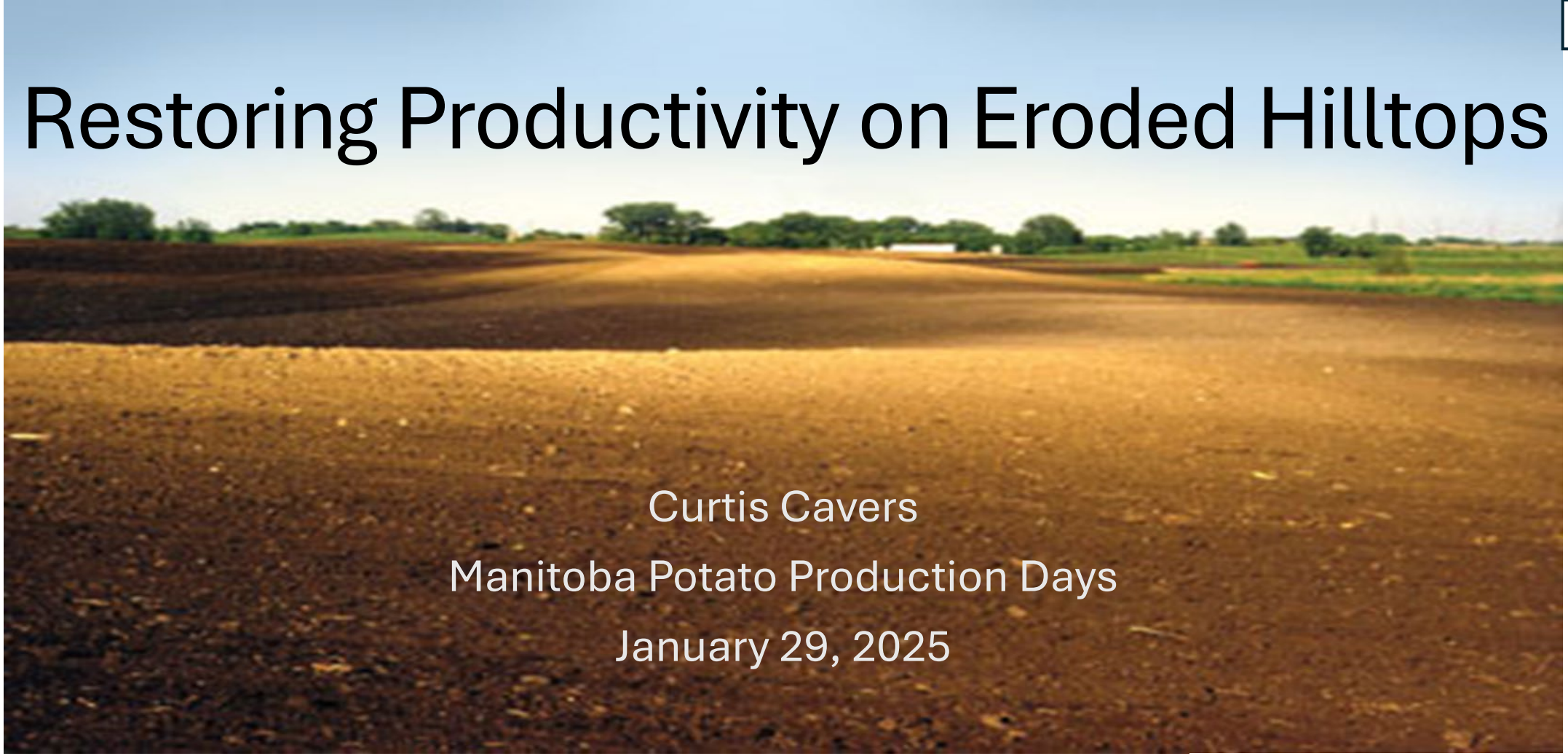
Restoring Productivity on Eroded Hilltops



