

Exploring the Ecological Role of Viruses in Grassland Soil Dynamics

Can we link viral gene flow and life cycle to carbon storage within grassland ecosystems?

Grassland soils store a substantial portion of global carbon, yet the role of soil viruses in carbon cycling is poorly understood. By infecting bacterial hosts, viruses modulate carbon dynamics through lytic and lysogenic pathways. Lytic infections release organic matter via host cell lysis, influencing respiration and organic matter stabilization. Lysogenic viruses may integrate into host genomes and express auxiliary metabolic genes (AMGs), reprogramming microbial metabolism and altering carbon turnover. **By identifying both AMGs, and the genetic markers left behind after lysogenic infection, can we integrate viruses into predictive models for soil carbon sequestration?**

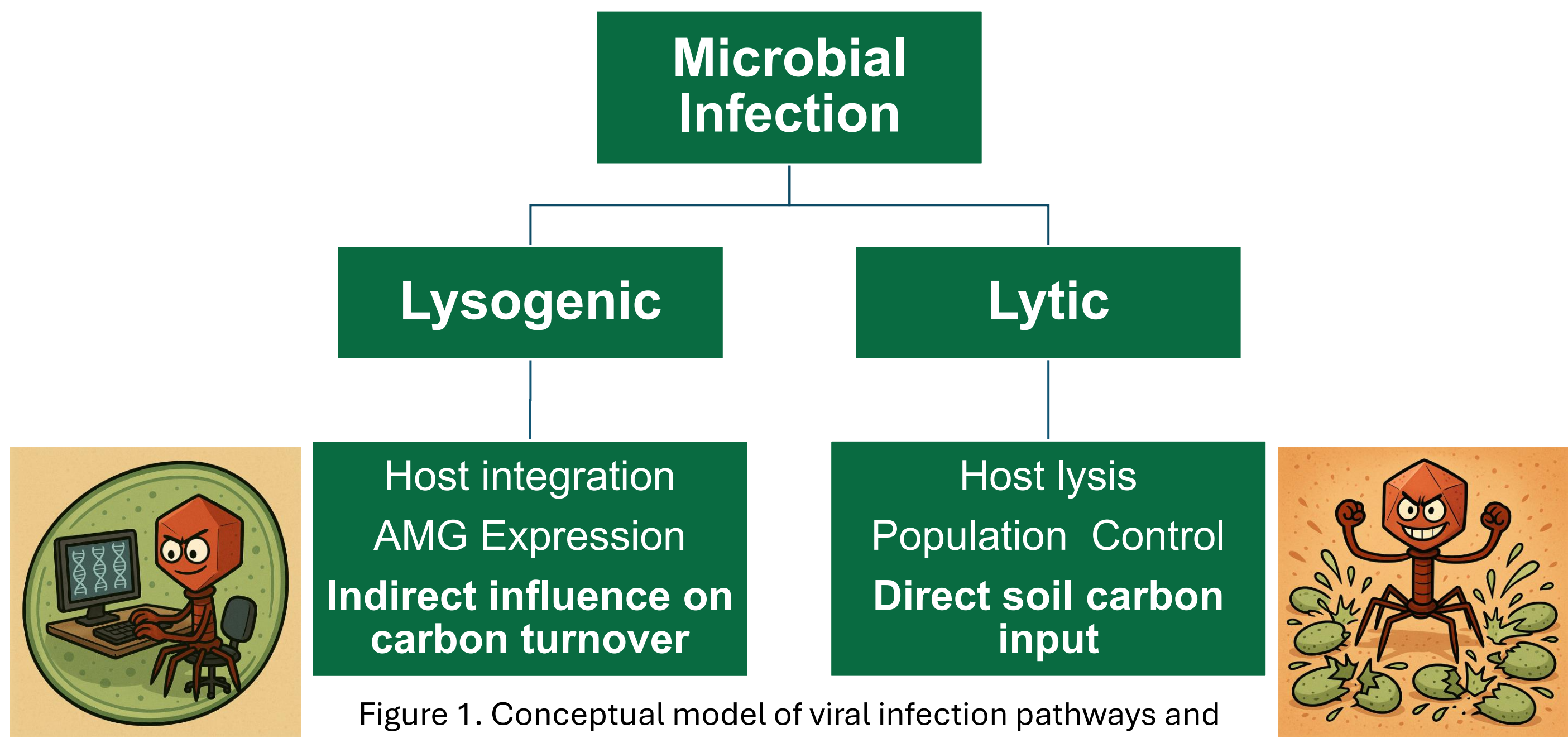


Figure 1. Conceptual model of viral infection pathways and their potential impacts on soil carbon cycling.

