Build up of glyphosate/AMPA residues in western Canadian field soils

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Introduction

Glyphosate use in the Canadian prairies tripled in the past decade, raising concerns about potential accumulation of glyphosate and its main metabolite aminomethylphosphonic acid (AMPA) in agroecosystems[1]. Glyphosate is the most widely used herbicide in the world for several reasons, including: broad-spectrum and systemic activity on a wide range of plant species, low residual activity in soil, low mammalian toxicity, minimal environmental impact, and low herbicide cost[2]. However, overuse of any tool in cropping systems can result in detrimental impacts on agroecosystem function and environmental health.

Canola in bloom

Glyphosate undergoes microbial degradation in soil, and is considered moderately persistent often with a half-life ranging between 20 and 100 days[1,3]. In contrast, AMPA is more persistent in soil than glyphosate with a half-life typically ranging from 76 to 240 days[1,4]. These chemicals bind tightly to soil particles, making them less-available for plant uptake. However, this is a reversible process, and certain conditions like excess soil moisture or phosphorous fertilization may cause glyphosate or AMPA to desorb from the soil[5-7], resulting in increased availability for plant uptake.

The issue:
It is currently unknown whether frequent use of glyphosate at high rates could cause accumulation of these chemicals in soils to concentrations which may impact crop productivity.

The objective:
Determine whether recurrent use of glyphosate at high rates could cause accumulation of glyphosate or AMPA residues in western Canadian field soils.

Materials & Methods

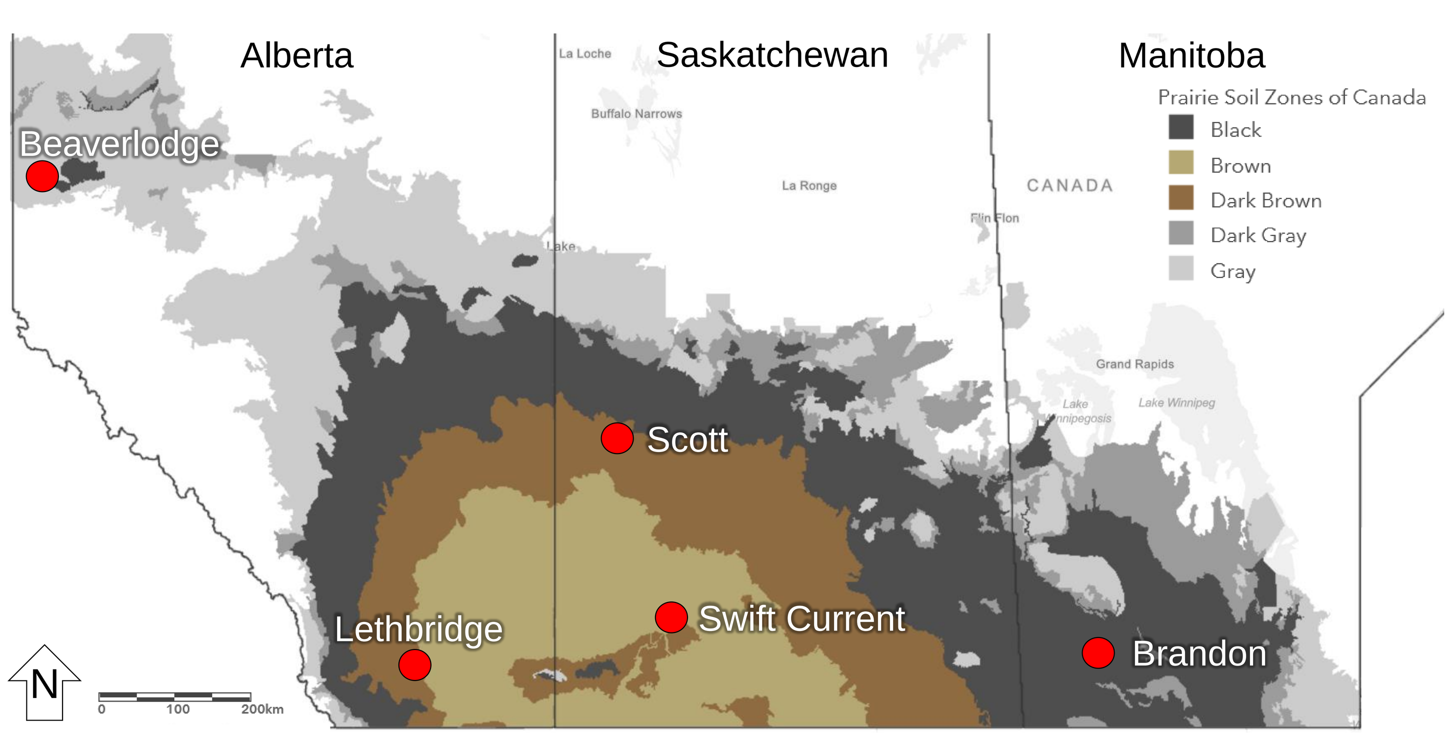
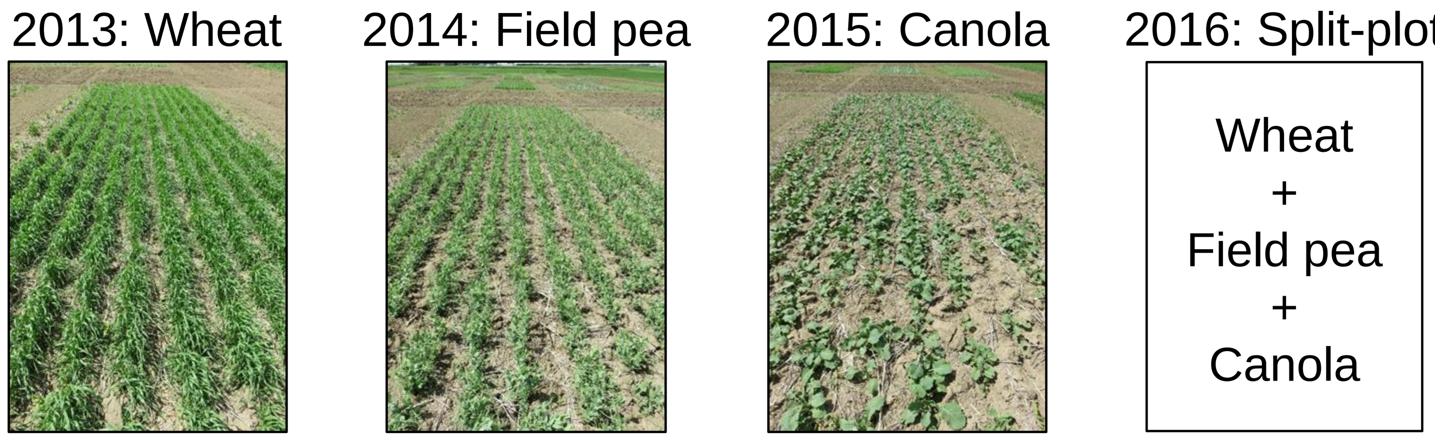


