Crop Rotations & Soil Health
Long-term crop rotation studies

J. Diane Knight

Professor, Soil Science,
University of Saskatchewan

February 7, 2018

"…What now remains compared with what then existed is like the skeleton of a sick man, all the fat and soft earth having wasted away, and only the bare framework of the land being left.."

- **Plato from "Critias" (~ 360 B.C.E.)**

- Sustainable production has become an important aspect of maintaining and accessing the marketplace….
- Can no longer just do what we **think** produces food in a way that protects or improves soil health ….we need to be able to **provide evidence** that we're producing food in a way that protects or improves soil health
- What is Soil Health?
- How can we measure Soil Health?

Soil Health?

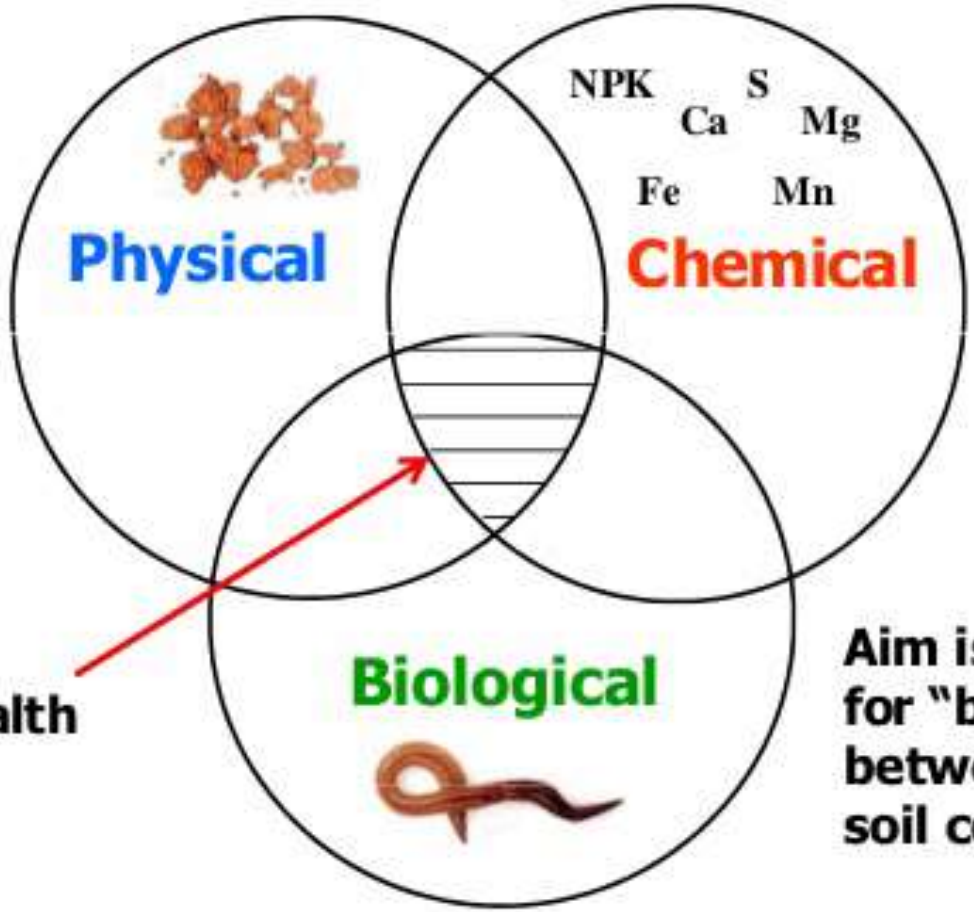
- "…is simply the ability to grow a profitable crop while maintaining the ability to do the same down the road, while not messing with our neighbours or other parts of the environment we jointly occupy and value..."

(Les Henry, Grainnews, March 1, 2016)

Specific Elements of Soil Health

- Meaningful assessment requires “purpose” and “place”:
  - Purpose = “sustain biological productivity” or “grow a profitable crop” or “optimize crop yield” (grains, forage, grass)
  - Place = yield potential (climate regime, parent geological material, landscape position)

Soil quality is the capacity of a soil to function (in a farm or ecosystem) and thereby sustain productivity, maintain environmental quality, and promote plant and animal health



Aim is to manage for "balance" between all three soil components

Soil health indices

- Cornell Soil Health Assessment (CSHA) - Measures 20 soil attributes
- Grant for developing Soil Health Index for western Canada – measuring 20 soil properties:

Texture	Organic matter	Potentially mineralizable N
Available water capacity	Soil respiration	Root pathogen pressure
Surface hardness	Active carbon	pH
Subsurface hardness	Nutrients – N, P, K, S, Ca, Mg, micros.	Salinity
Aggregate stability	Soil protein	

