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A Reconsideration of Grazing Impacts on Soil Carbon in Northern Temperate Grasslands

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Overall Research Objectives

- Quantify the size of carbon stores in northern grasslands, including within different ecosystem components (veg & soil; shoot, root & litter)
- Assess whether grazing increases or decreases carbon, including where and when these changes occur
- Identify mechanisms responsible for carbon changes (i.e., to improve predictability of carbon increases)

Long-term GOAL: Provide a quantitative foundation that can be used to reward ranchers for enhanced carbon storage

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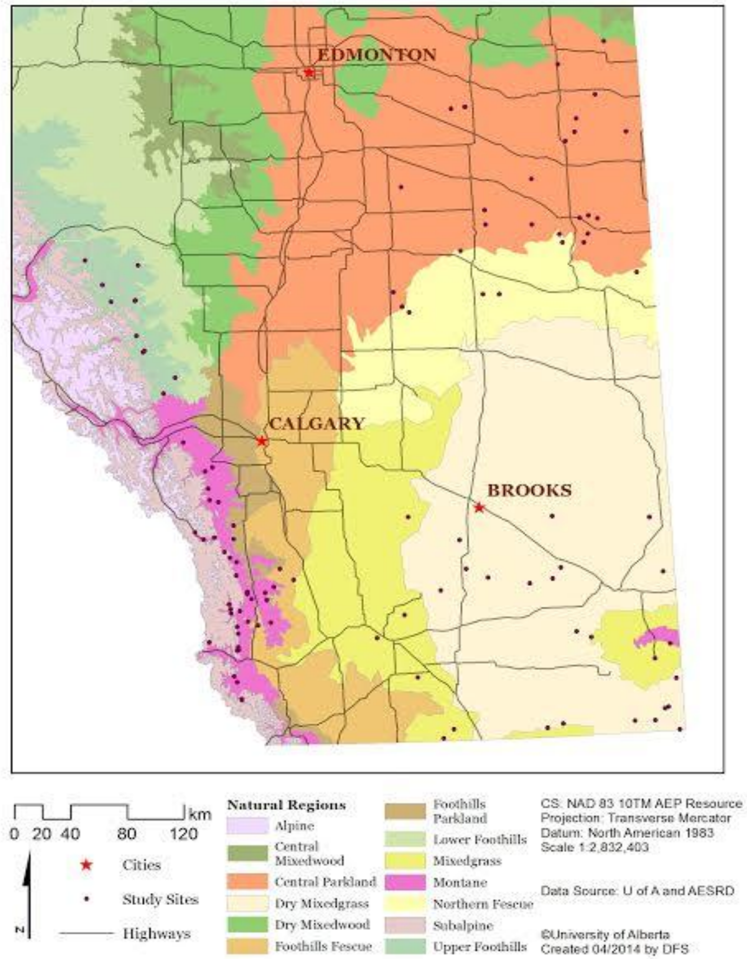
Study Methods (Phase 1)

- Carbon benchmarking study (2012-2015) sampled 106 grasslands covering 6 natural subregions (wide agroclimatic variation)

Harold Creek, Upper Foothills

Schuler, Dry Mixedgrass

Carbon Benchmarking Sites in Alberta



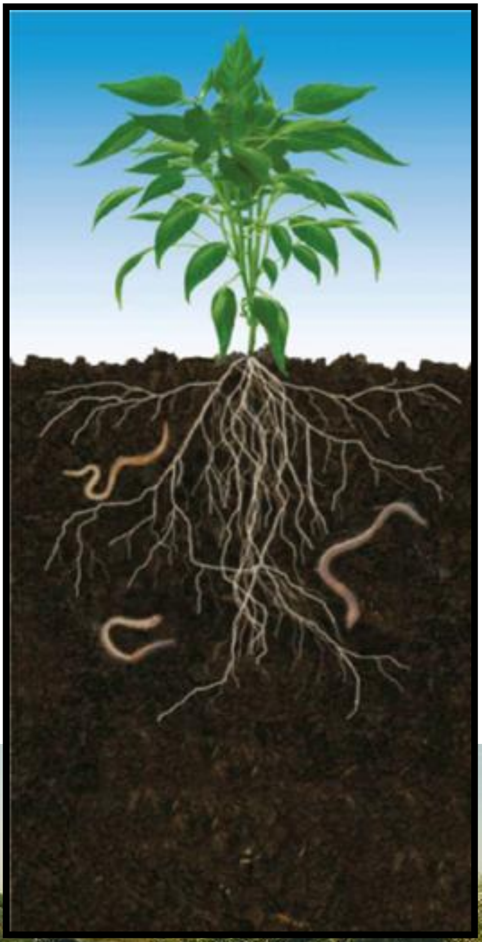
ALMA
Alberta Livestock and Meat Agency Ltd.

Methods (Study 1)

- Sampled vegetation and soil for carbon (C)
  - Vegetation: Shoot herbage, litter, and mulch, and roots (0-30 cm)
  - Soil carbon within organic and inorganic pools

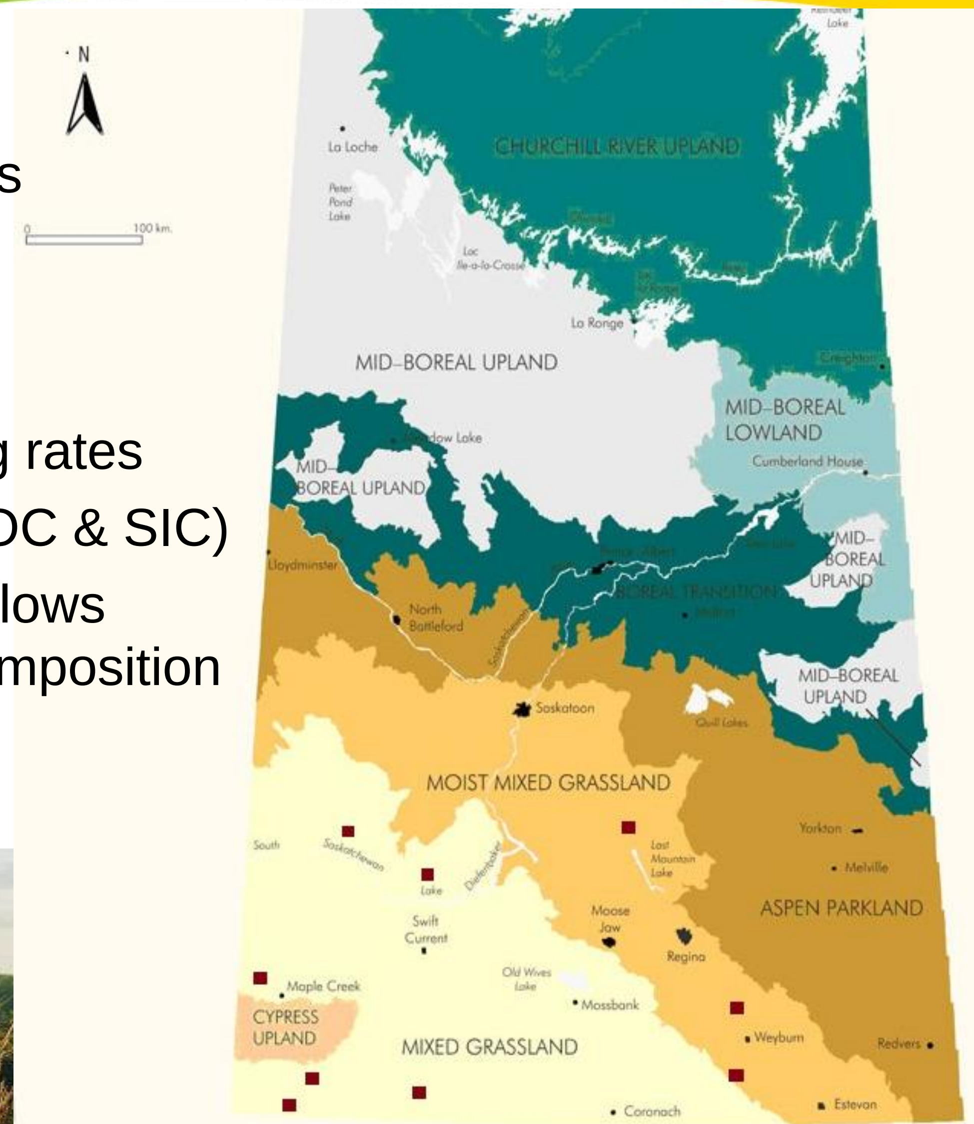
- Strengths – large number of study sites (> 100), varied ecosystems, comprehensive vegetation data
  - Biomass & composition

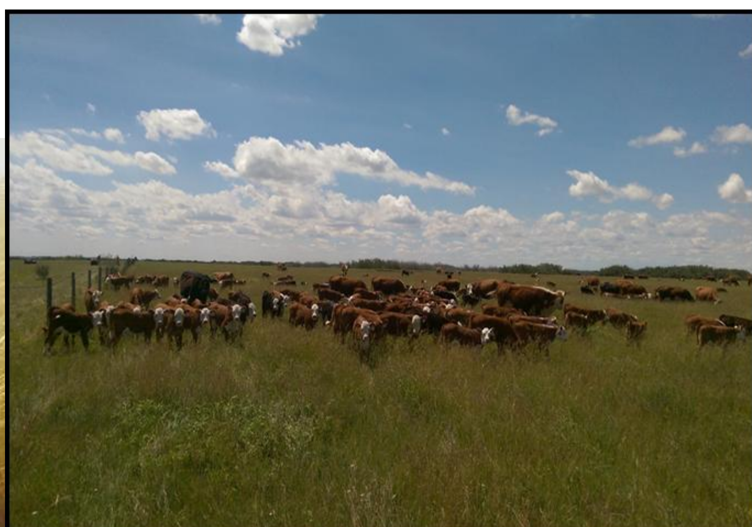
- Limitations – soil C assessed to only 30 cm; no test of variable stocking rates
  - All study areas subject to moderate stocking (public lease land)



Methods (Study 2)

