Patterns of soil nutrients and herbaceous vegetation in relation to isolated trees in pasture

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Introduction

- Savannas and grasslands cover ~25% of Earth and support millions of people, primarily by provisioning livestock1-2.
- Trees may compete with forage grasses but can also provide benefits to livestock such as shading3 and erosion control4. Trees are also known as "islands of fertility" for localized nutrient enrichment beneath the canopy5-6.
- Enrichment may be due to leaf litter inputs of nutrients from deeper soil horizons7, atmospheric deposition and stemflow during rainfall8-9, or increased animal waste inputs10. If such enrichment extends beyond the canopy, trees may enhance fertility nearby11.
- At the MacArthur Agro-ecology Research Center (MAERC) in Lake Placid, FL, two tree species occur at varying densities in semi-native pastures12:
  - Cabbage Palm (Sabal palmetto, Arecaceae), a monocot, occurs in small clumps on high ground, scattered in lower areas, or mixed in hammocks.
  - Virginia Live Oak (Quercus virginiana, Fagaceae), a dicot, occurs in large hammocks or along the spoil banks of ditches in pastures.
- We investigated how species and distance impact soil nutrients and understory properties, and the factors responsible for these patterns.

Hypotheses:

- Leaf litter and animal usage will be the best predictors of nutrient levels, while canopy openness will best predict herbaceous biomass.
- Nutrients and soil moisture will be highest under canopies and decline with distance.
- Grass height, herbaceous & belowground biomass, and soil organic matter will be lowest under canopies and increase with distance.
- Oaks will have higher nutrient levels than palms (due to root & litter differences).

Methods

- Trees identified in ArcGIS: 9 palms clusters and 8 oaks isolated from other trees (>70 m away in the direction of the transect).
- Transects established N, S or both directions away from the trunk or cluster center.
- Four points sampled along each transect: A) halfway from the trunk/center to the canopy edge [dripline], B) 5 m from the edge, C) 15 m, D) 35 m.
- In a 0.25 m² quadrant at each point, canopy cover, grass height, herbaceous biomass, leaf litter biomass, and 5 cm soil cores were taken.
- Animal use quantified by counting cow pies & pig sign.
- Soils analyzed for 3 spp. of inorganic N: Ammonium (NH₄) and Nitrate / Nitrite (NO₃⁻ / NO₂⁻).
- Also inorganic Orthophosphate (PO₄⁻) and Total P (Ortho-P + organic P).
- Soil moisture & organic matter (%), belowground biomass and pH also calculated.
- Linear models used to predict sub-canopy nutrient levels and herbaceous biomass.
- Relationships between species, distance, and understory/soil variables tested with linear mixed-models, with tree ID as a random effect.

Results: Predictors of sub-canopy (A) variables (linear models)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Top 3 Predictors (adjusted R²)</th>
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<tbody>
<tr>
<td>Nitrate/Nitrite Concentration</td>
<td>(+) Canopy cover (0.029)</td>
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<tr>
<td></td>
<td>(-) Herbaceous Biomass (0.022)</td>
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<tr>
<td></td>
<td>(+) Belowground biomass (0.001)</td>
</tr>
<tr>
<td>Ammonium Concentration</td>
<td>(+) Canopy cover (0.288)*</td>
</tr>
<tr>
<td></td>
<td>(-) Herbaceous biomass (0.057)</td>
</tr>
<tr>
<td></td>
<td>(+) Belowground biomass (0.026)</td>
</tr>
<tr>
<td>Orthophosphate Concentration</td>
<td>(+) Belowground biomass (0.44)*</td>
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<td></td>
<td>(+) pH (0.132)</td>
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<td></td>
<td>(+) Canopy area (0.118)</td>
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<tr>
<td>Herbaceous Biomass</td>
<td>(-) Animal usage (0.083)</td>
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<tr>
<td></td>
<td>(+) Total mineral nitrogen (0.071)</td>
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<tr>
<td></td>
<td>(-) Canopy cover (0.071)</td>
</tr>
</tbody>
</table>

Discussion

- Nutrient enrichment pronounced (except Ammonium), but not beyond canopy.
- Unexpectedly, soil moisture was lowest under the canopy (for palms), possibly due to higher elevation.
- Trees depressed herbaceous biomass and grass height [not shown] beyond canopy, especially palms.
- Soil organic matter (not shown) lower only under canopies; belowground biomass (not shown) higher.
- Palms had higher nutrient levels than oaks, especially for Orthophosphate and Total Phosphorus (not shown).
- Elevated soil pH (more neutral) may partially explain higher nutrient availability. Neutralization could be due to leaf litter inputs10 or limestone (CaCO₃) substrate (palms).
- Small sample size and effect sizes limit conclusions about sub-canopy, but herbaceous biomass, driven by canopy cover, may influence N levels, while P may be related to pH and atmospheric deposition (canopy area).
- Trees likely represent another trade-off for ranchers13, with a loss of some provisioning services offset by other ecosystem services, including biodiversity enhancement and carbon sequestration.
- However, grass under and near trees could be more nutritious, leading to more grazing and less biomass.
- Beyond-canopy nutrient enrichment may exist but at a smaller scale than we tested.
- Natural systems are dynamic, with tree turnover from fire and hurricanes; enhancing turnover may allow grass production to benefit from nutrient enrichment and acid neutralization on sites of former trees.

References