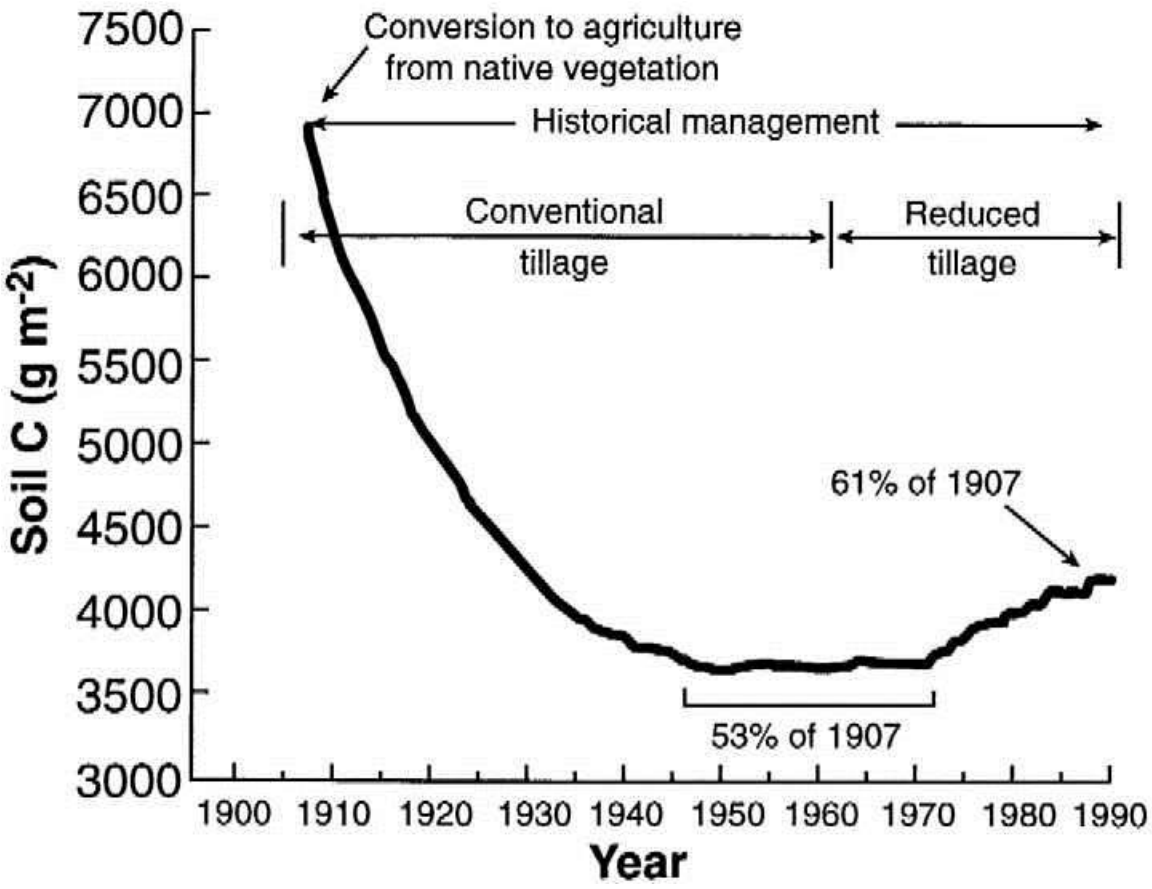
My soil health score is “5” - did I win??

- **.....as Einstein once said “it’s all relative...”**
- Index (score) is somewhat controversial. (e.g. Congreves, et al. 2016)
- Tracking your soil health score (lab or observational) over time can be useful
- Individual indicators perhaps more meaningful as a diagnostic tool.

Soil Organic Matter (SOM)

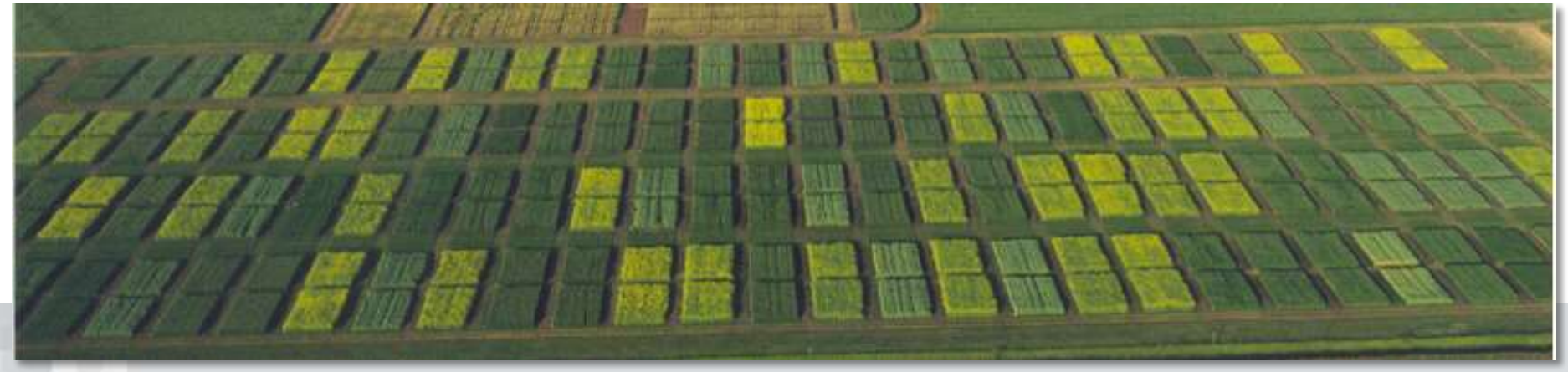
- Appears in all soil health indices – everyone acknowledges its importance
- Long time period (minimum of ~ 5 years) before change in SOM is measureable
- If SOM is lost after implementing a change – long time before we know

Loss of soil organic carbon:



Crop rotations

- Essential to study actual crop rotations – sustained over numerous rotations of the entire crop sequence
  - Need time to establish if there is any impact (positive or negative) of a particular sequence/ operation etc.
  - AAFC long term rotations studies are an indispensable resource



AAFC – Long-term sites:

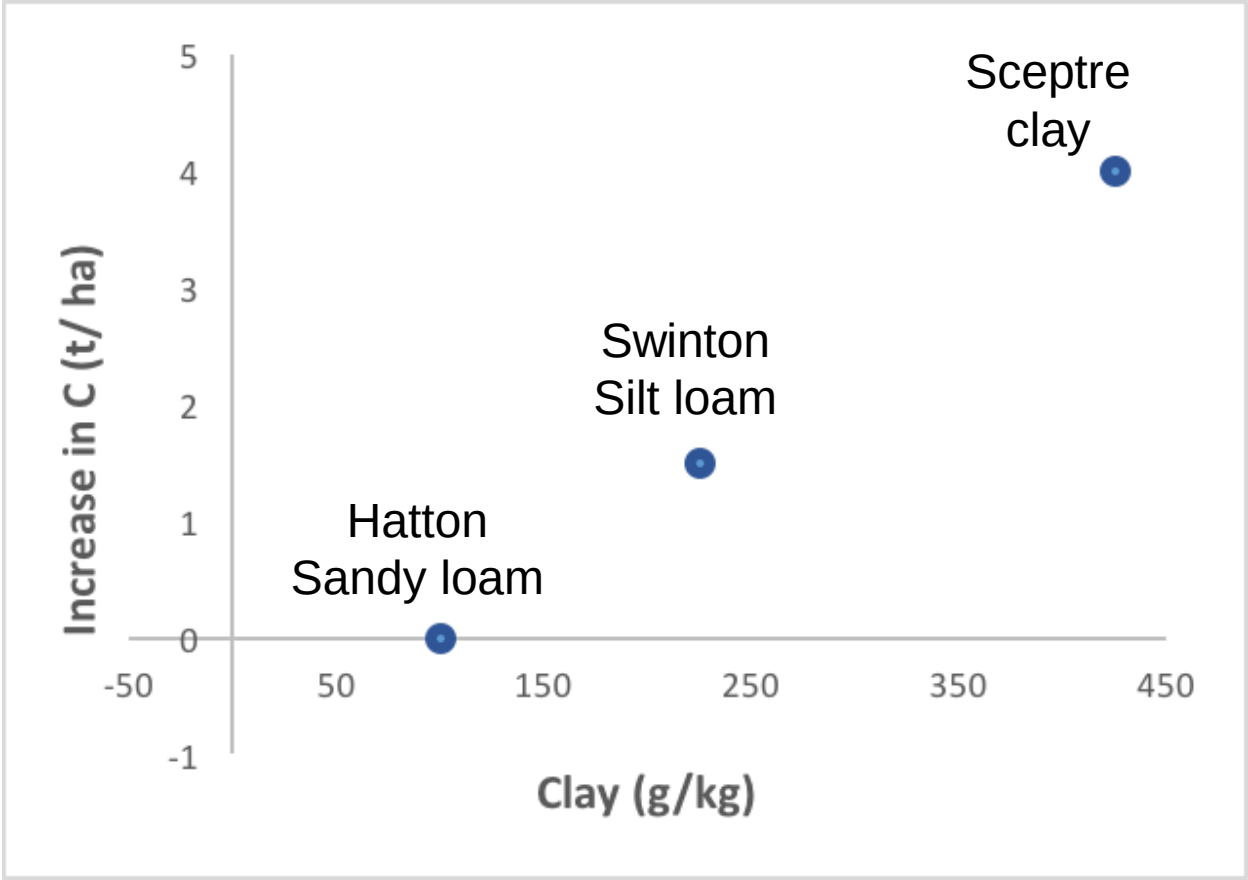
Swift Current (Brown Soil)

Scott (Dark Brown Soil)

Indian Head (Black Soil)