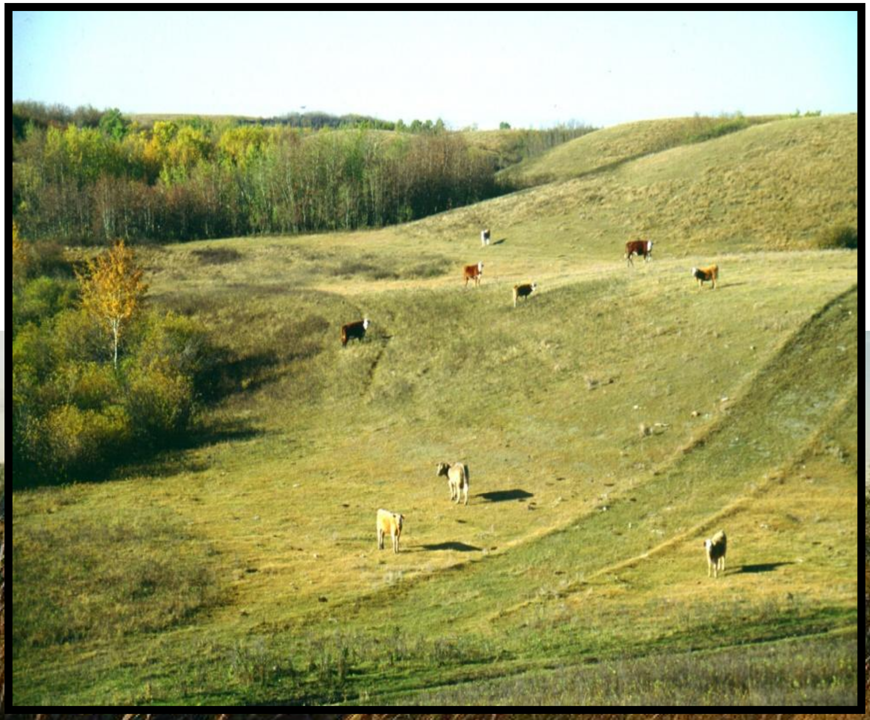
- Companion study from mixed grass sites in Saskatchewan
  - 9 Community pastures
  - 33 paddocks
- Long-term (25-year) cattle stocking rates
- Soil C sampled to 60 cm depth (SOC & SIC)
- Associated range condition data allows linkage between soil C and veg composition





Methods (Study 3)

- Nutrient cycling study (2014-2017) assessed litter decomposition and extracellular enzyme activity in 15 grasslands covering 3 subregions in AB (Mixedgrass, Parkland, Foothills Fescue):
  - Examined 8 different grasses with known differences in response to grazing
  - Decreasers (foothills & plains rough fescue, needle & thread grass)
  - Increasers (Junegrass, western wheatgrass, blue grama grass)
  - Introduced spp. (Kentucky bluegrass)



Methods (AgroForestry Study)

- Agro-forestry (2012-2016) comparison at 36 locations across central AB (Chang, Bork & Carlyle)
- Contrasted 3 agroforestry systems, including contribution of ‘forested’ and ‘herbaceous’ areas within:
  - Shelterbelt – Annual cropland
  - Hedgerow – Annual cropland
  - Aspen forest – Grassland


Forest-Grassland


Shelterbelt-Cropland

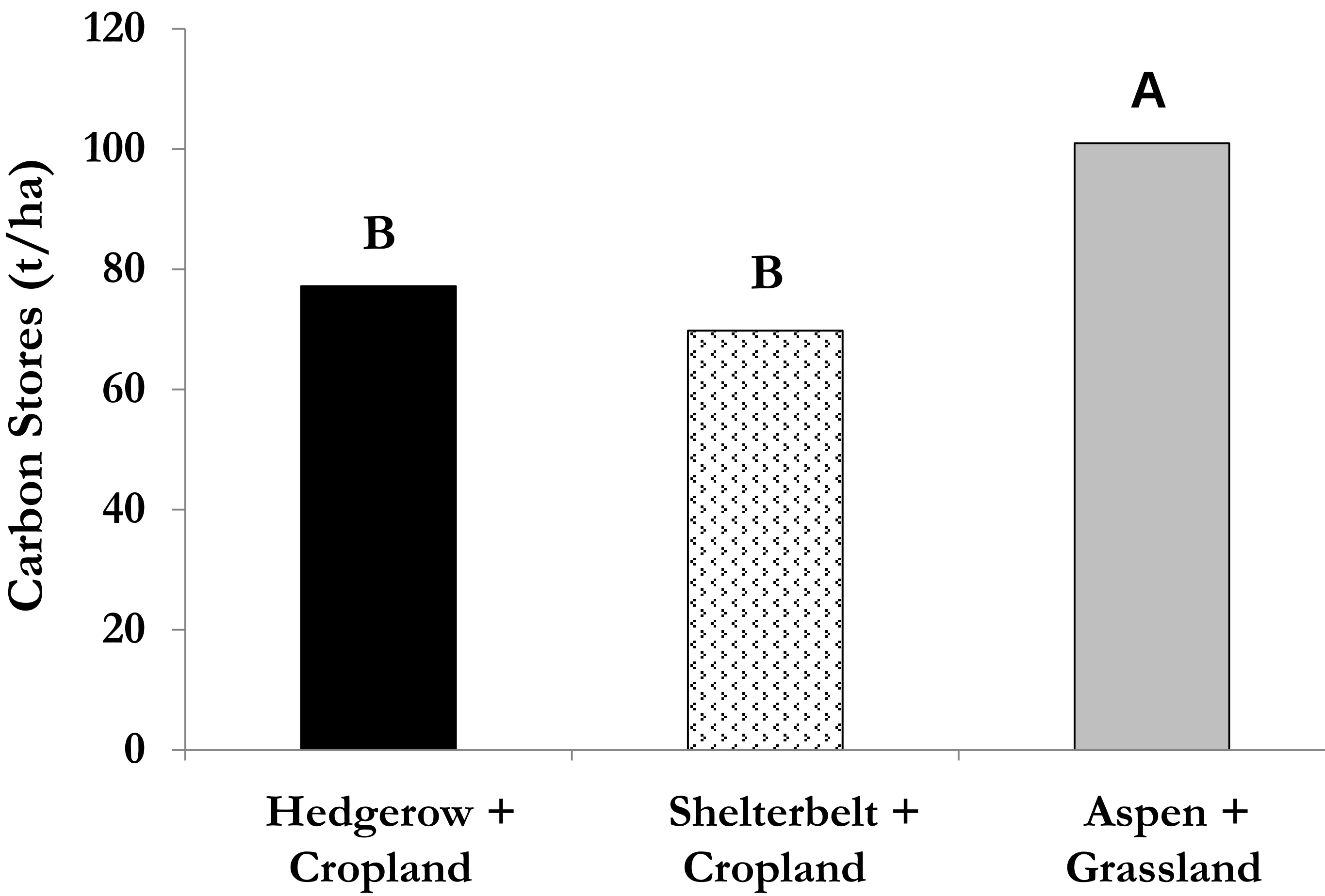

Hedgerow-Cropland

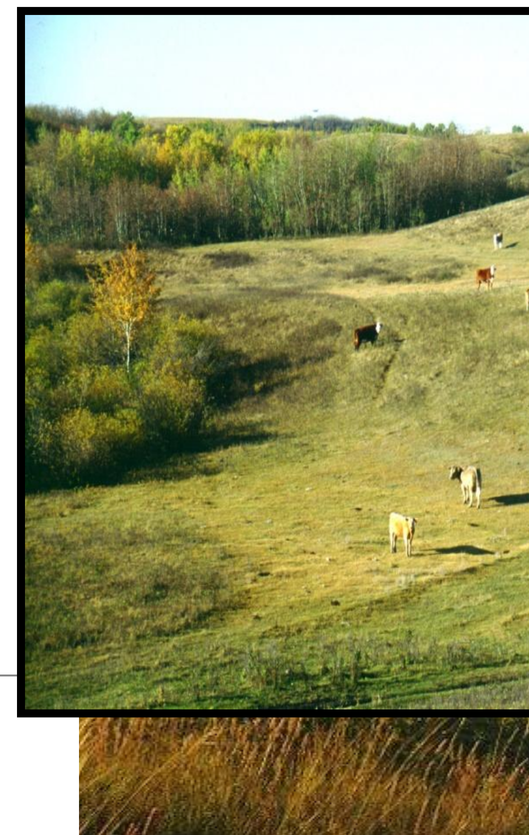
Question 1

What is the role of grasslands in storing carbon?

Results (Agroforestry)

