



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 livestock^{1,2}.
- 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 canopy^{5,6}.
- Enrichment may be due to **leaf litter inputs** of nutrients from deeper soil horizons^{5,7}, **atmospheric deposition and stemflow** during rainfall⁷, or **increased animal waste inputs**⁸. If such enrichment extends beyond the canopy, trees may enhance fertility nearby^{3,9}.
- At the MacArthur Agro-ecology Research Center (MAERC) in Lake Placid, FL, two tree species occur at varying densities in semi-native pastures¹⁰:
 - **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)*



Cabbage palms, *Sabal palmetto*, in a small cluster in semi-native pasture. The ground is often raised and may include limestone. Avg. canopy area = 629.7 m² Avg. relief = 40.8 cm



Virginia Live Oak, *Quercus virginiana*, in semi-native pasture. Oaks are less flood tolerant and often found near drainage ditches. Avg. canopy area = 152.3 m² Avg. relief = 0.7 cm

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**
- W/in a **0.25 m² quadrat** at each point, **canopy cover, grass height, herbaceous biomass, leaf litter biomass, and 5 15-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 (PO₄³⁻)** 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

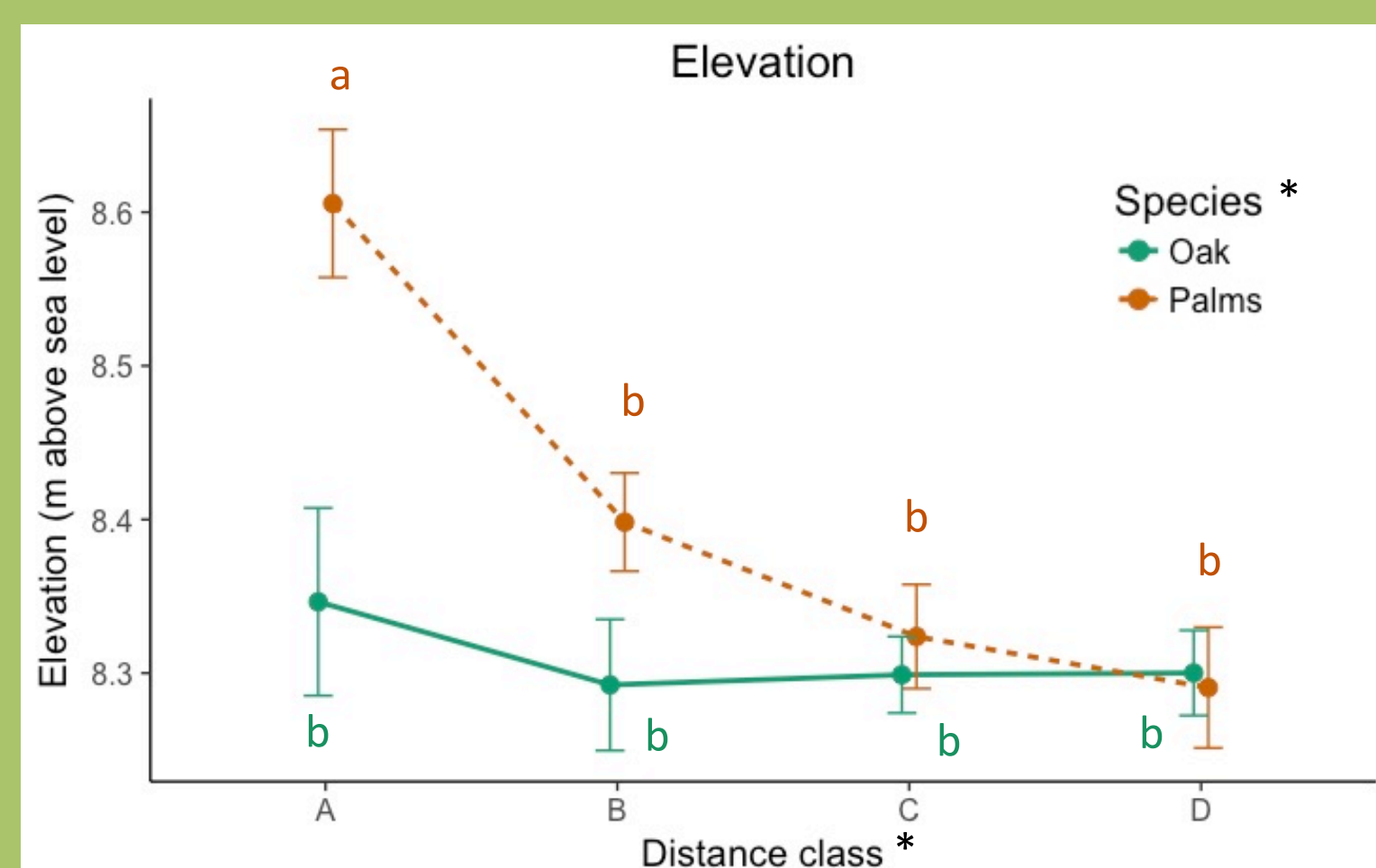
Results: Predictors of sub-canopy (A) variables (linear models)