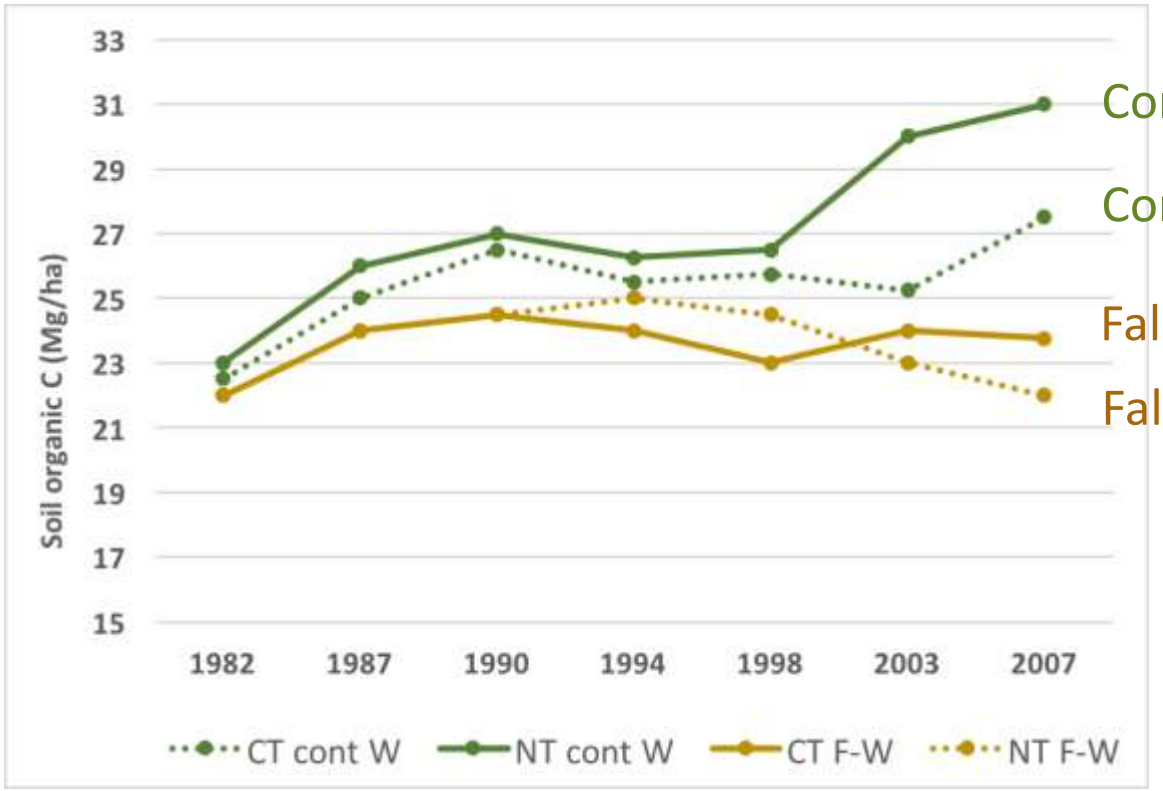
Swift Current – Brown Soil Zone

Change in SOC after 11 or 12 yr no-till



Campbell et al., 1996, Can J Soil Sci. 76; 395-401

Cropping frequency and tillage on SOM



Cont wheat: no till

Cont wheat: conventional

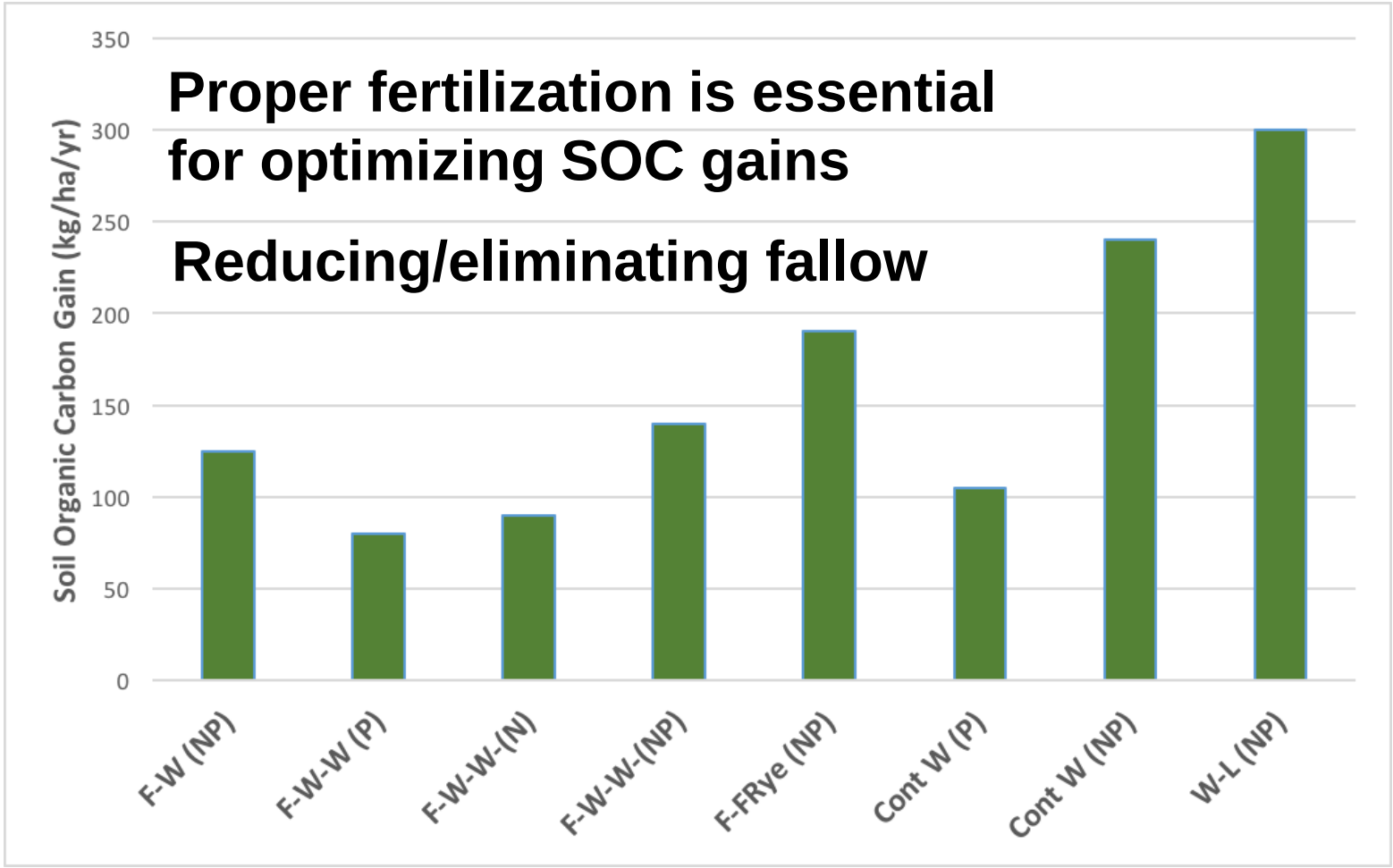
Fal - wheat: no till

Fal - wheat: conventional

Swift Current – Old Rotation Study

- Initiated in 1966
- Evaluate the influence of rotation length, fallow substitute crops and fertilization (N & P)
- Spring wheat – fallow rotations for moisture conservation led to erosion, salinization and a decline in soil and water quality

