the group claims that value (minus 50% for buffer)

Australian Protocol for Saskatchewan?

- Protocol requires no measured loss of carbon for *three consecutive samplings* to claim back the buffer
  - All three of the benchmarks were sampled for 20 level 2 site in 2005
  - Classical statistics: no individual field had significant SOC change, the mean SOC change to 2005 was 1.1 t C/ha but that was not significant from zero so all fields
  - Australian protocol:
    - 4 sites that had credited increases in 1999 had credited SOC losses below baseline in 2005 (lose individual buffer from 1999)
    - 6 sites that had credited decreases in 1999 had credited SOC increases (they probably dropped out anyway once saw initial loss)
    - *Only 5 sites with credited gain in 1999 had credited gain in 2005* with a mean of 1.0 t C/ha for 2005
    - If *aggregated under the Australian protocol*, the 20 fields had a *credited loss of 0.2 t C/ha (aggregated fields lost set-aside buffer for 1999)*
- Conclusion
  - Changes as large as losses of 4.8 t C/ha or gains of 13.5 t C/ha almost certainly not valid estimates of expected (average) behaviour over 3 years (unless major erosion or addition of carbon from elsewhere) but are real estimates due to chance from inherent variability. The Austrailian protocol considers all measurements valid estimates of expected behaviour but with small discount chance effects.
  - Attractiveness of Australian Protocol depends on the confidence of getting a credited SOC increase for three consecutive samplings and degree of acceptance of risk of not getting credited for sequestration even if occurring. The PSCB findings indicate there can be a lot of risk so careful risk analysis needed.

Learnings

1. Soil organic carbon (SOC) increases with conservation cropping
   - Average rate 0.18 t CO_2/ac/yr from 1996 to 2018
   - Lower but within bounds of expected performance
2. SOC increased most for soil with low initial SOC
   - semiarid prairie topsoil and lower profile in subhumid prairie
3. SOC is variable in space and time
4. Soil organic carbon is sequestered in relatively stable forms in a healthier soil
5. Measurements are needed
   - Bulk density effects
   - To improve and underpin any estimates from SOC process models
6. Measurement based offset protocols need careful consideration
   - Expected variability impacts the optimal design of measurement strategy and adds risk to whole venture

Overall Summary

- Match the measurement plan to the purpose
- Beware the two common delusions
  - Confusing best methods to estimate C stocks (total amount) with best methods to estimate C stock change
  - Thinking you are less ignorant than you are (i.e. expect the unexpected!)
- Protocols based on conventional statistics make it difficult to detect small changes in SOC (e.g. < 4-10 t C/ha)
  - Zero change if not statistically significant
- Australian SOC protocol discounts the amount of credited SOC change but increases likelihood of detecting C change
  - Uncertainty of the broad stakeholder acceptance of C credits produced under the Australian Protocol

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To all the PSCB cooperators who made it possible

To funders

Thank You!

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