Curtis Cavers

Manitoba Potato Production Days

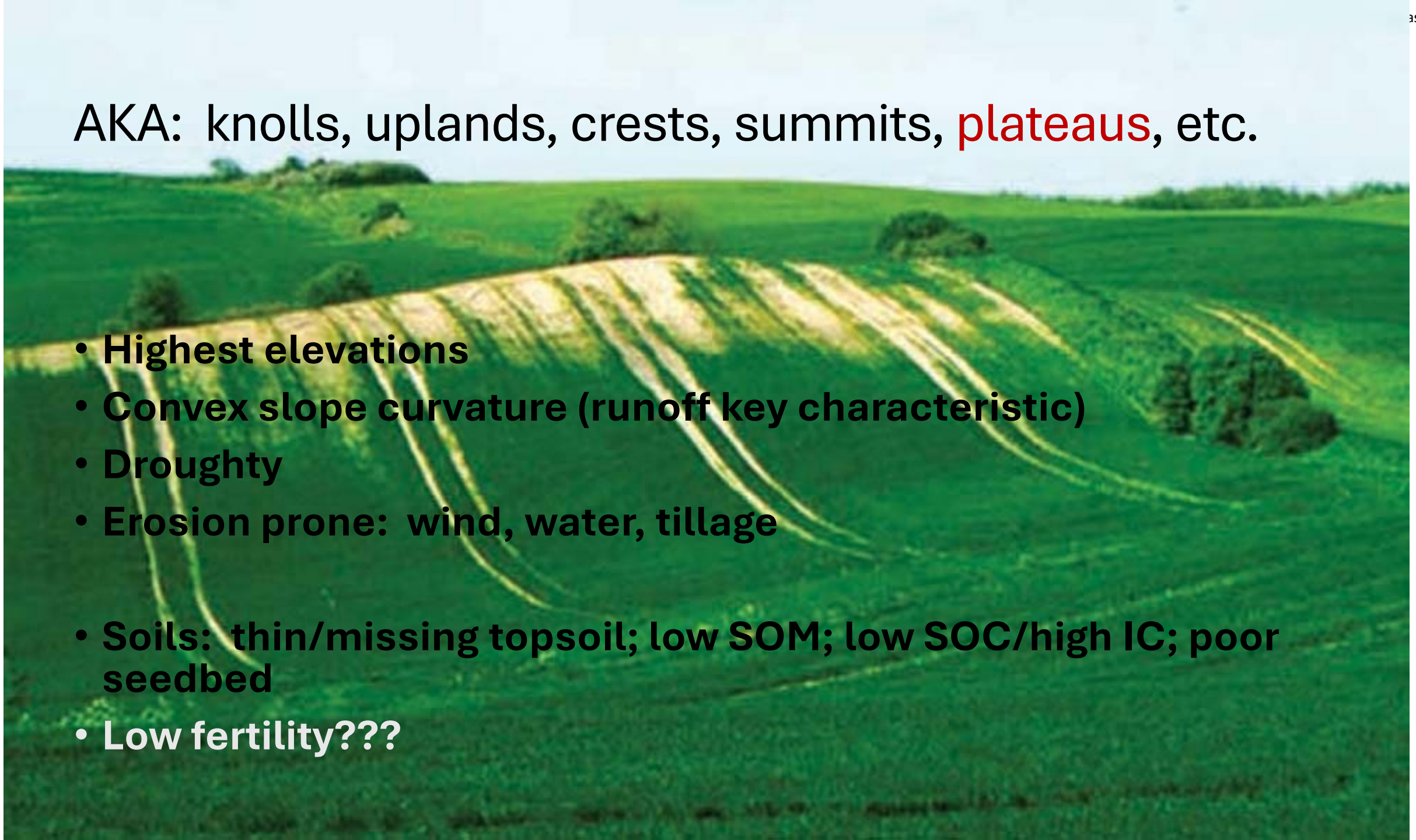
January 29, 2025

Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada

University of Manitoba

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AKA: knolls, uplands, crests, summits, plateaus, etc.