Average annualized SOC gained 1967-2003

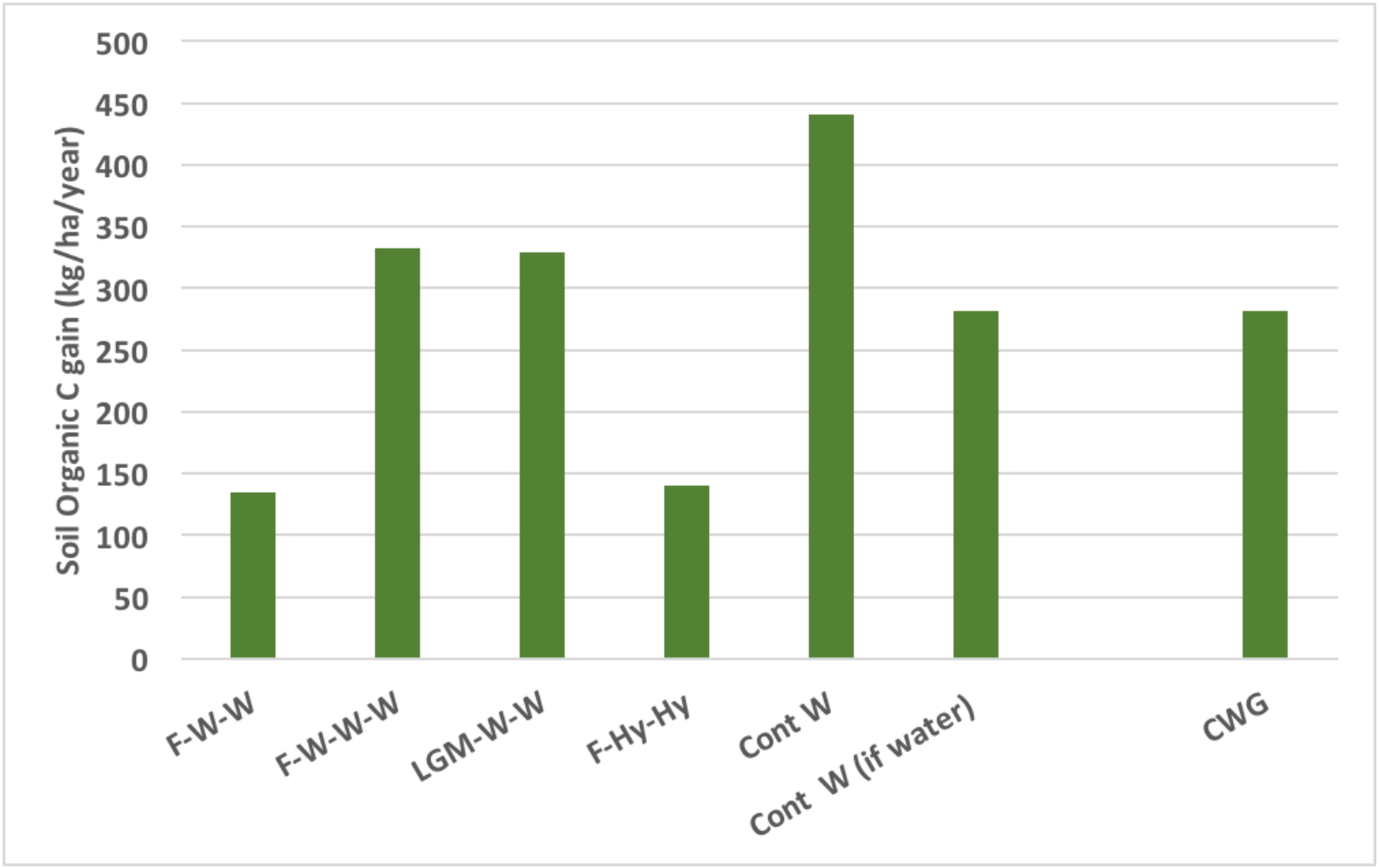


F=fallow; W=spring wheat; FRye=Fall Rye; Cont W=continuous wheat; L=lentil
(NP)=N & P fertilizer applied; (N)=N fertilizer only; (P)=P fertilizer only

Swift Current - New Rotation Study

- Initiated in 1987
- Evaluate (under conservation tillage) influence of crop and rotation type

Average annualized SOC gained 1981-2008



F=fallow; W=spring wheat; LGM=Legume green manure; Cont W=continuous wheat; Cont W (if water) =continuous wheat when sufficient moisture – fallow insufficient moisture; Hy=(hybrid) Canadian Prairie Spring Wheat; CWG=crested wheat grass

Scott – Alternative Cropping Systems Study

- Established in 1994
- Prior to establishing the study, area maintained in a cereal-fallow or cereal-cereal –fallow rotation