Methods

Sample selection

- Four grasslands across the US.
- Wetland, forest, pasture and woodland area included for comparisons.
- Soil metagenomes & environmental data sourced from NEON & JGI.

Bioinformatics

- Viral genomes assembled from a variety of virus-specific assembly tools.
- Viral genes were annotated with functional pathways (KEGG Orthologs).

Lysogeny & statistics

- Raw reads mapped to custom database of lysogenic markers.
- Read counts normalized for between-sample comparisons.
- Mixed modelling for interaction effects.

Do viral metabolic genes suggest functional roles in grassland carbon cycling?

- **Metabolism pathways** dominated functional roles of soil viruses.
- Sub-categories were related to amino acid, carbohydrate, and cofactor/vitamin metabolism, all vital in nutrient cycling.
- Suggests viruses in grassland soils may influence carbon turnover through the modulation of bacterial metabolism.

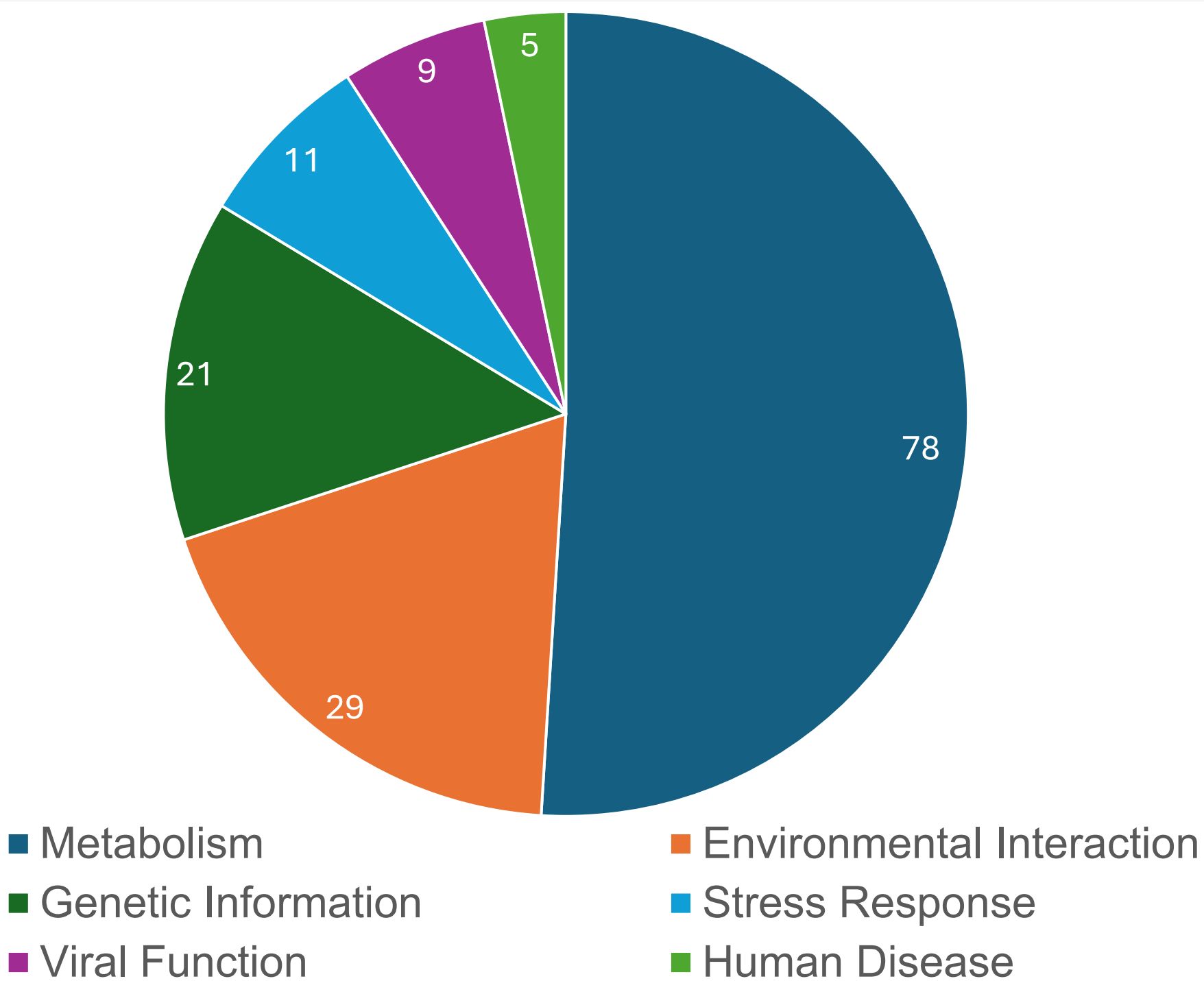


Figure 2. Snapshot of broad functional pathway classifications reveal dominance of metabolism-related genes in grassland virus communities.