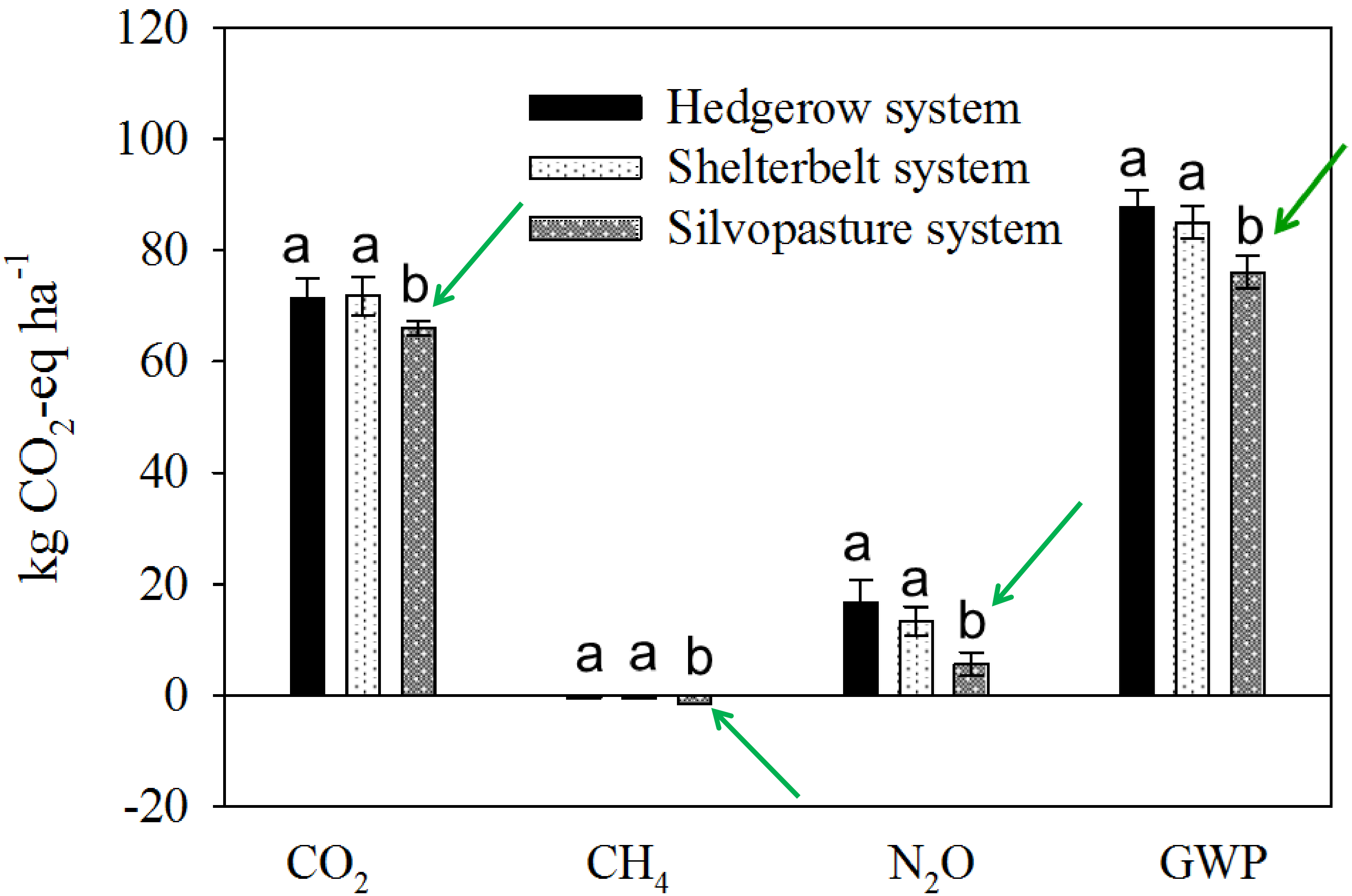
- Silvo-pastures (aspen + perennial grassland) stored more C in the top 10 cm of soil due to the combination of 2 perennial vegetation types (Baah-Acheamfour et al. 2015)





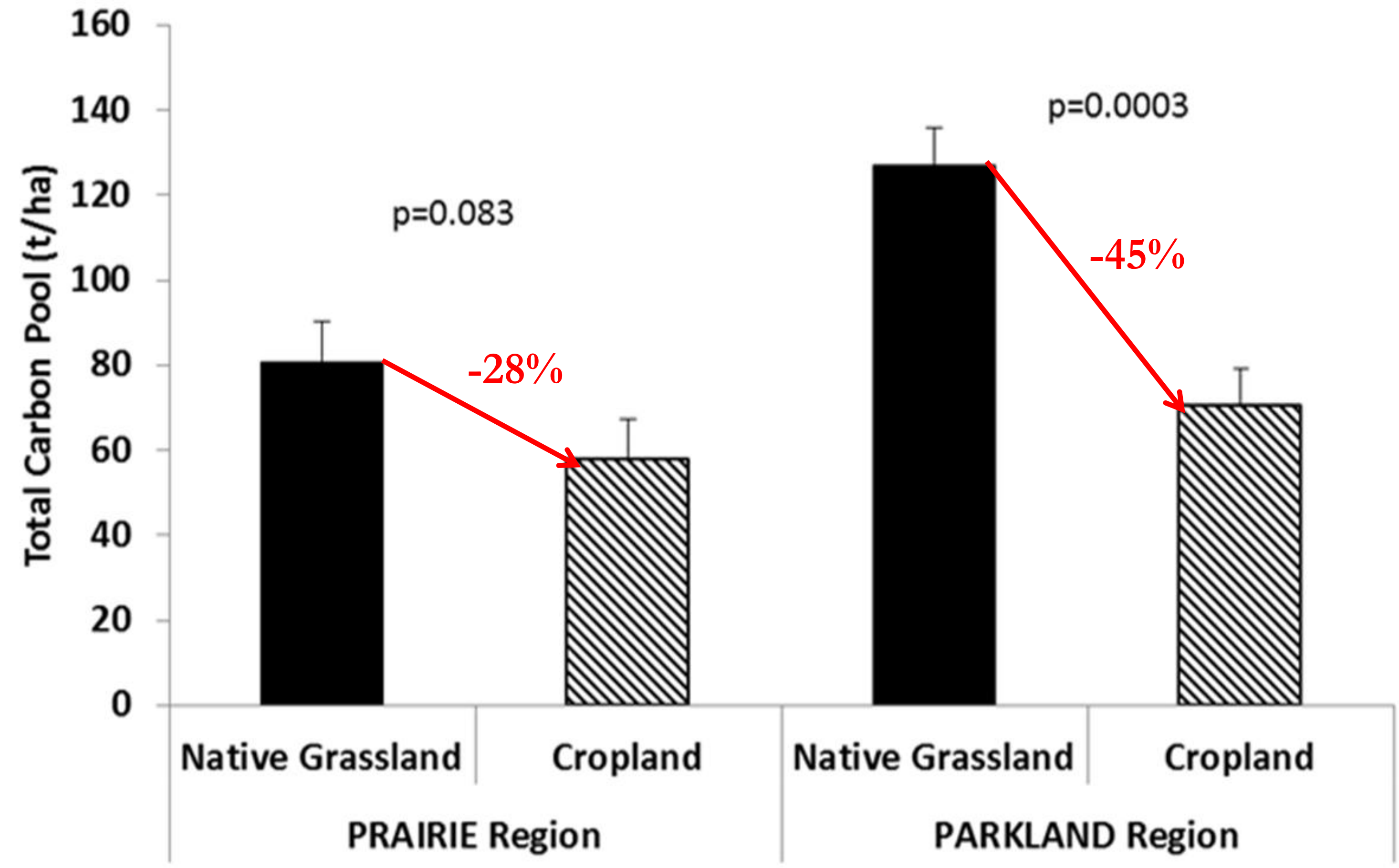
Results (Agroforestry)

- Silvo-pastures had lower CO_2 and N_2O flux, as well as greater CH_4 uptake, leading to less Global Warming Potential (Baah-Acheamfour et al. 2016)



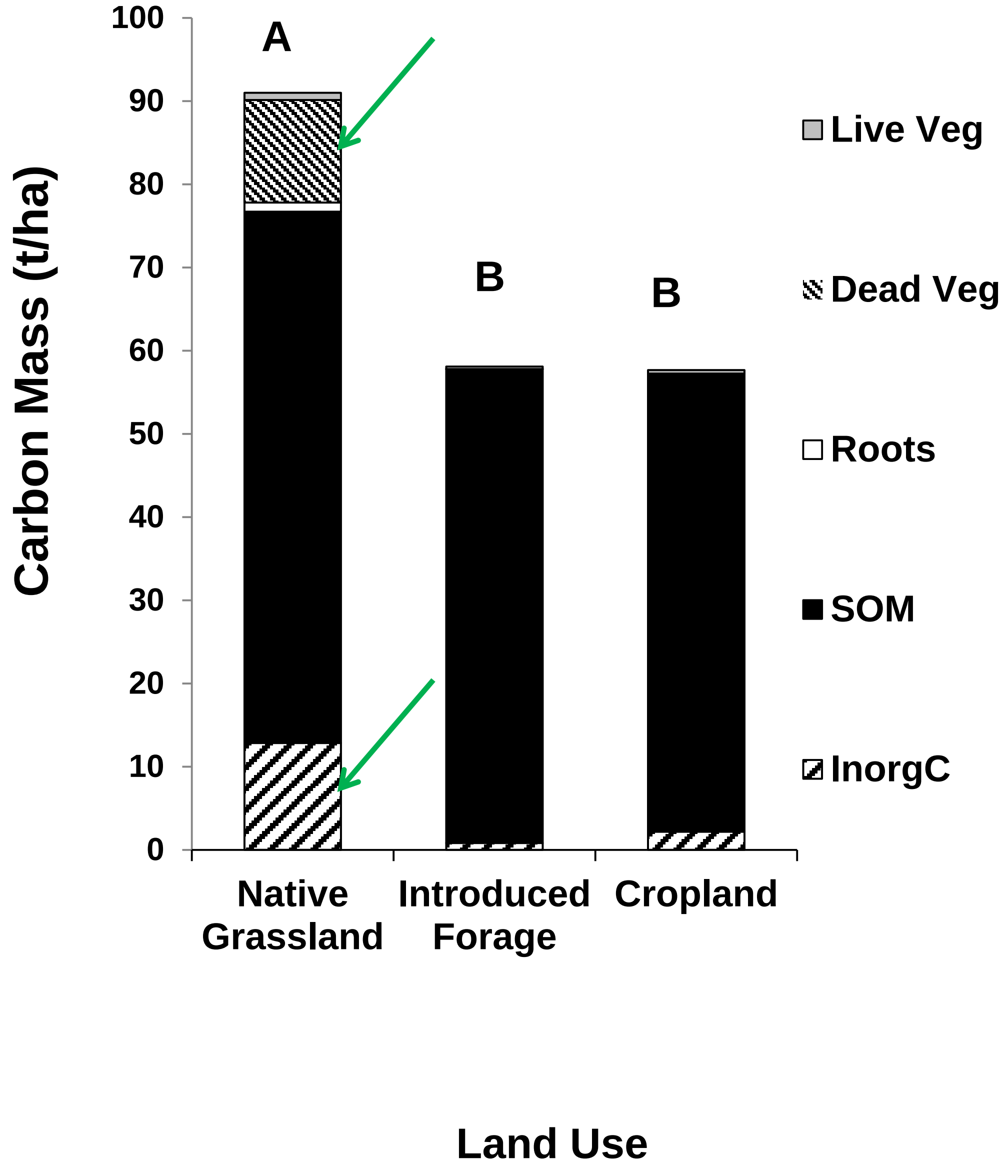
Results (C Benchmark Study)

- Similar results regarding land use conversion effects on ecosystem C in the benchmarking study



Results (C Benchmark Study)