ACS Scott

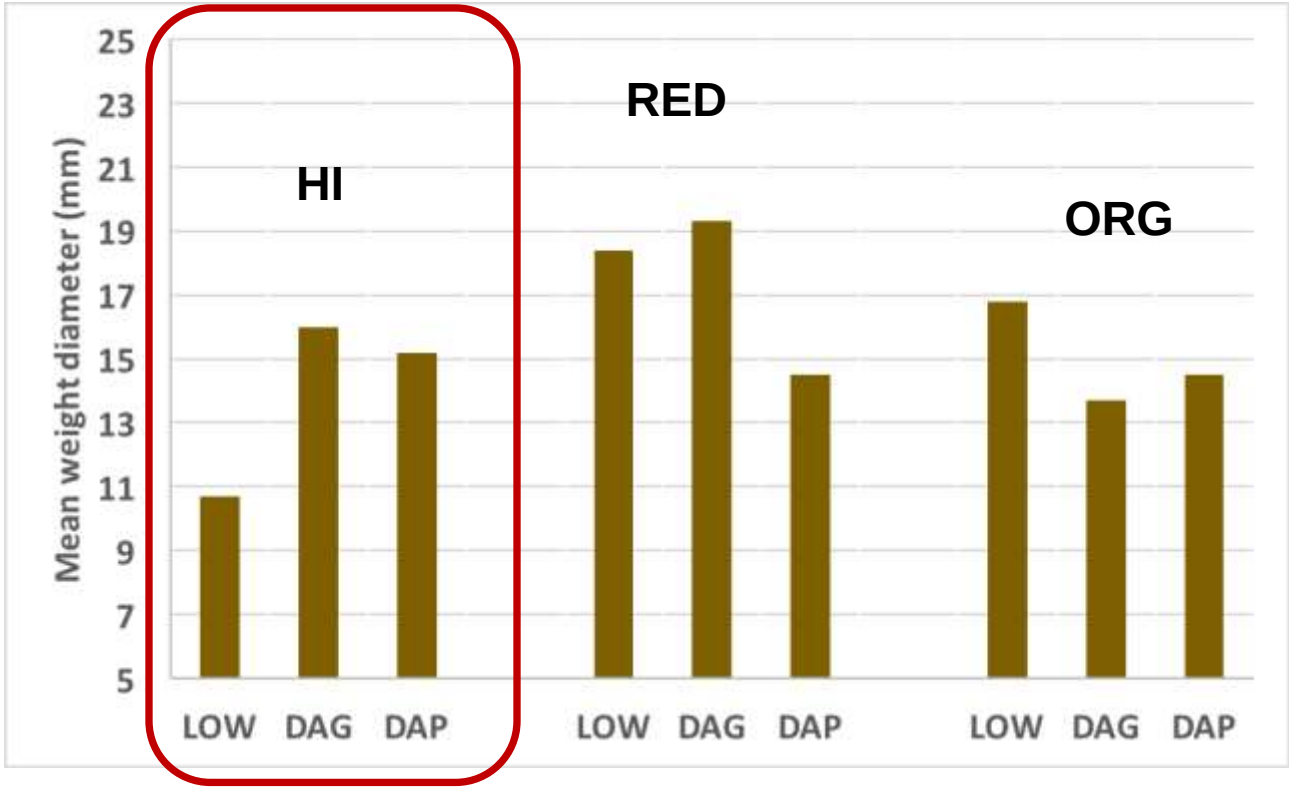
Diversity level	Input level	Crop sequence
LOW	ORG	GrM-W-W-GrM-Must-W
	RED	GrM-W-W-Chem fallow-Canola-W
	HI	Fallow-W-W-F-Canola-W
DAG	ORG	GrM-W-Pea-Barley-GrM-Mustard
	RED	Canola-Soft W-Pea-Barley-Flax-W
	HI	Canola-Soft W-Pea-Barley-Flax-W
DAP	ORG	Must-W-Barley-Alf-Alf-Alf
	RED	Canola-W-Barley-Alf-Alf-Alf
	HI	Canola-W-Barley-Alf-Alf-Alf