- **Highest elevations**
- **Convex slope curvature (runoff key characteristic)**
- **Droughty**
- **Erosion prone: wind, water, tillage**

- **Soils: thin/missing topsoil; low SOM; low SOC/high IC; poor seedbed**
- **Low fertility???**

Upland Soils – Characteristics

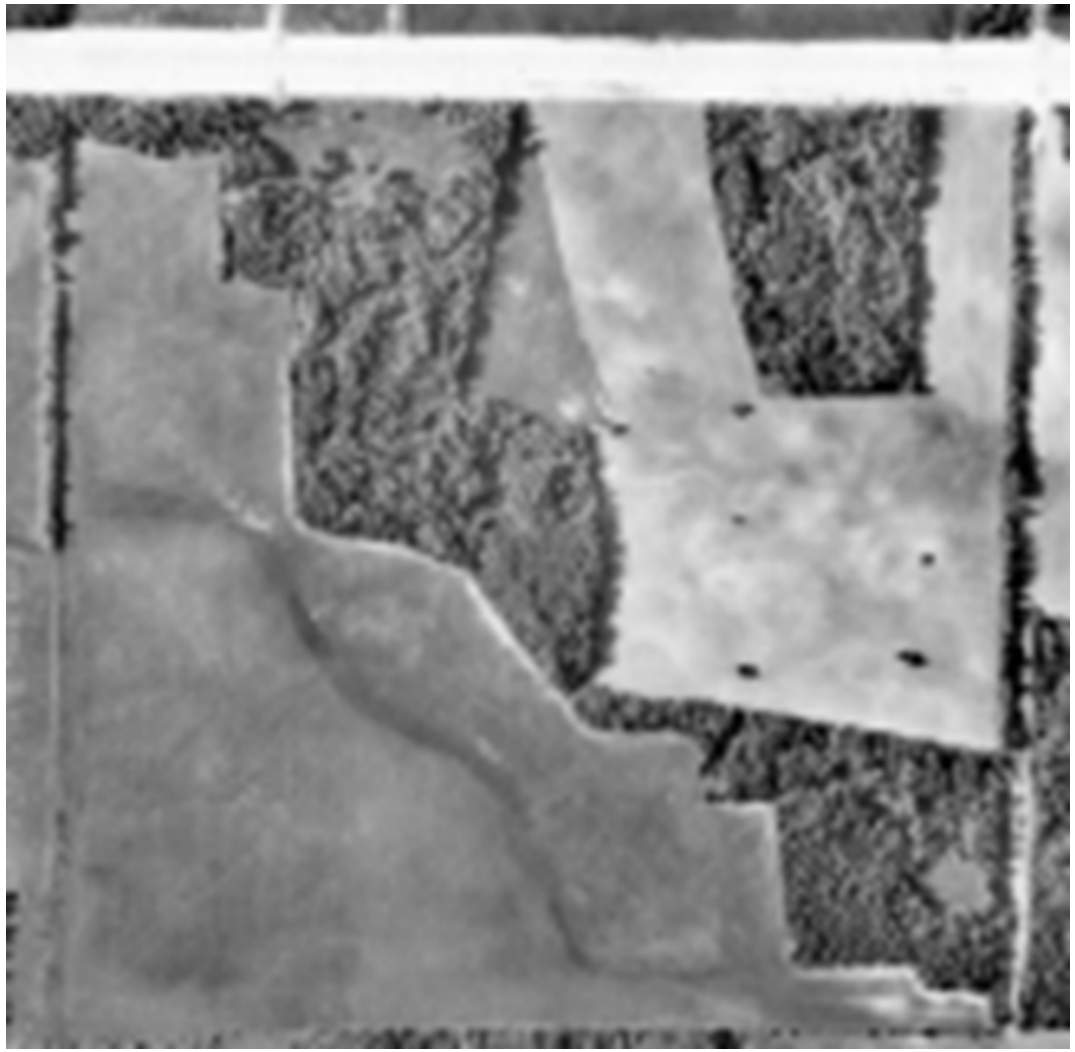


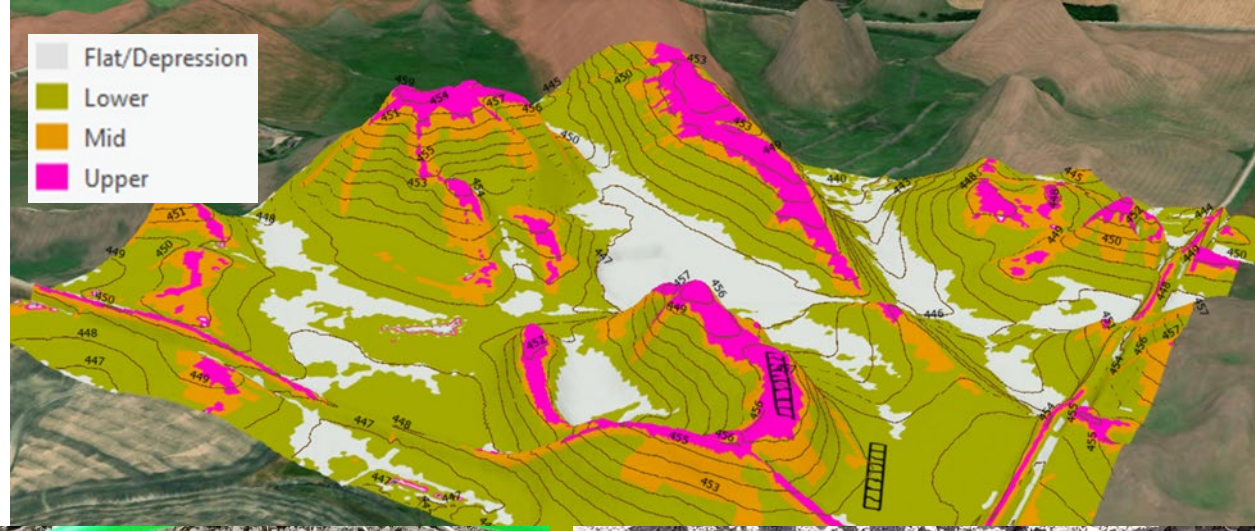
- Texture: variable
- Drainage: well/moderately well (dominantly runoff vs infiltration)
- Agriculture Capability limitations: E (eroded)
  M (lack of moisture, droughty)
  T (topography) – slopes
- Weedy: poor crop competition;
  poor herbicide efficacy/breakdown due to low SOM



- What they are NOT: wet, saline, compacted

What they look like…









Why It (the title) Matters…

- Eroded Hilltops are consistently the lowest-yielding areas of a given field, especially in years of low-normal rainfall – but typically occupy 10-30% of the landscape
- Relative productivity: 30-50% of yields from midslope/depression
  - Goal: 80% (F. Zvomuya)
- Isn't it enough to practice "No-Till"? (R. Stevenson & others: No!)
  - 2 reasons:

1) SOIL FORMATION IS A VERY SLOW PROCESS, EVEN UNDER NO-TILL… not years – decades/centuries! (Pimentel et al, 1976)

The Dominant Erosion Pathway:
2) Tillage Erosion

- The Good News:
  - Not the entire field (usually)
  - Little soil has left the field (redistribution)
  - Reversible

- The Bad News:



Topsoil: The Secret Ingredient

- Organic Carbon (OC) (Bullock & Kravchenko) – the “hero”
- versus

Inorganic Carbon (IC) (Schneider et al)

– the “villain”



Restoring Productivity on Eroded Hilltops – Options

1. Increase cropping inputs
2. Increase water supply
3. Redistribute crop residues
4. Add livestock manures/compost
5. Add other organic amendments
6. Plant cover crops
7. Add topsoil from downslope