- Native grasslands contained large amounts of C, especially in comparison to other land use types
- Most C was in soil, including substantial levels of inorganic carbon
- Vegetation, particularly the litter & mulch layer, also stored significant amounts of C

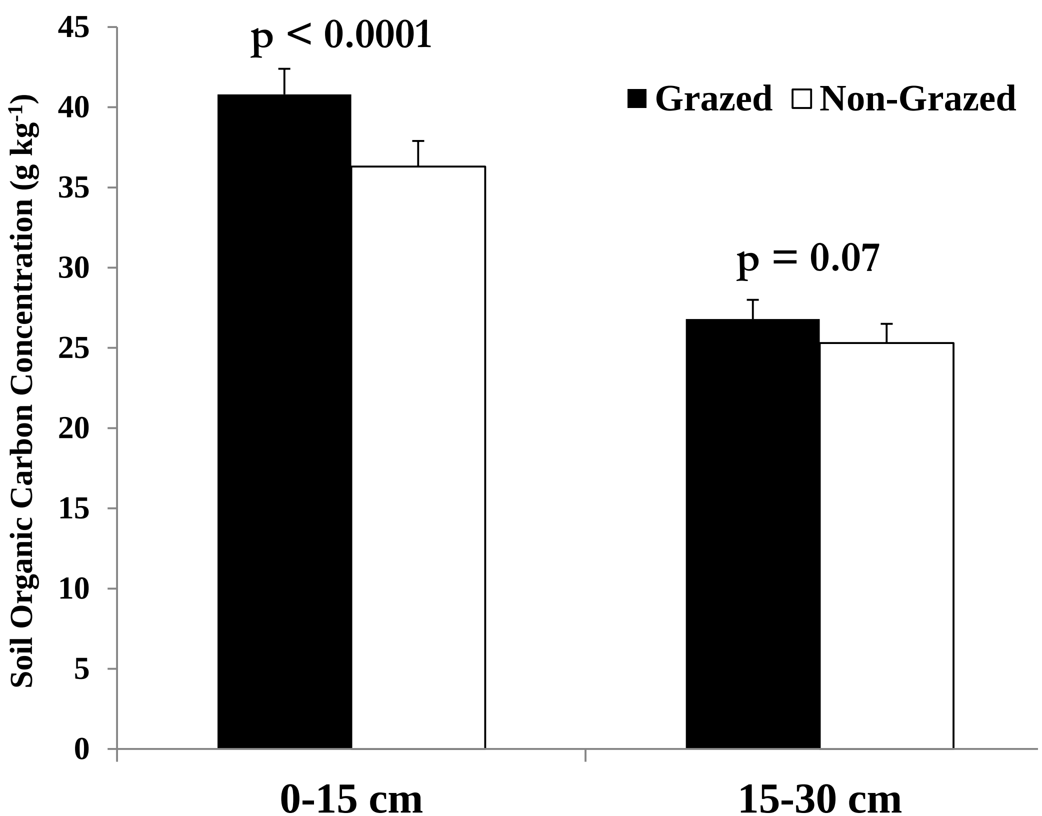


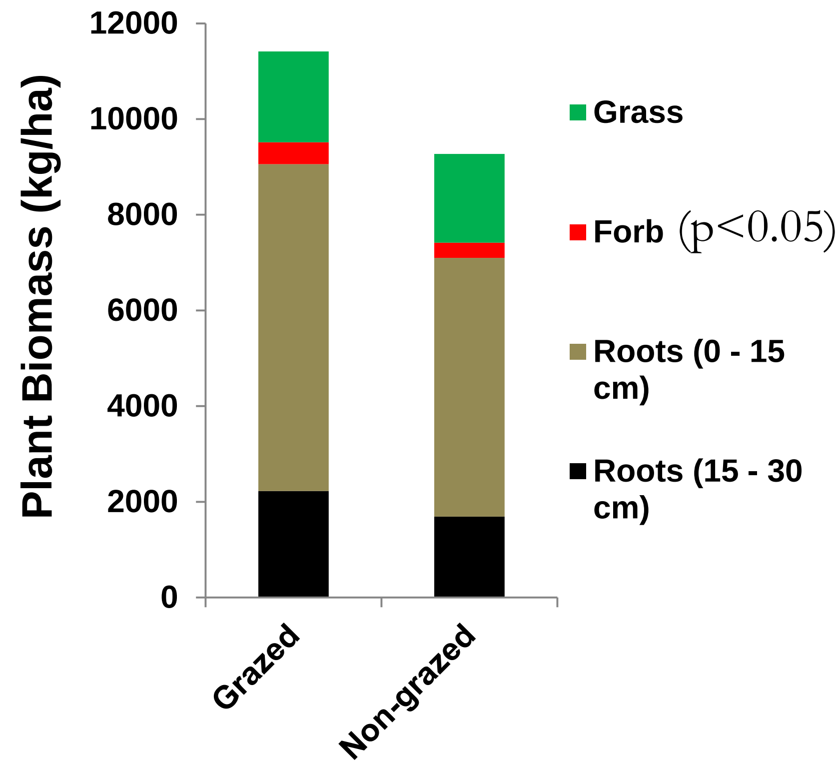
Question 2

What is the specific role of grazing in regulating carbon stores within northern temperate grasslands?

Results (C Benchmark Study)

- Across all 106 study sites, soil C concentrations were greater under grazing (Hewins et al. 2018)
- This response appeared to be largely independent of plant biomass – only forb mass increased significantly (Bork et al., in revision)

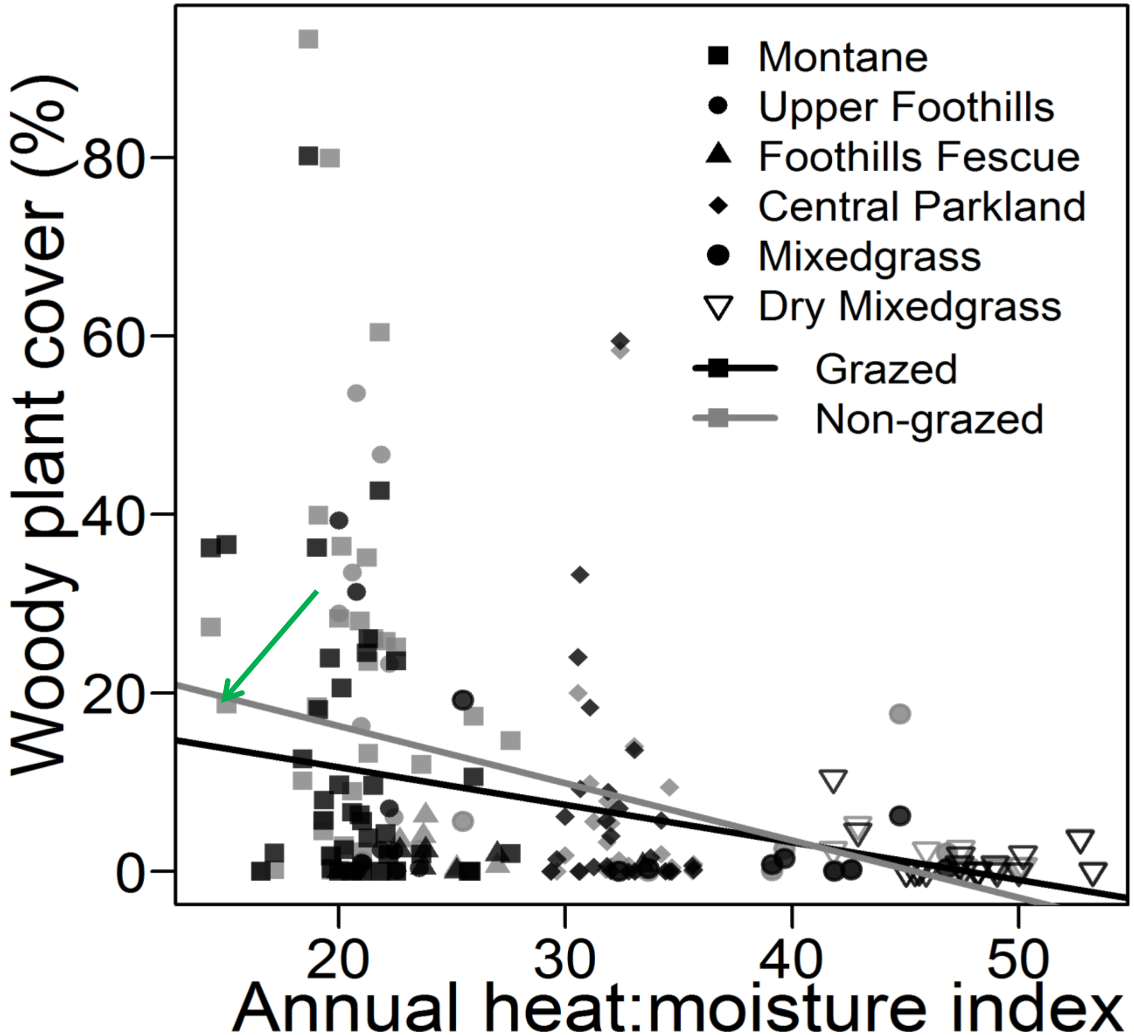




Results (C Benchmark Study)

- BUT … grasslands lacking livestock grazing had more shrubs under high precipitation (i.e., low AHM) (Lyseng et al. 2018)