DAG=diverse annual grain; DAP = diverse annual & perennial

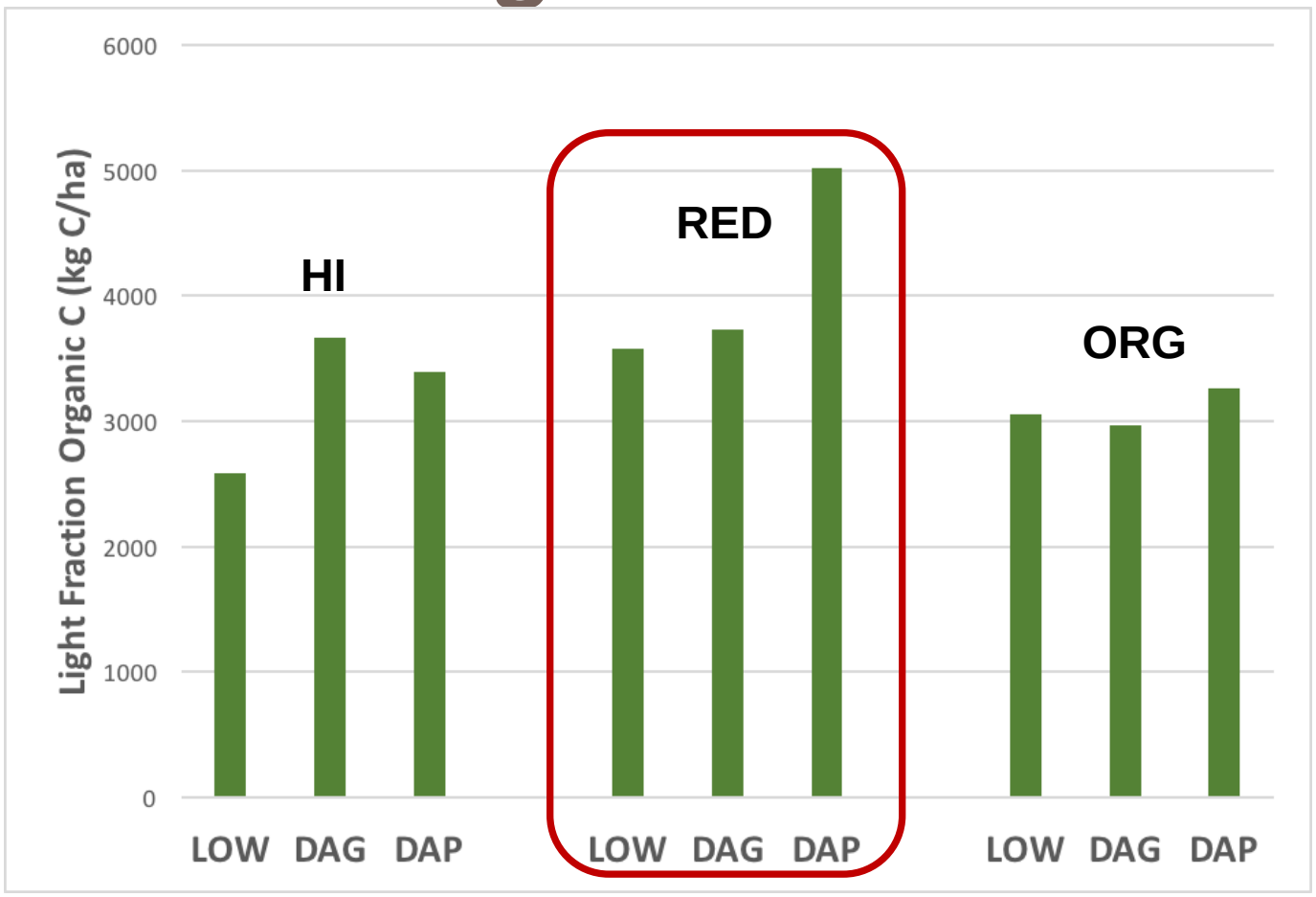
Scott-ACS: Soil organic C and N

- No effect of input level or diversity on total organic C and N (0-15 cm)

Scott-ACS: Aggregate Size



Scott-ACS: Light Fraction OM



Final Observations from Scott ACS

- Systems with greatly reduced tillage combined with perennial forages promoted improved soil quality and nutrient supplying power
- RED had more mites and more suborders of mites than the HI and ORG systems – but still much lower than native prairie reference

Indian Head – Black Soil Zone

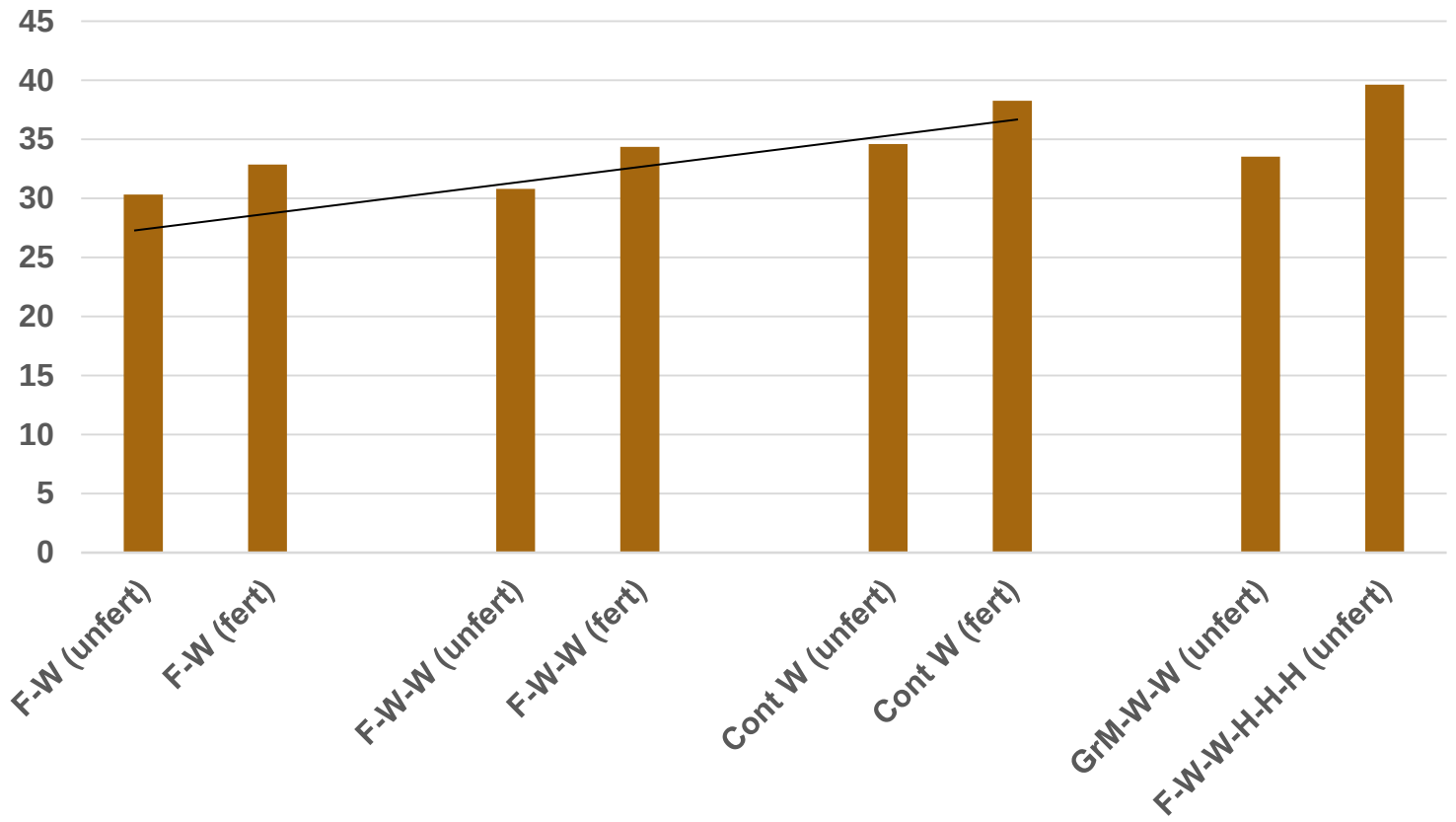
- Established in 1957
- Converted from conventional – tillage to no-tillage in 1990
- Evaluate different summerfallow frequencies and fertility through the use of N and P fertilizers, legume green manures and forage crops