GOOD
EXPENSIVE
TAKES TIME
DOES NOT EXIST
FAST
CHEAP
LOW QUALITY

1. Increase Cropping Inputs

a. Add more fertilizer

- Kapoor & Shaykewich (1987):

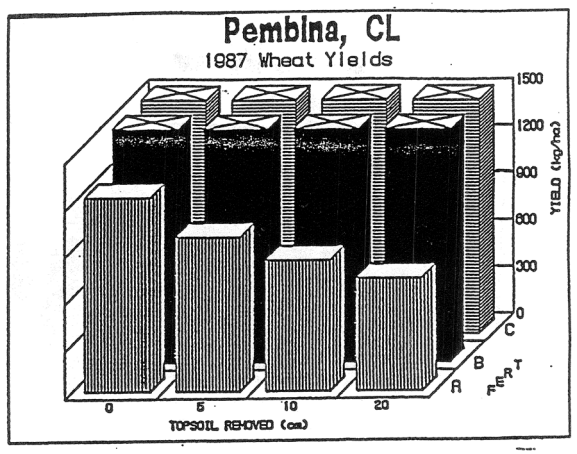


Figure 1. Effect of topsoil removal and fertilizer applications on wheat yields grown on a Pembina clay loam.

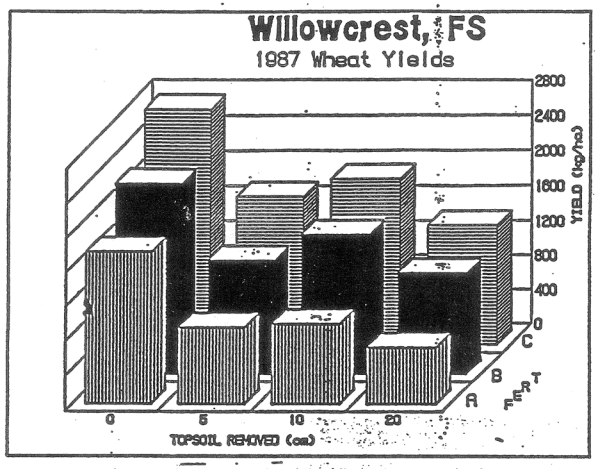


Figure 3. Effect of topsoil removal and fertilizer applications on wheat yields grown on a Willowcrest fine sand.

b. Increase seeding rates

- Gyssels et al (Belgium)
- Cavers (2022/23 demos):

Wheat (bu/ac)	Portage (level)	Altamont (eroded knoll)	
Check	70	Check	11
2X seed	55	2X seed	17
2X fert	72	+ topsoil	15
2X seed + fert	49	2X seed+ topsoil	20

c. Strategic Planting (“Crop the Best, Diversify the Rest”)

2. Increase Water Supply (aka Irrigation)

- Andrew McGuire (from WSU, at MPPD, ~2019):
  - “Crop Yields: it’s all about the WATER!”
  - Irrigation overcomes climate and specific soil limitations (Egli & Hatfield, 2014)
  - **Soil Health ≠ Crop Productivity (Be careful!)**

- Economics & other considerations:
  - Cost of irrigation equip
  - Cost of tile drainage?
  - Assume land base is suitable for irrigation
  - Assume available water resources?

- McGuire’s rule of thumb: Maximize photosynthesis; minimize tillage…

3. Redistribute Crop Residues

- Relatively cheap, easy; available resource (Duane Thompson - SK)
  - Reduce evaporation & runoff, conserve moisture
- Cavers 2023 demo:

Altamont 2023 (eroded knoll)	Wheat yield (bu/ac)
Control	11
Added straw	9
Added topsoil	15
Added topsoil + straw	13



- Chaff >> straw
- Rates???
- Weed management?
- Heavy harrows → tillage… (***not*** no-till, technically) – Dwayne Beck - SD
- Livestock Integration (Bale Grazing)

4. Add Livestock Manure/Compost

- Livestock Integration (Bale Grazing)
- Availability?
- Nutrient over-applications (regulations)
- Odour



- Larney: “legacy effects”
- Lobb/Beauchamp: How long to increase SOM by 1% (10 g kg^{-1}) (using beef manure annually @ P rates)?