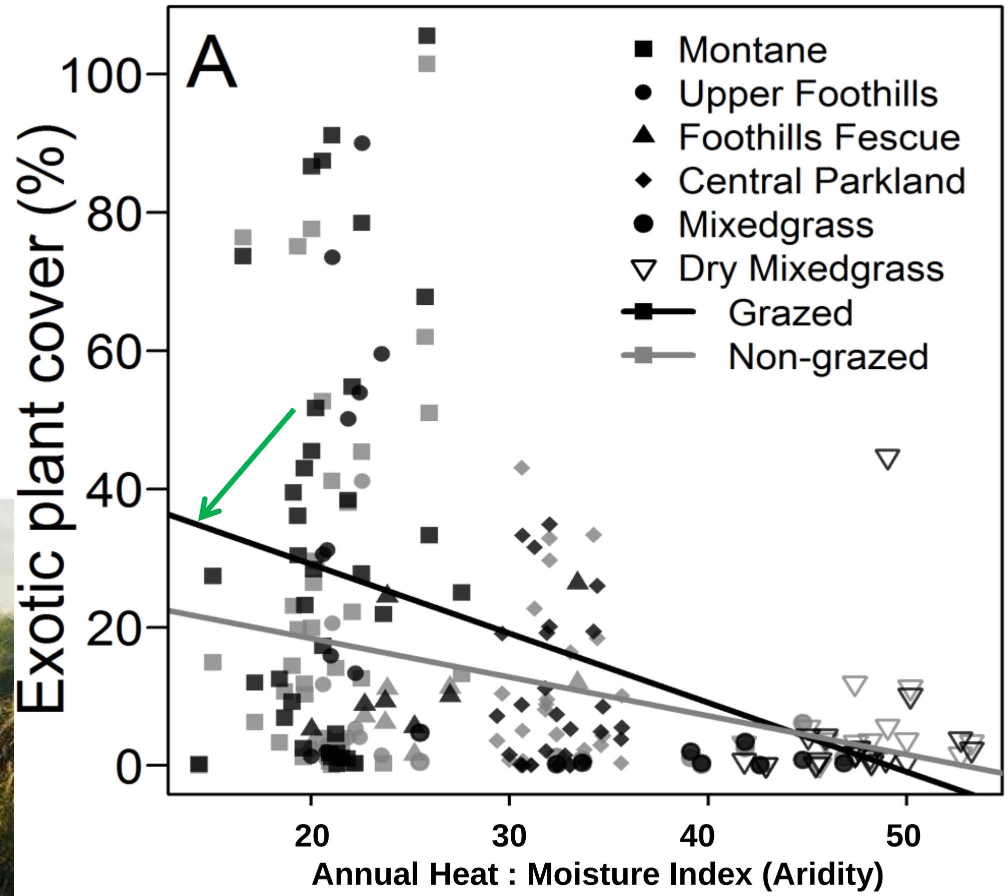
- Could shrub encroachment explain the lower carbon in non-grazed grasslands?



Results (C Benchmark Study)

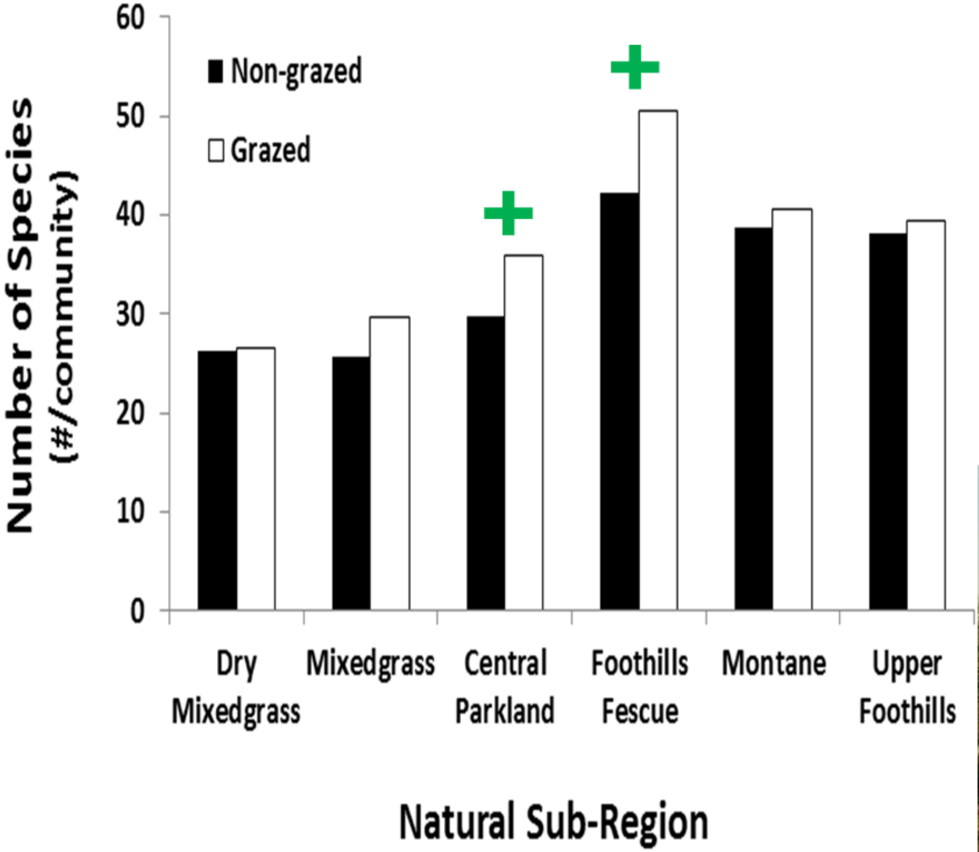
- When sites with >10% shrub cover were removed, no difference in soil C concentration existed in the remaining 73 sites (Bork et al., in revision):
  - Grazed = 1.29 ± 0.04% C *vs* Non-grazed = 1.18 ± 0.04% C ($p = 0.19$)

- Additionally, mesic grasslands (AHM < 30) had more exotic plant species when exposed to grazing (Lyseng et al. 2018)



Results (C Benchmark Study)

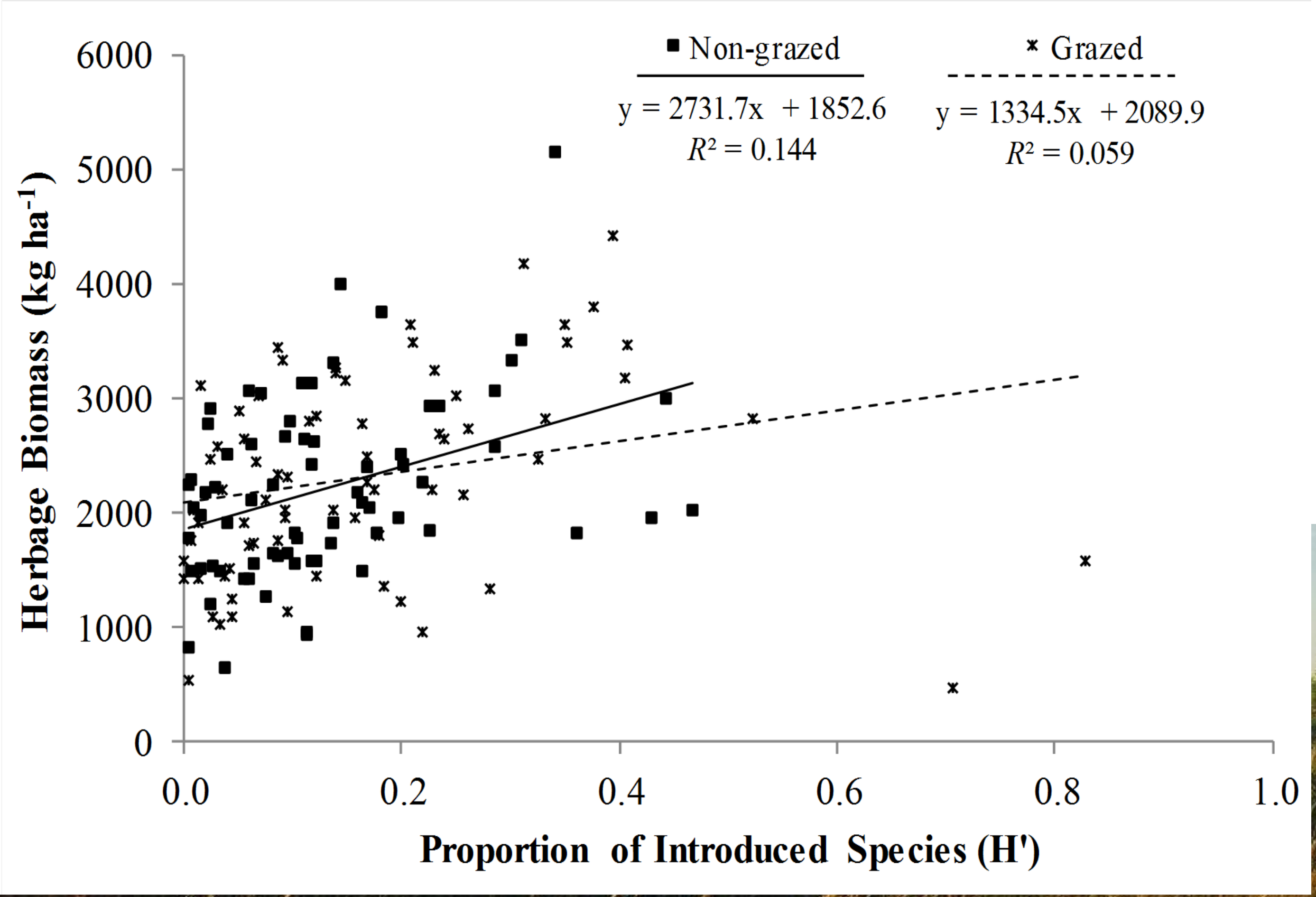
- Overall increases in plant diversity were also found due to grazing, in part due to the presence of introduced plant species growing with natives
- Increases in diversity, including of introduced spp., could enhance soil C under grazing (as per Sollenberger et al. 2019)



Results (C Benchmark Study)

- Herbage increases, in general, were closely tied to the relative abundance of introduced species (Bork et al., under revision)