Is lysogenic infection linked to soil organic carbon in grassland soils?

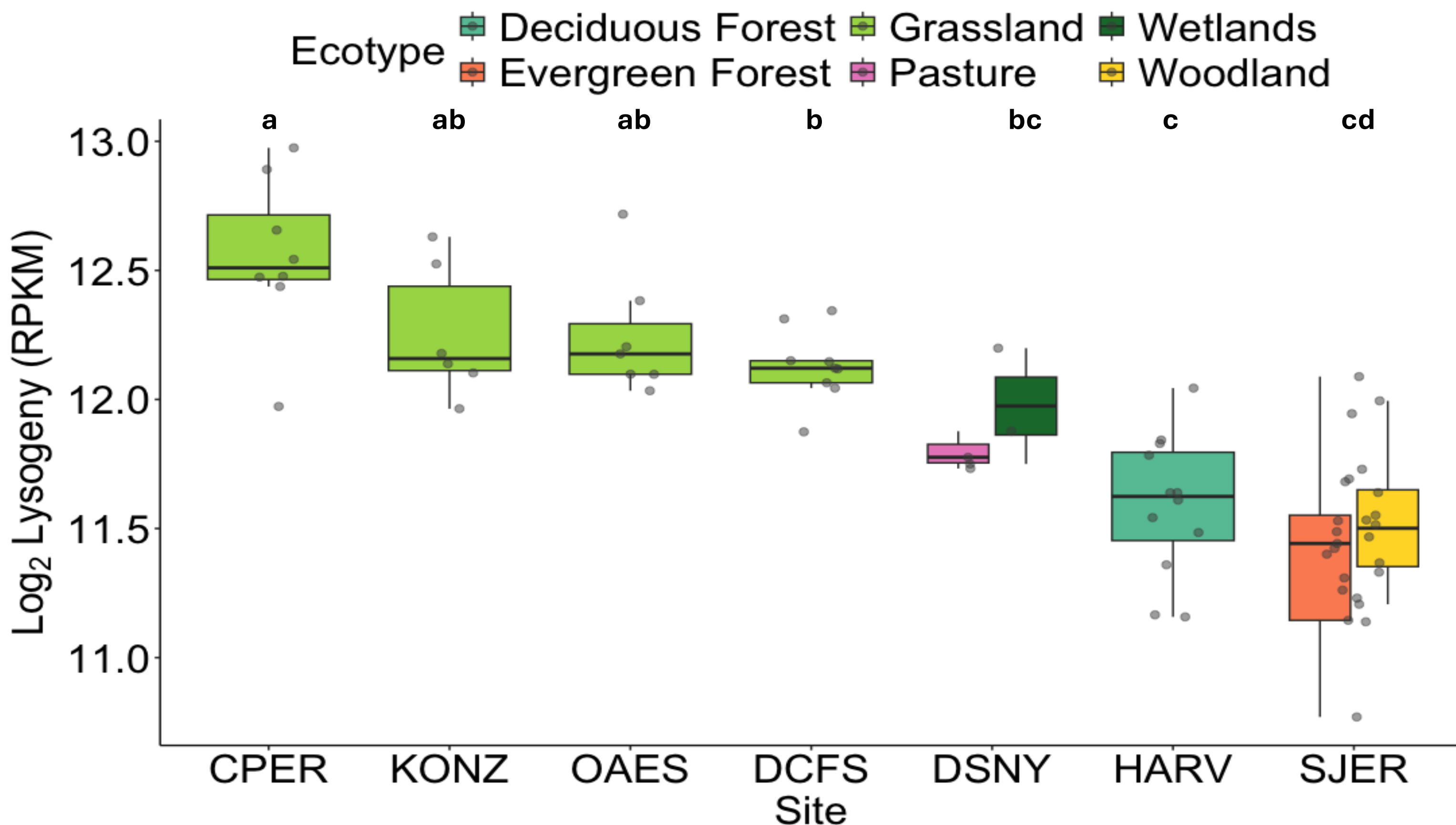


Figure 3. Lysogeny markers and carbon associations across ecosystems. Viral lysogeny markers were significantly more abundant in grassland soils compared to non-grasslands.

- Lysogenic markers were significantly enriched in grassland soils, though did not strongly predict SOC within grasslands alone - likely due to the fungal dominance of carbon sequestration potential in these systems.
- Grasslands exhibited a significantly higher occurrence of lysogenic markers ($p < 0.01$).
- Mixed-effect modeling revealed lysogeny and ecosystem significantly predicted SOC ($p < 0.05$).