Figure 1. Experimental locations.

- Randomized complete block design:
  - **5 locations** (Fig. 1; Table 1)
  - **4 years**, 2013-2016 (Panel 1)
  - **4 replications**
- **5 glyphosate rates** (*Roundup WeatherMax*®, Bayer CropScience) applied pre-plant and post-harvest to the same plots every year for four years
  - 0, 1, 2, 4 and 8 kg ae ha^{-1}
  - Glyphosate and AMPA concentrations in soil (0-15 cm depth) were measured yearly in July using high performance liquid chromatography tandem mass spectrometry (AGAT Laboratories)
- Minimum-tillage system (disturbance via hoe-type seed-row openers)
- Statistical analyses
  - Linear mixed effects regression using proc GLIMMIX in SAS 9.4.



Panel 1. The crop rotation implemented.

Results

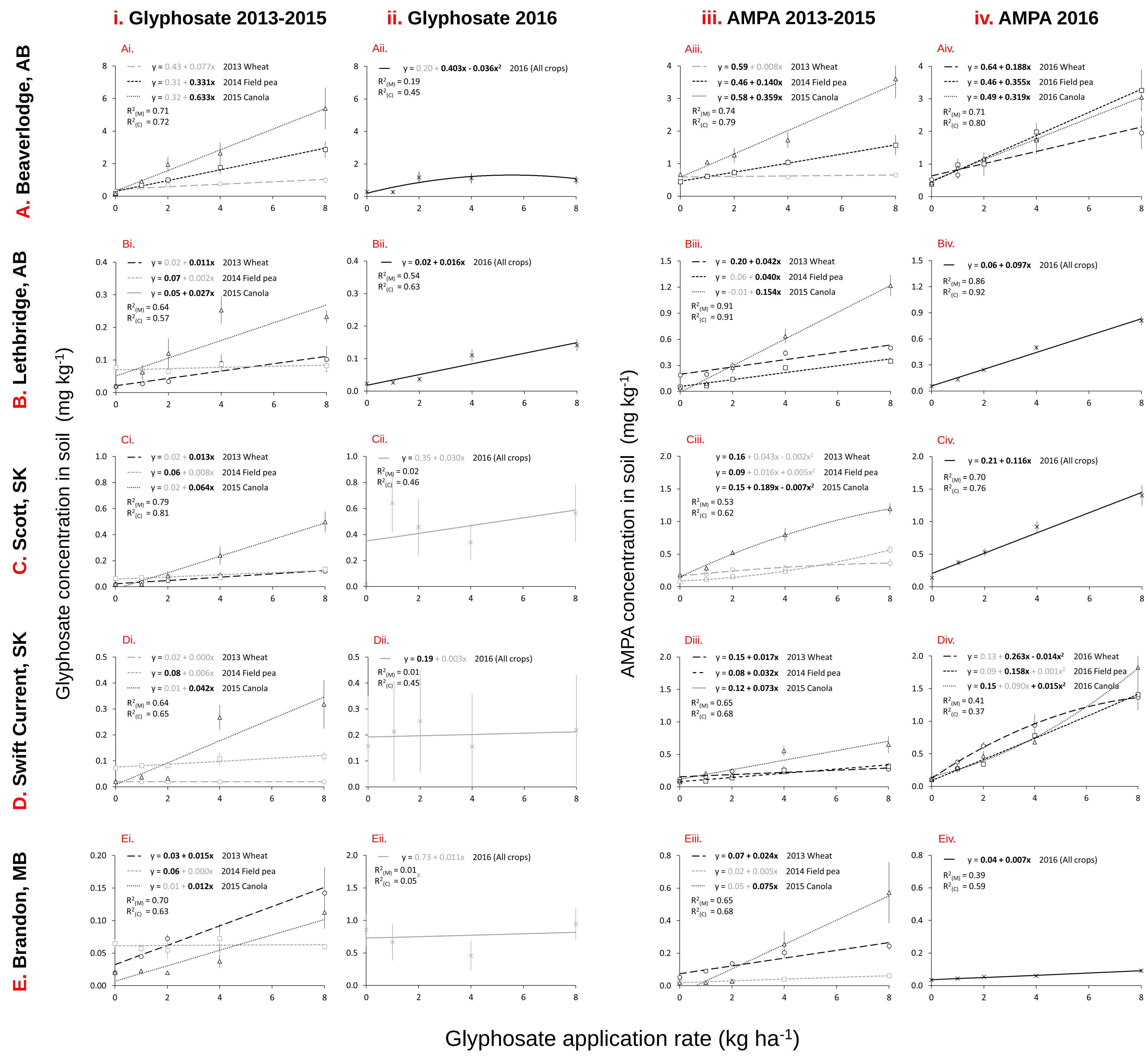


Figure 2. Glyphosate (i & ii) and AMPA (iii & iv) concentrations in field soils in response to increased glyphosate rates applied recurrently pre-emergence and post-harvest to the same plots over four years [(i & iii) 2013, 2014, 2015, and (ii & iv) 2016] at (A) Beaverlodge, AB, (B) Lethbridge, AB, (C) Scott, SK, (D) Swift Current, SK, and (E) Brandon, MB. Lines and regression components in black are **significantly different from zero**, while grey indicates **lack of statistical significance** (α = 0.05). $R^2_{(M)}$ and $R^2_{(C)}$ indicate marginal and conditional coefficients of determination for each linear mixed effects model.

Table 1. Soil characteristics (0-15 cm) and growing season (April-September) precipitation (mm) compared with the long-term average (LTA; 30 year) precipitation for each experimental location.