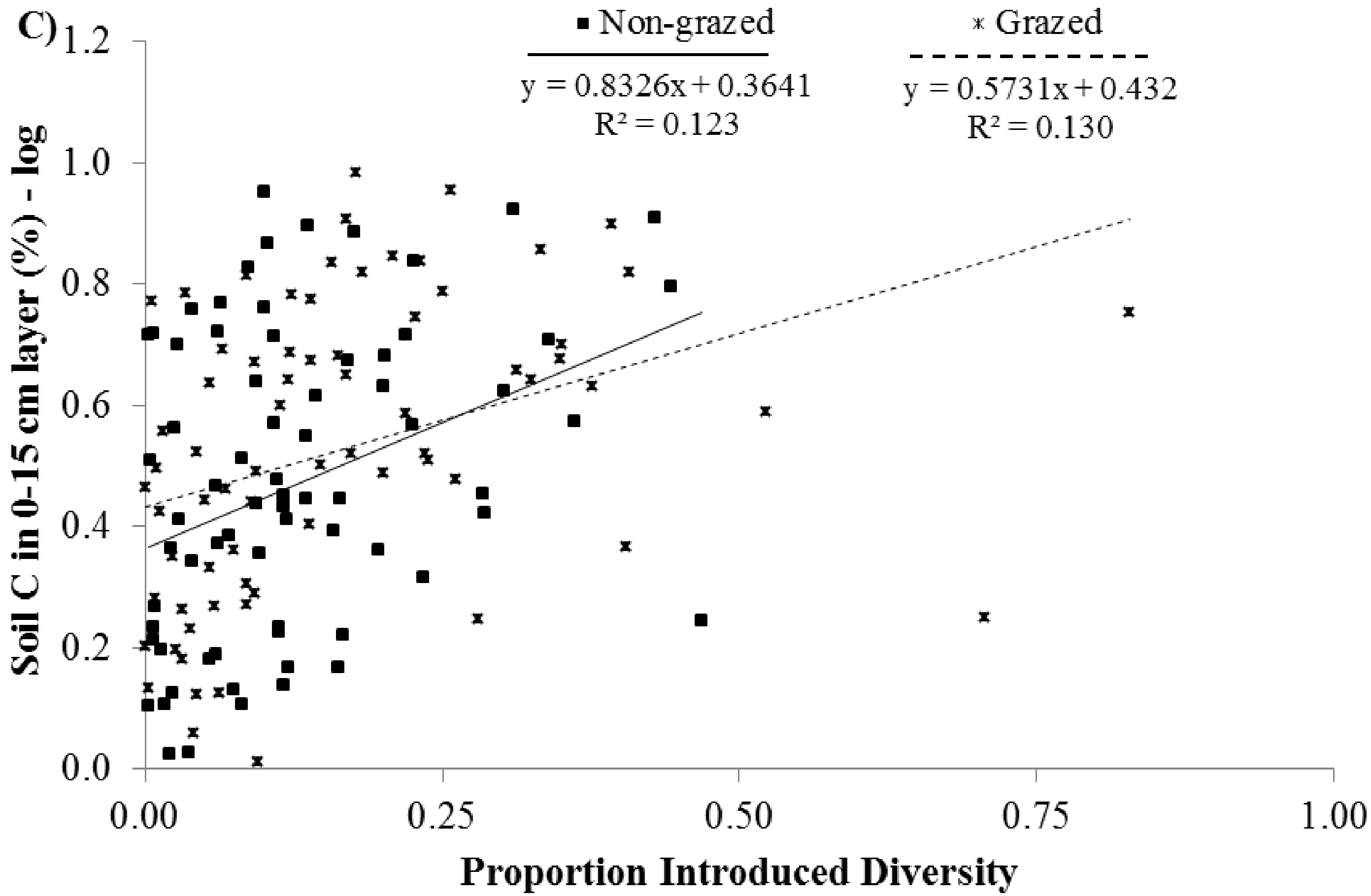
- Notably, these increases were evident in BOTH grazed and non-grazed areas (Bork et al., under revision)



Results (C Benchmark Study)

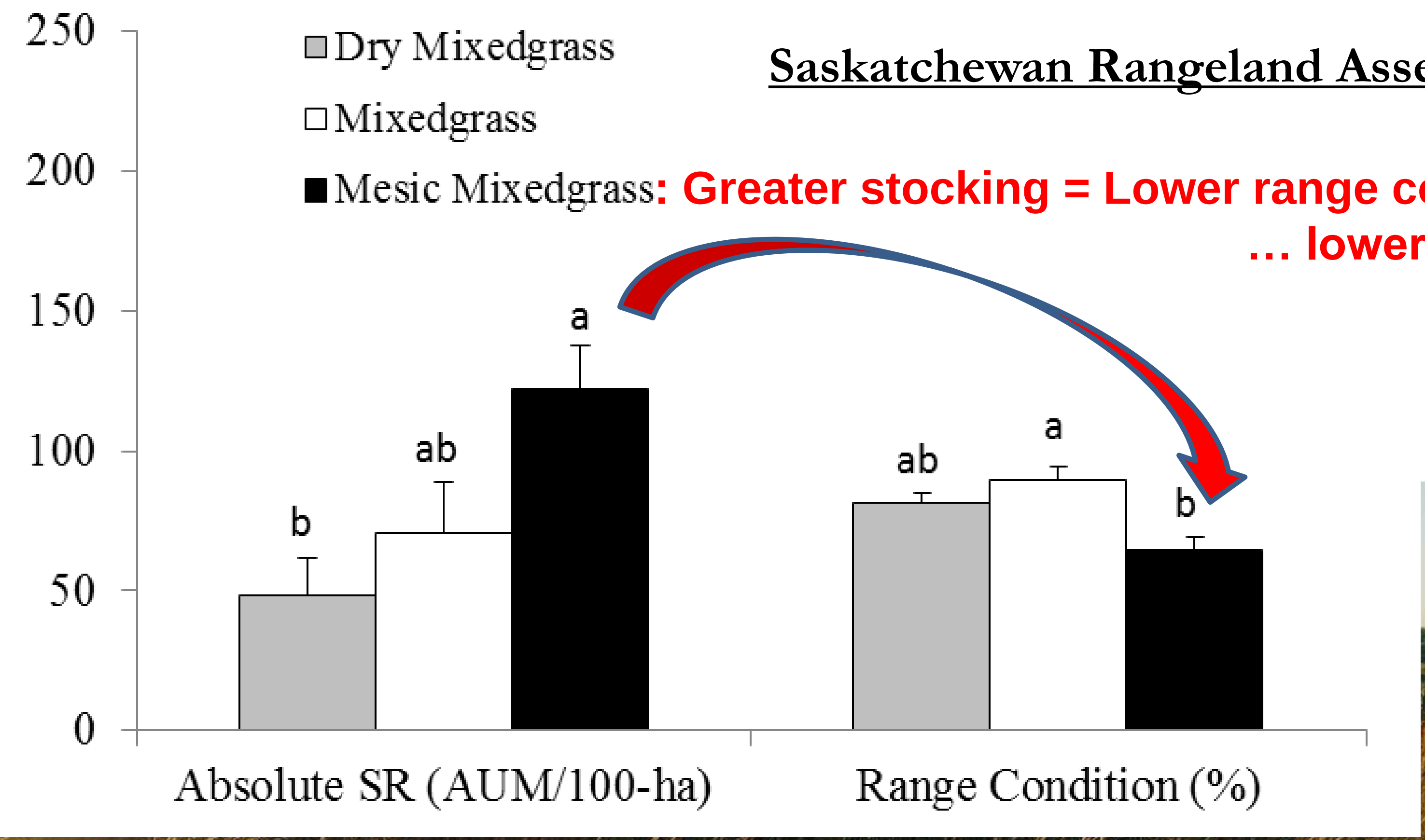
- Regardless of grazing history, soil C was positively related to the proportion of grassland diversity comprised of introduced/exotic species

Is this coincidence, or cause & effect?



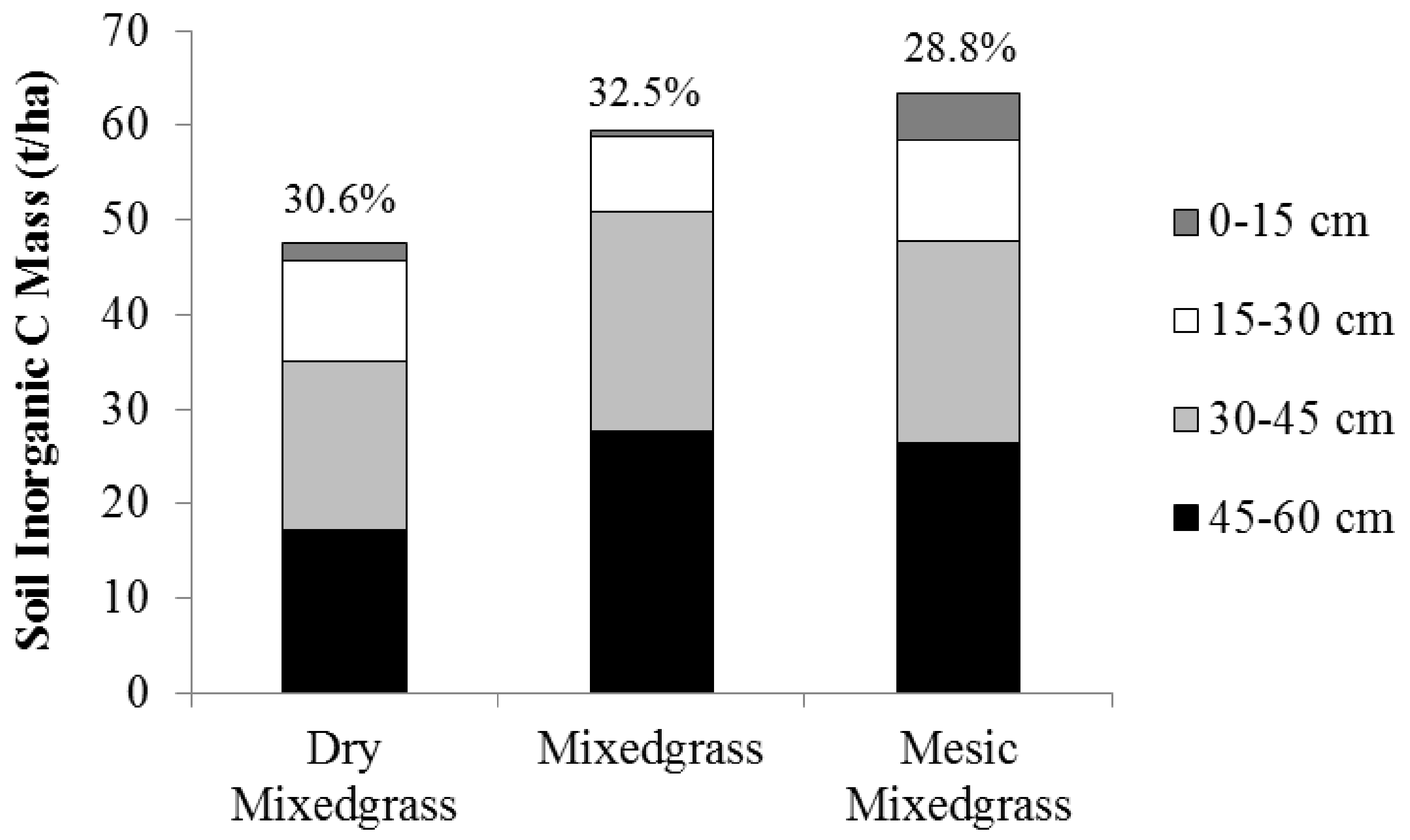
Results (SK Grasslands)