Nine crop rotations established:

No Fertilizer	N & P fertilizer
Continuous wheat	Continuous wheat
F-W	F-W
F-W-W	F-W-W
F-W-W (straw removal)	
GrM-W-W	
F-W-W-H-H-H	

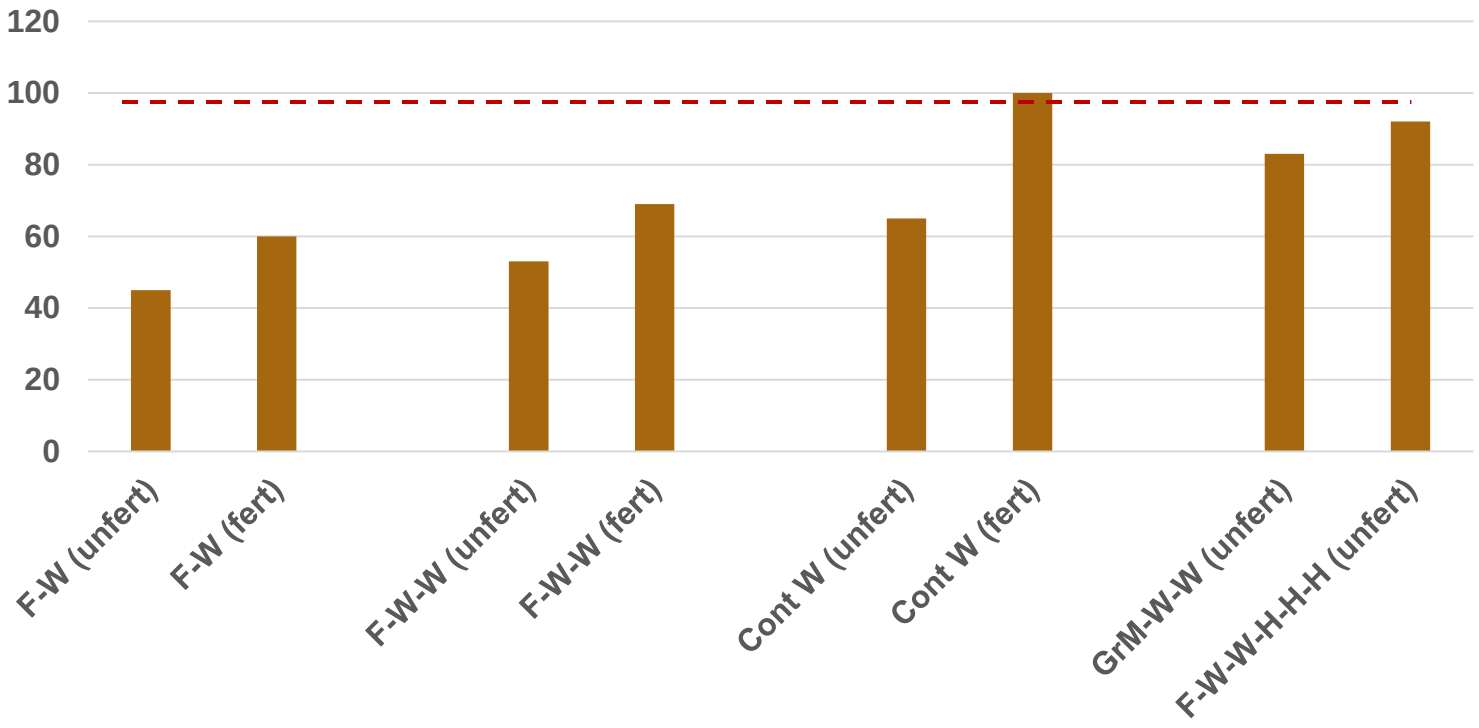
F=fallow, W=wheat, GrM=green manure – sweet clover or lentil, H=hay – alfalfa + bromegrass or straight alfalfa

SOC 30 (t/ha) yr after implementation of rotation



- Use of Fertilizer increased SOC in Cont W rotation
  - not in F-W or F-W-W
- Reduction in Fallow increased SOC
- Including GrM or forage increased SOC

Relative estimate (%) of potential mineralizable N



Fertilizers as/more effective as green manure or forage legumes for increasing the quantity and quality of SOM

Soil Microbial Biomass

- Eliminating fallow increased MB-N by ~50%
  - (82 kg/ha to 122 kg/ha)
- MB-C:N indicated a shift in the microbial biomass populations in rotations with increased SOM
  - Rotations with more SOM (Cont W, GrM-W-W & F-W-W-H-H-H) smaller ratios

Final Observations from Indian Head

- Soils with low organic matter due to erosion or poor management cannot be made to produce comparably to soils with higher organic matter simply by adding inorganic fertilizers
- Building soil quality will build crop yields over time.

Take Home Messages

- More difficult to increase SOM in sandy soils than clays
  - Clays may/do protect SOM from mineralization
- Decreasing frequency of fallow (eliminating) key to increasing SOM
  - Continuous inputs of roots and aboveground residues
- Proper fertilization of growing crop key to improving SOM
  - Inorganic fertilizers as effective as organic inputs (GrM)
- Including perennial crops in rotations appears to positively impact soil quality.

Acknowledgements

- Saskatchewan Ministry of Agriculture Strategic Research Program-Soil Biological Processes
- AAFC
- Dr. Reynald Lemke

UNIVERSITY OF SASKATCHEWAN

Questions?

Saskatchewan Agriculture: 130^{ish} years

- Production and export of wheat dominated 1880s – 1950s
- Experimental farms established 1886
- Focus on preserving the soil

www.umanitoba.ca/libraries/archives/prairie_immigration