Location	Soil characteristics							Precipitation				
	Texture	Sand %	Silt %	Clay %	OM %	pH	EC dS m^{-1}	2013 mm	2014 mm	2015 mm	2016 mm	LTA 30yr
Beaverlodge, AB	Clay	23	35	42	3.4	5.3	0.36	519	199	389	591	299
Lethbridge, AB	Sandy clay loam	45	26	29	1.6	7.6	0.53	369	418	189	266	293
Scott, SK	Loam	37	48	15	4.1	6.4	0.20	313	306	250	296	273
Swift Current, SK	Silt loam	31	51	18	3.0	6.9	0.56	272	375	235	464	302
Brandon, MB	Clay loam	38	32	30	2.5	7.6	0.74	349	517	154	352	336

Main Findings

- In general, glyphosate and AMPA soil residues had a positive linear response to increased glyphosate application rate; however, responses varied among location and year (Fig. 2).
- The greatest glyphosate (5.4 mg kg^{-1}) and AMPA (3.6 mg kg^{-1}) soil residues were observed at Beaverlodge, the location with the highest clay content (42% clay vs. ≤30% at other sites) and lowest pH (pH 5.3 vs. ≥6.4 at other sites) (Fig. 2Ai & 2Aiii; Table 1). This suggests that glyphosate and AMPA were less available for microbial degradation due to strong adsorption to soil with high clay content.
- Glyphosate or AMPA soil residues did not increase consistently over the four years (Fig. 2).

In conclusion, increased glyphosate use can result in greater glyphosate and AMPA residues in field soils; however, residue accumulation is a function of soil, environment and time.

Further research is warranted to determine the potential impact of increased glyphosate and AMPA residues on crop productivity and agroecosystem function[8].

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