- Alberta findings suggest that introduced plant species are boosting soil C. A more definitive test of the role of grazing is warranted
- Data from SK grasslands add further clarification (Bork et al., in prep)



Results (SK Grasslands)

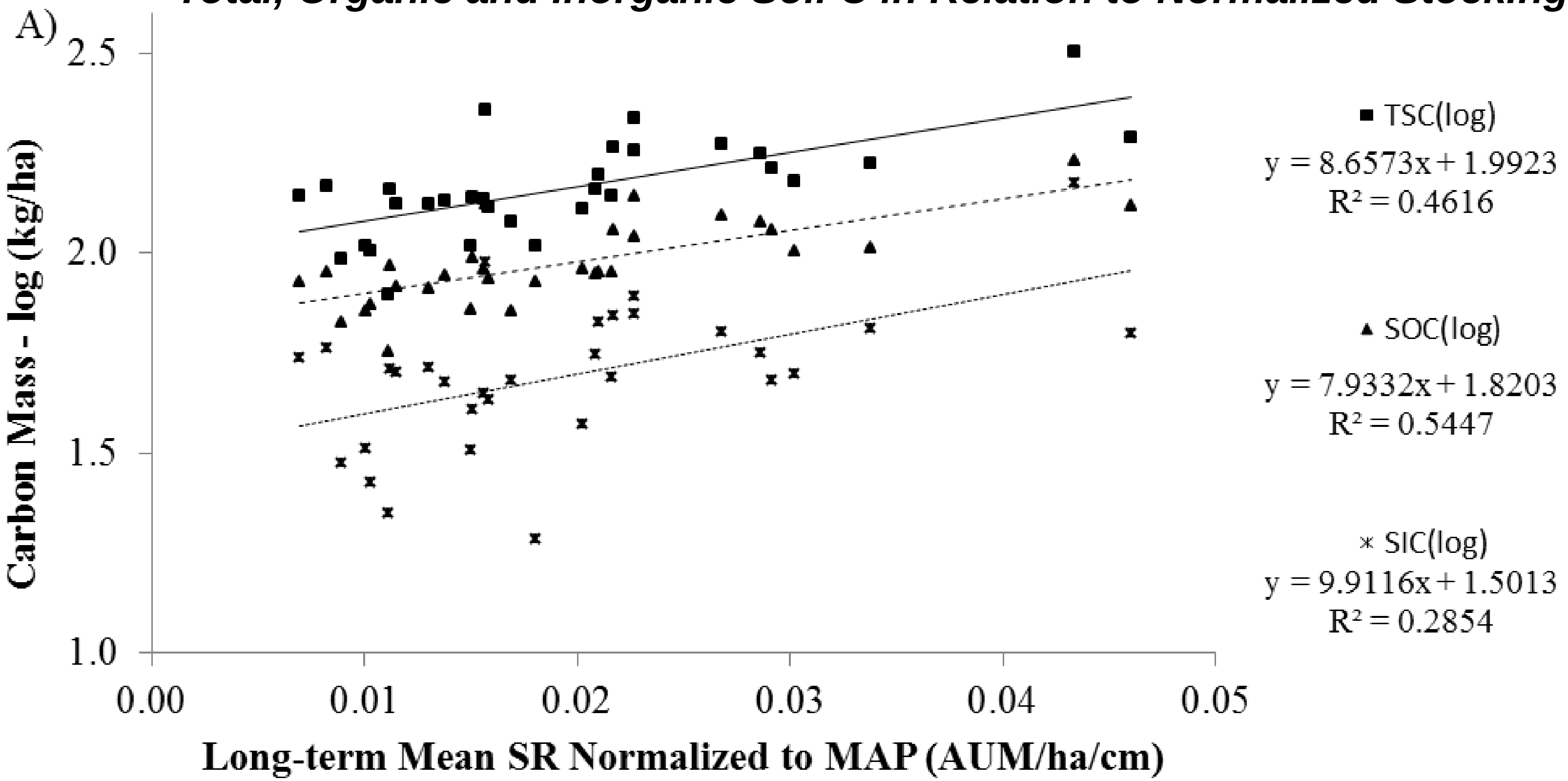
- The SK Mixedgrass pasture soils also had abundant inorganic C, comprising 28.8 – 32.5% of total soil C (total ~150-200+ t/ha)



Results (SK Grasslands)

- SK Mixedgrass sites demonstrated a positive relationship between soil C (both organic & inorganic) and livestock stocking rates, even when stocking is 'normalized' for rainfall (Bork et al., in prep)

Total, Organic and Inorganic Soil C in Relation to Normalized Stocking



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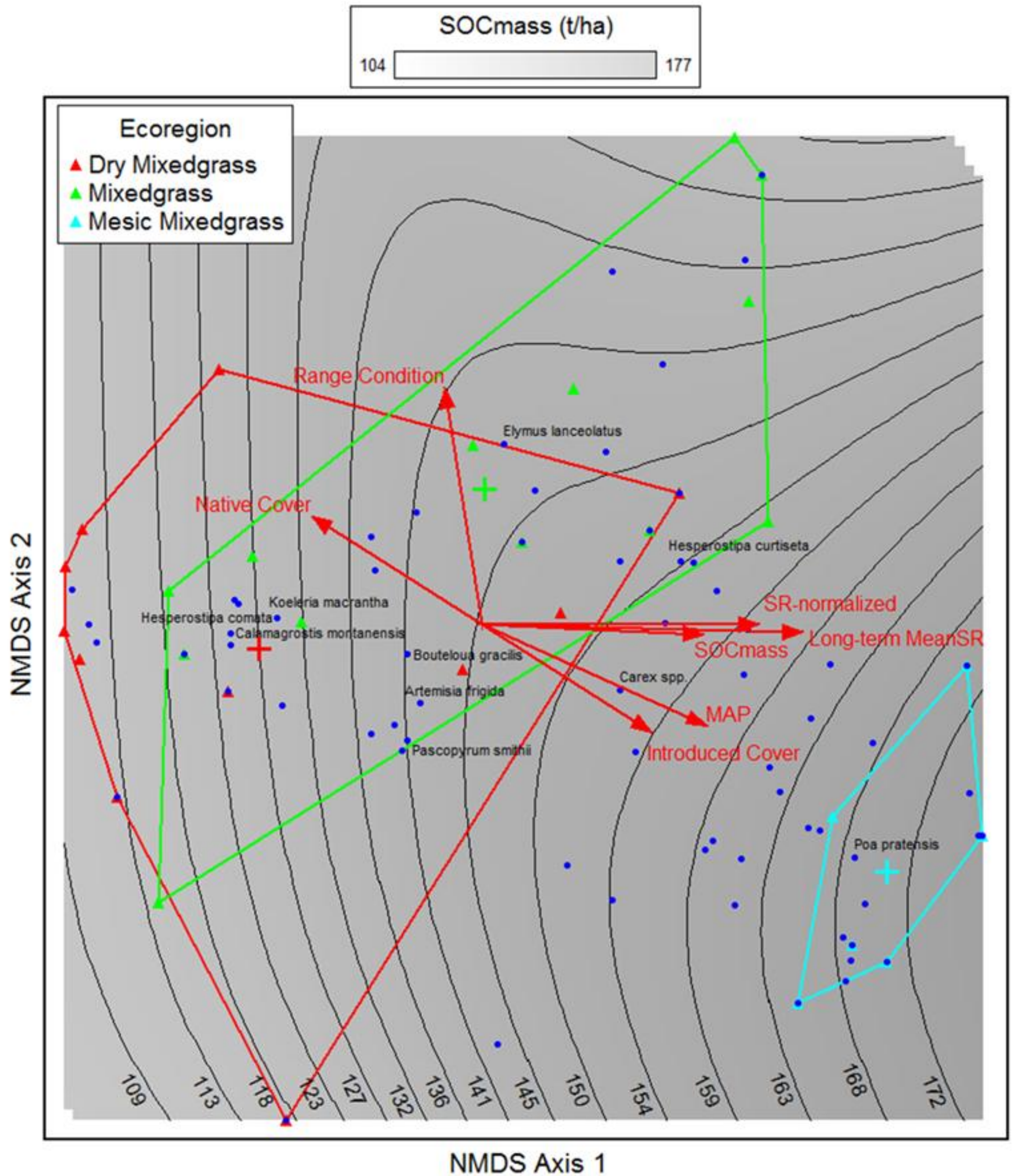
- More heavily grazed grasslands in SK had greater soil C - despite a ‘lower’ condition (Bork et al., in prep)

- Vectors for cattle stocking, rainfall and <u>introduced plant cover</u> were all closely aligned (with each other & the Mesic Mixedgrass)



