Unravelling spatial heterogeneity of soil legacy phosphorus in subtropical grasslands

Dr. Jiangxiao Qiu
School of Forest, Fisheries, and Geomatics Sciences
Fort Lauderdale Research and Education Center
University of Florida

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Acknowledgements

Coauthors and collaborators

Ran Zhi, Elizabeth Boughton, Haoyu Li, Charlotte, Henderson, Daniel Petticord, Amartya Saha, Jed Sparks, Ramesh Reddy

Funding supports
Phosphorus (P) is critical to global food security
Human modification of regional and global P cycle

(Chen and Graedel 2016)
Causes of ‘soil legacy P’

• Fertilization
• Manure
• Human sewage
• ...

(Image source: Baltic Eye; McCrackin et al. 2018)
Persistent and long-term consequences of legacy P

- Algal bloom
- Fish die-off
- Reduced water clarity
- Limited recreational uses
Current knowledge gaps

• Fine-scale spatial heterogeneity of legacy P and underlying environmental factors not well understood
  o Spatially target hotspots for interventions
  o Improve agroecosystem management
  o Less in low-latitudes grasslands

• Patterns of variance across spatial scales less investigated
  o Within pastures
  o Among pastures
  o Between pasture types
Q1: What is the spatial variability and hotspots of soil legacy P?

Q2: Does soil legacy P vary primarily within pastures, among pastures, or between pasture types?

Q3: How does soil legacy P relate to land management and soil characteristics?

Q4: What is the relationship between soil legacy P and aboveground plant tissue P concentration?
Study area: Buck Island Ranch

- Subtropical grasslands
- Managed for cattle production
- Two management intensities: high vs. low
### Study area: Buck Island Ranch

#### Intensively-managed (i.e., high-intensity)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N, P, K (P and K were up <strong>until 1987</strong>) fertilizations received</td>
<td>No fertilization received</td>
</tr>
<tr>
<td>Forage grasses (e.g., Bahiagrass) introduced</td>
<td>No forage grass introduced</td>
</tr>
<tr>
<td>Lime applied</td>
<td>No lime applied</td>
</tr>
<tr>
<td>Extensive drainage ditch constructed</td>
<td>Less extensive drainage ditch constructed</td>
</tr>
<tr>
<td>Water retention infrastructure (e.g., riser board)</td>
<td>No water retention infrastructure</td>
</tr>
<tr>
<td>Heavy grazing activity mainly in wet seasons</td>
<td>Light grazing activity mainly in dry seasons</td>
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#### Semi-natural (i.e., low-intensity or **control**)

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Approach

• Gridded sampling at 150-m interval (i.e., ~1,400 samples)

• Lab analysis of Mehlich-1, Mehlich-3 and total P, along with other soil covariates (e.g., pH, organic matter, C, N, Fe, Al, etc.)

• Geospatial analysis to identify hotspots

• Variance partitioning

• Spatial regression models
Result

Q1: Substantial spatial variability in soil legacy P

Qiu et al. Ecol Apps, In revision
Result

**Q1:** Relationships among different forms of soil legacy P

![Graphs showing relationships among different forms of soil legacy P](Qiu et al. Ecol Apps, In revision)
Result

Q1: Hotspots of soil legacy P

(D) Total P hotspots

(E) Mehlich-1 hotspots

(F) Mehlich-3 hotspots

Qiu et al. Ecol Apps, In revision
Result

Q2: Scales of variation in soil legacy P

Qiu et al. Ecol Apps, In revision
Result

Q2: Scales of variation in soil legacy P
Q3: Effects of land management and soil characteristics on soil legacy P

Result

68.9% variation
Q3: Effects of land management and soil characteristics on soil legacy P

23.2% variation
Q3: Effects of land management and soil characteristics on soil legacy P

48.1% variation

Qiu et al. Ecol Apps, In revision
Result

Q3: Effects of land management and soil characteristics on soil legacy P

(A) Total soil phosphorus

(B) Mehlich-1 soil phosphorus

(C) Mehlich-3 soil phosphorus

68.9% variation

23.2% variation

48.1% variation

Qiu et al. Ecol Apps, In revision
Result

Q3: Effects of land management and soil characteristics on soil legacy P
Result

Q4: Relationships between legacy soil P and plant tissue P

(A) Log(Total soil P) (mg/kg) vs Plant tissue P concentration (mg/g DM)
   $r = 0.22^{***}$

(B) Log(Mehlich-1 soil P) (mg/kg) vs Plant tissue P concentration (mg/g DM)
   $r = 0.40^{***}$

(C) Log(Mehlich-3 soil P) (mg/kg) vs Plant tissue P concentration (mg/g DM)
   $r = 0.33^{***}$

Qiu et al. Ecol Apps, In revision
Take-home messages

• Substantial spatial variations in legacy soil P

• SOM, pH, available Fe and Al, elevation, and grassland management are crucial predictors for soil P
  • More predicative for total P than labile P

• Intensification rescaled and increased variance in total soil P

• Pattern of variance greatest in small scales, suggesting that broad pasture- or farm-level BMPs may be limited and less efficient, especially for high-intensity grasslands

• Management to curtail legacy P should be implemented at fine scales and spatially target P ‘hotspots.’
Thank you!

Questions?

Jiangxiao Qiu
qiuj@ufl.edu
@Jiangxiao_Qiu