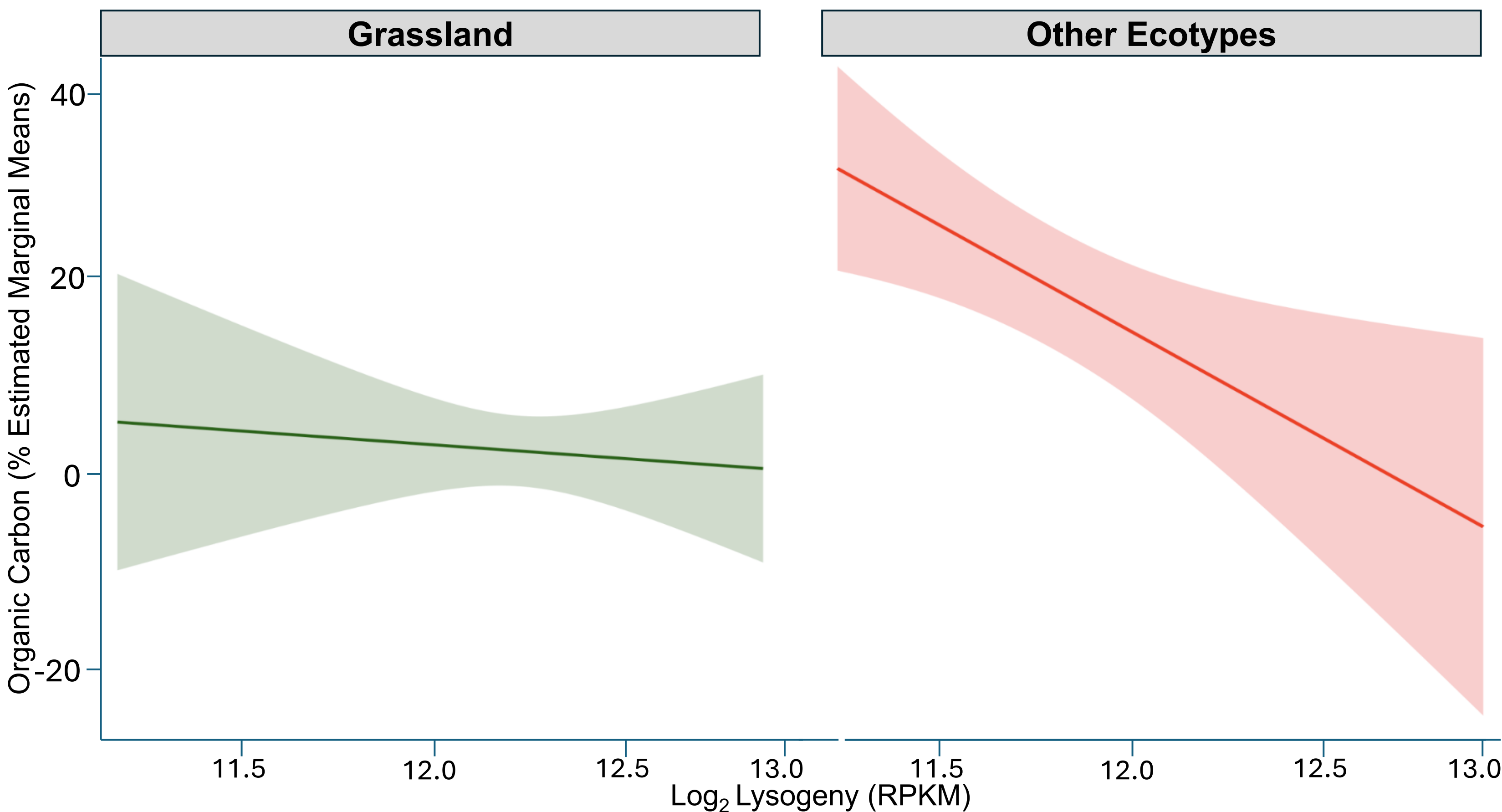


Figure 4. Mixed-effects modelling revealed a marginal relationship between lysogeny and (SOC) in grasslands.

Future directions

While fungi are the theoretical driver of carbon storage, these results indicate we may be able to utilise viral traits as an additional predictor of carbon sequestration in soil environments. Next steps will be to integrate climate, vegetation, and microbial host data to fully identify drivers of viral trait distributions. We can then assess the potential of viromics as an added layer in early indicator modelling of carbon sequestration rates in Canadian grassland ecosystems.