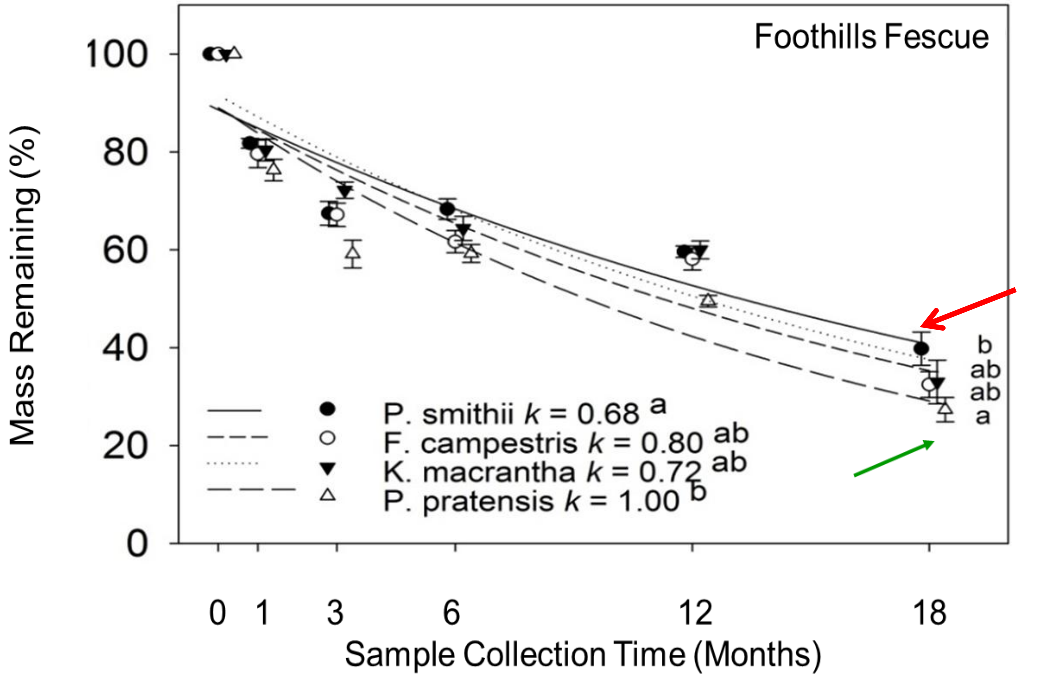
Question 3

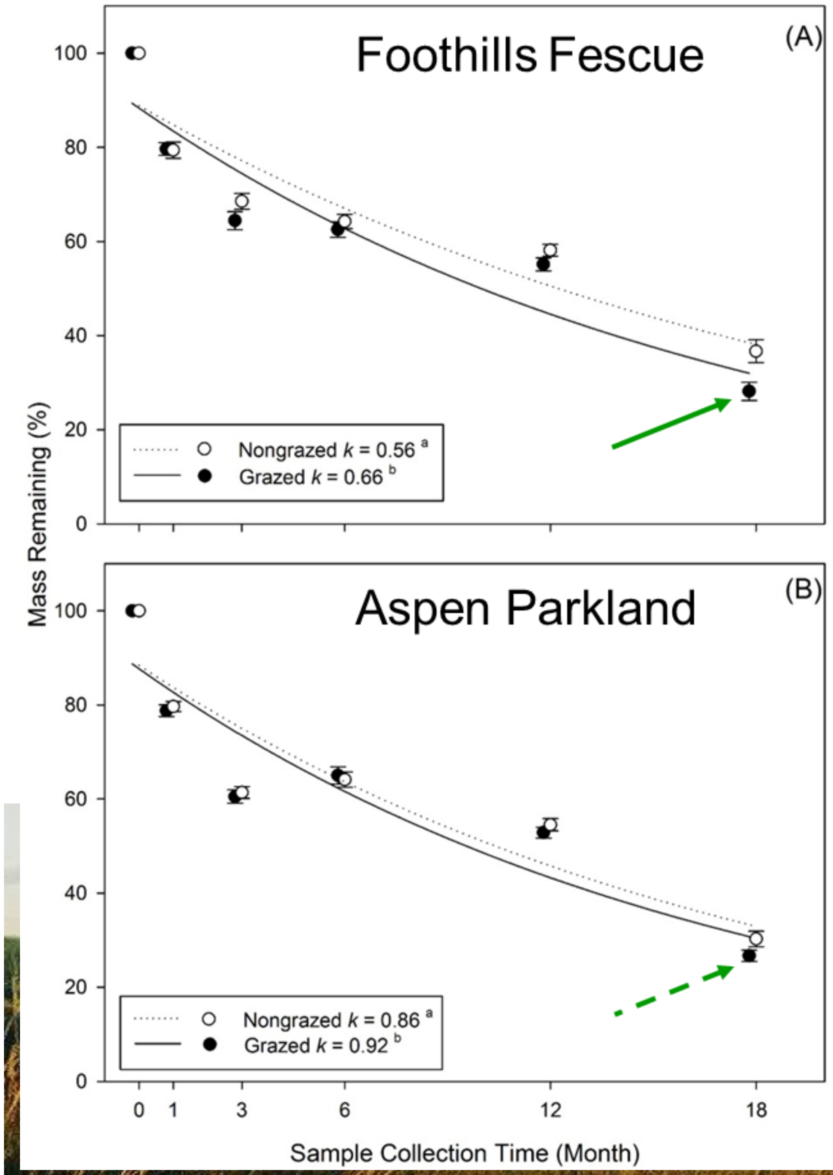
What biogeochemical mechanisms explain grazing impacts on grassland soil carbon?

Does plant species change lead to altered C accumulation?

Results (Nutrient Cycling)

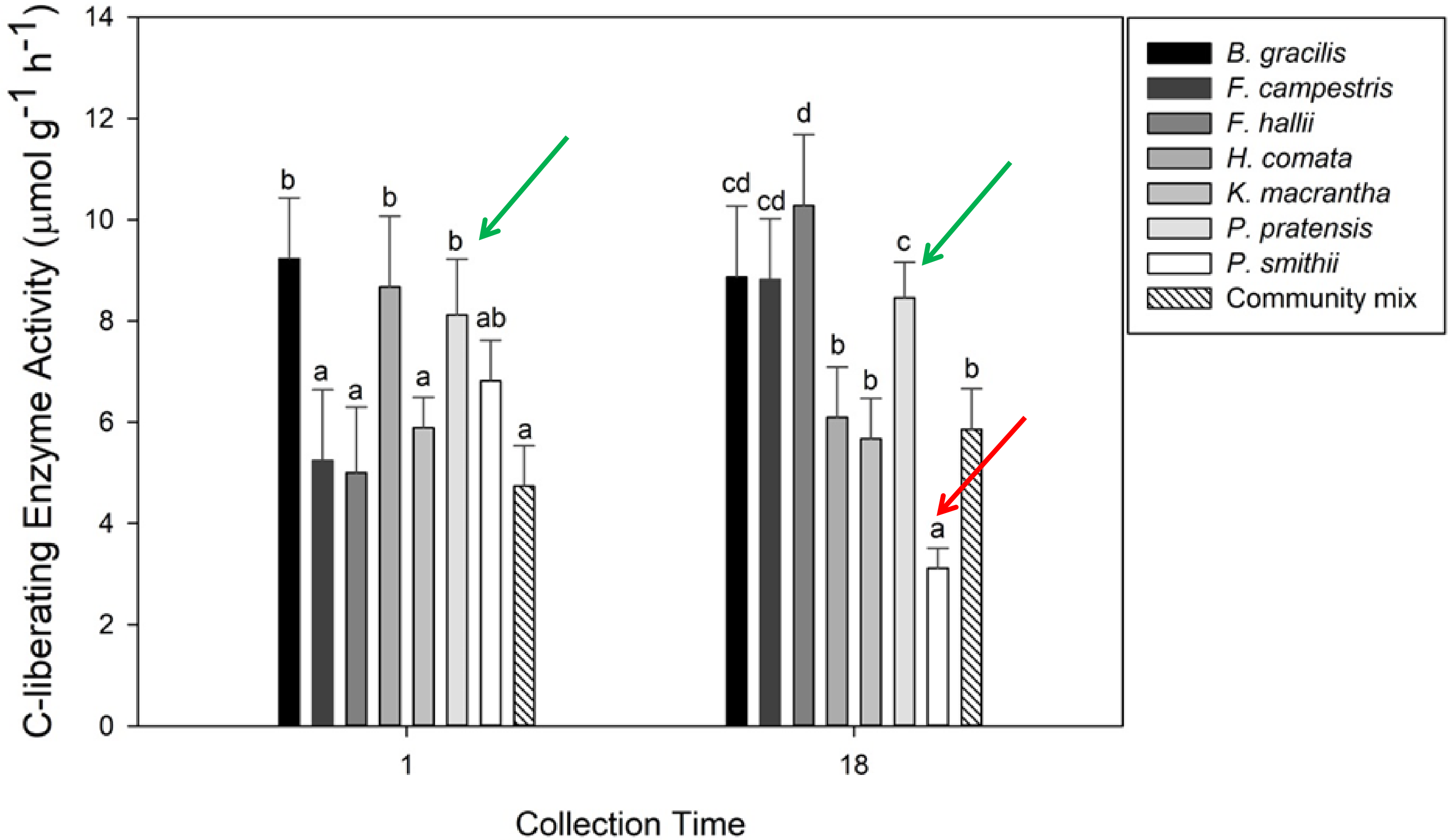
- Litter decay was faster in grazed environments (esp. foothills), and more rapid in Kentucky bluegrass than native grass species (Chuan et al. 2018; Caplan et al. 2018)
- What is the fate of this carbon?





Results (Nutrient Cycling)

- Enzyme activity responsible for C-liberation varied among grass species, and was often greater in bluegrass than others, indicating grazing can alter C cycling via changes in plant composition (Chuan et al., in review)



Conclusion & Wrap-Up

- Perennial grassland, particularly in comparison to cropland, contain large amounts of carbon, including within organic soil C, inorganic C and litter/mulch
- Changes in vegetation composition, even independent of grazing, appear to regulate biomass, as well as soil carbon
- An abundance of introduced species (and greater diversity), within moist grasslands, and possibly under greater cattle stocking, may increase soil C, in part due to altered carbon/nutrient cycling

Other Studies Underway

Adaptive Multi-Paddock Grazing (AMP) and EG & S (Boyce, Bork, Carlyle, Chang, Cahill & others)

- Goal is to understand whether and how divergent grazing systems alter soil carbon and greenhouse gas fluxes
  - 30 ranch pairs
  - AB, SK & MB

Microbial Responses to Grazing & Linkages to GHGs (Carlyle, Bork, & others)

- Goal is to understand how microbial diversity & composition alters soil C and grassland GHG fluxes, particularly under contrasting grazing systems and stocking levels

Defoliation Impacts on Carbon 'Flow' in Grasslands (Chang)

- Objective is to use C13 to understand how variable defoliation intensities alter the fate of photosynthetic carbon (root:shoot allocation, root exudates, & soil carbon)

Acknowledgements

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- Small army of summer students and lab assistants …

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