30 years!!!

5. Add (Other) Organic Amendments

- Examples include: biochar, biosolids, paper mill by-products, etc

- Larney and Angers (2012): considerations (like manure mgmt.)
  - readily-decomposable vs. stable (C:N ratio)
  - waste vs resource
  - large single application vs cumulative loading

- Cost? Effectiveness? Buyer beware…



6. Plant Cover Crops



- Lawley, Morrison, etc: numerous benefits, but:

- Difficult to establish on eroded hilltops under dry conditions
  - Less biomass – less C sequestered
  - LT forages better?
  - Economics vs annual cropping…

- Cover crops can ***deplete*** soil of moisture needed by the upcoming cash crop (a problem if moisture is limiting)

7. Add Topsoil from Downslope (aka Landscape Restoration)

- An immediate increase in SOC (not “sequestration”, but sets stage for future)
    - *“It is important to consider redistributing SOM-rich topsoil rather than trying to increase it in-situ.”* (McGuire, 2023)
    - Crop yield response – it depends…
- “One-time” practice, if done “right”…



Bruxelles, 2020





Comparisons…where possible

Research	Increase in SOM concentration (%) @ 0-6” depth	Increase in SOC stocks - % (sequestration rate)	Increase in Crop Yield (%)
LSR - Schneider et al (2021) – MN	**112%** From 29 to 62 g kg^{-1}		21-53% (corn); 12-59% (soybean)
LSR - Smith and Lobb (2008) – MB	**108%** From 22 to 46 g kg^{-1}		10-133% (various sites & crops)
LSR – Cavers et al (2024) - MB - Unpublished	**53%** From 33 to 50 g kg^{-1}	**36%** From 98,000 to 134,000 lb C ac^{-1}	TBD
No-Till for 21 years - SK (Schoenau* and Hangs, 2020)	**25%**	196-405 lb C ac^{-1} yr^{-1}	
Multiple beef manure app’s (Larney and Olson, 2018) - AB	**19%** From 25 to 30 g kg^{-1}		
Cover crops for > 5 years (Peng et al, 2023) - N. America	**8%**	**7%** 214 lb C ac^{-1} yr^{-1}	
Permanent grass seed-down for 8 years (Nelson et al*, 2008) - SK		1250 – 2600 lb C ac^{-1} yr^{-1}	N/A

Restoring Productivity on Eroded Hilltops - Summary

Management Practice	Pros	Cons
1. Increase seed, fertilizer rates	Easy	Cost; effectiveness (short term)
2. Irrigation	Effective	Cost; availability
3. Re-distribute Crop Residues	Soil/weed mgmt benefits; easy	Additional time, equipment
4. Manure/Compost	Builds SOM, nutrient source	Availability
5. Organic Amendments	Numerous products; claims (?)	Effectiveness
6. Cover Crops	Numerous benefits	Establishment; competition
7. Landscape Restoration	Fast; effective; consistent (?)	Still refining protocols; data…

Future Strategies

- "Hefty Bros approach" to buying new farmland: ***fix soils first!***
- Some combination of LSR + No-Till + one of the other practices?
- ***Pick one,*** either: 1. "true", low-disturbance No-Till, or
  2. consider a new approach to ***smart, strategic tillage***:
    - Speed
    - Direction
    - Horsepower
    - Timing/purpose

Conclusions

- Put SOM/SOC/topsoil where it is needed most to receive the greatest benefit

- Keep topsoil in its place, going forward

– minimize tillage erosion without totally eliminating tillage… heresy???

- Use precision ag principles that *may/may not* include variable rate application of inputs (is it necessary if the field is “uniform”?)

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Thank you!

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