Variable	Top 3 Predictors (<i>adjusted R</i> ²)		
Nitrate/Nitrite Conc.	(+) Canopy cover (0.029)	(-) Herbaceous biomass (0.012)	(+) Belowground biomass (-0.011)
Ammonium Conc.	(+) Canopy cover (0.188)*	(-) Herbaceous biomass (0.057)	(+) Belowground biomass (0.026)
Orthophosphate Conc.	(+) Belowground biomass (0.44)*	(+) pH (0.132)	(+) Canopy area (0.118)
Herbaceous Biomass	(-) Animal usage (0.083)	(+) Total mineral nitrogen (0.071)	(-) Canopy cover (0.071)

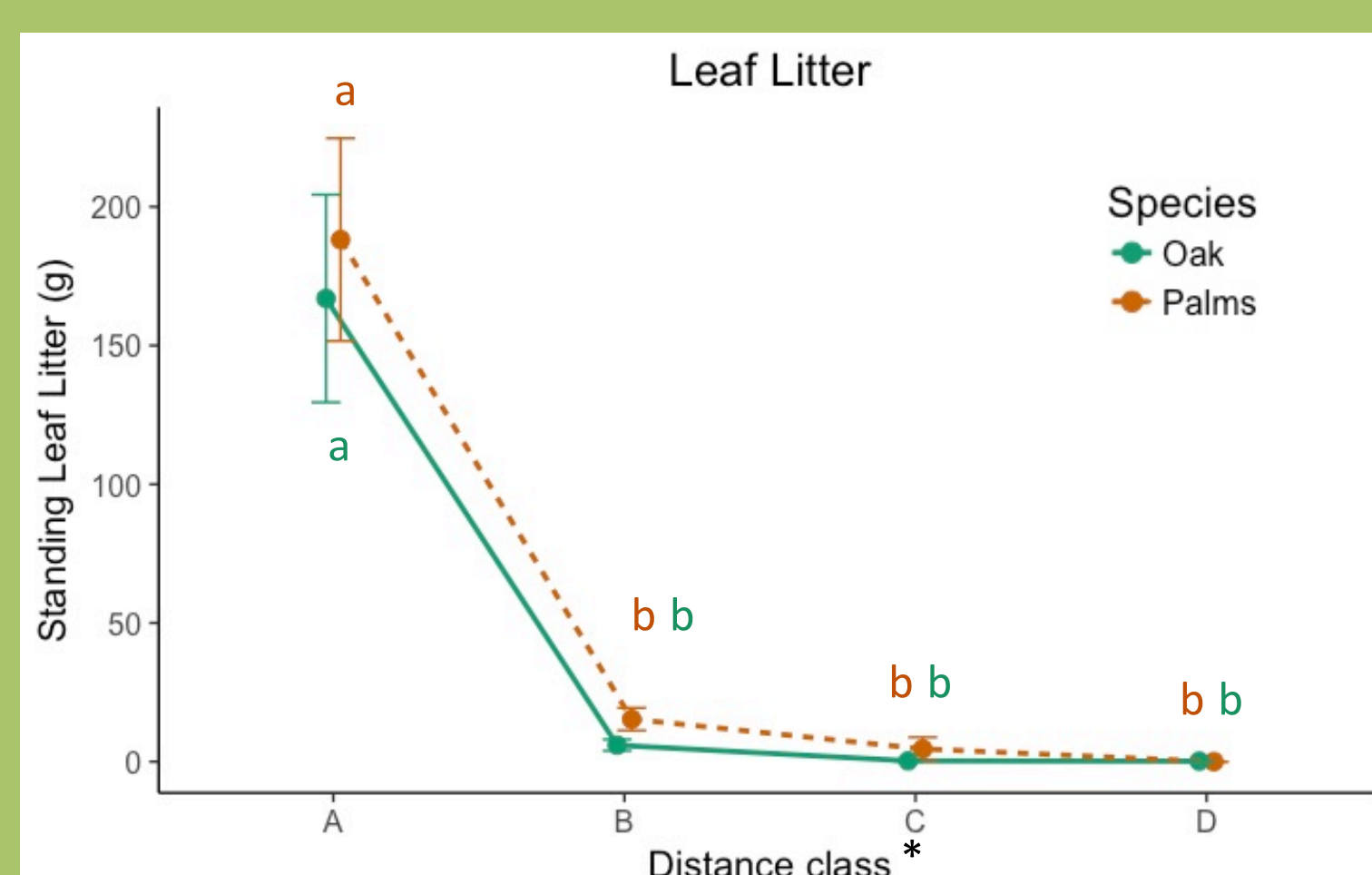
Results: Linear mixed-models

Distance Classes: A = Canopy, B = 5m from canopy, C = 15m, D = 35m

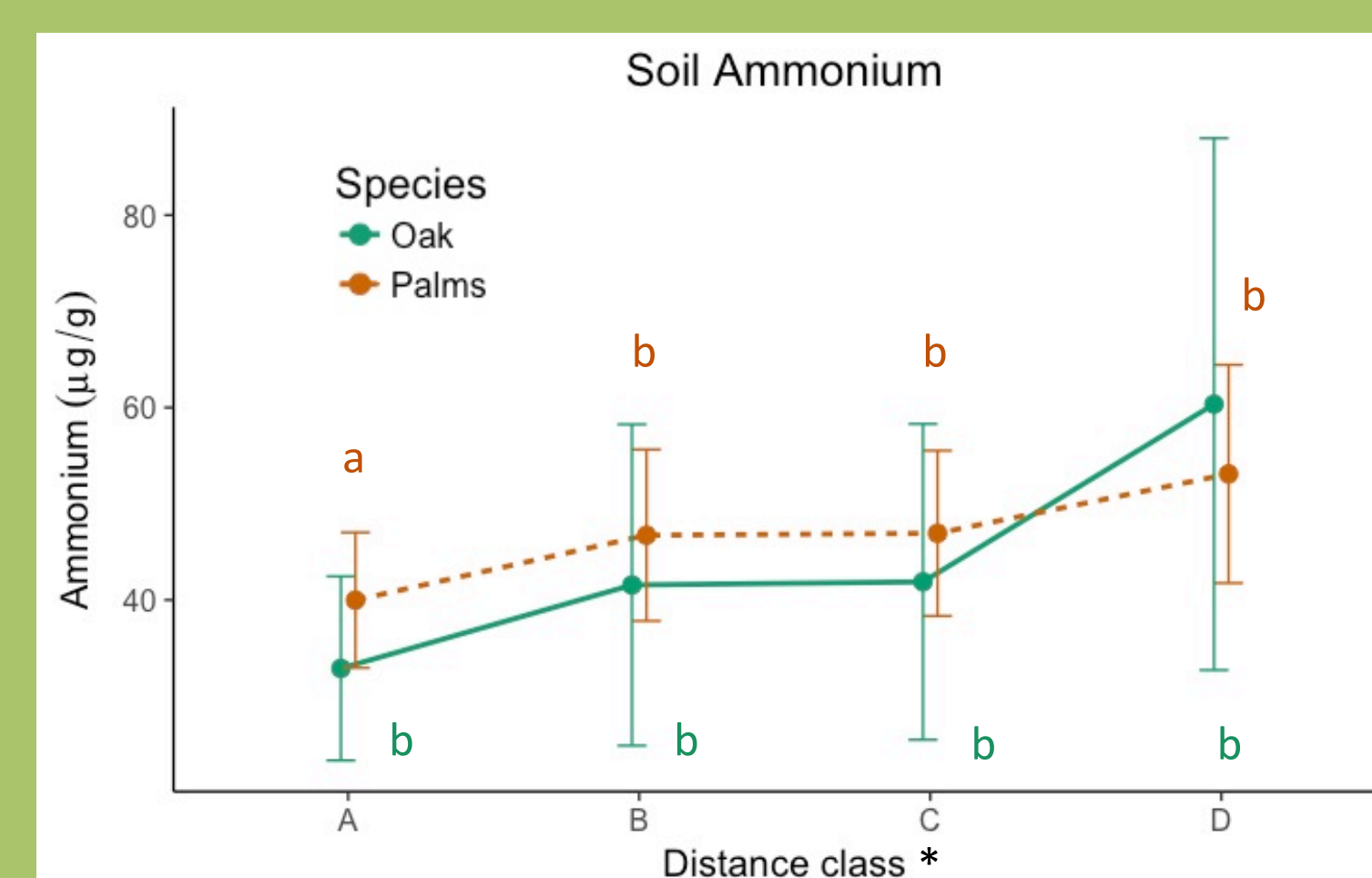
* = statistically significant factor (p<0.05)



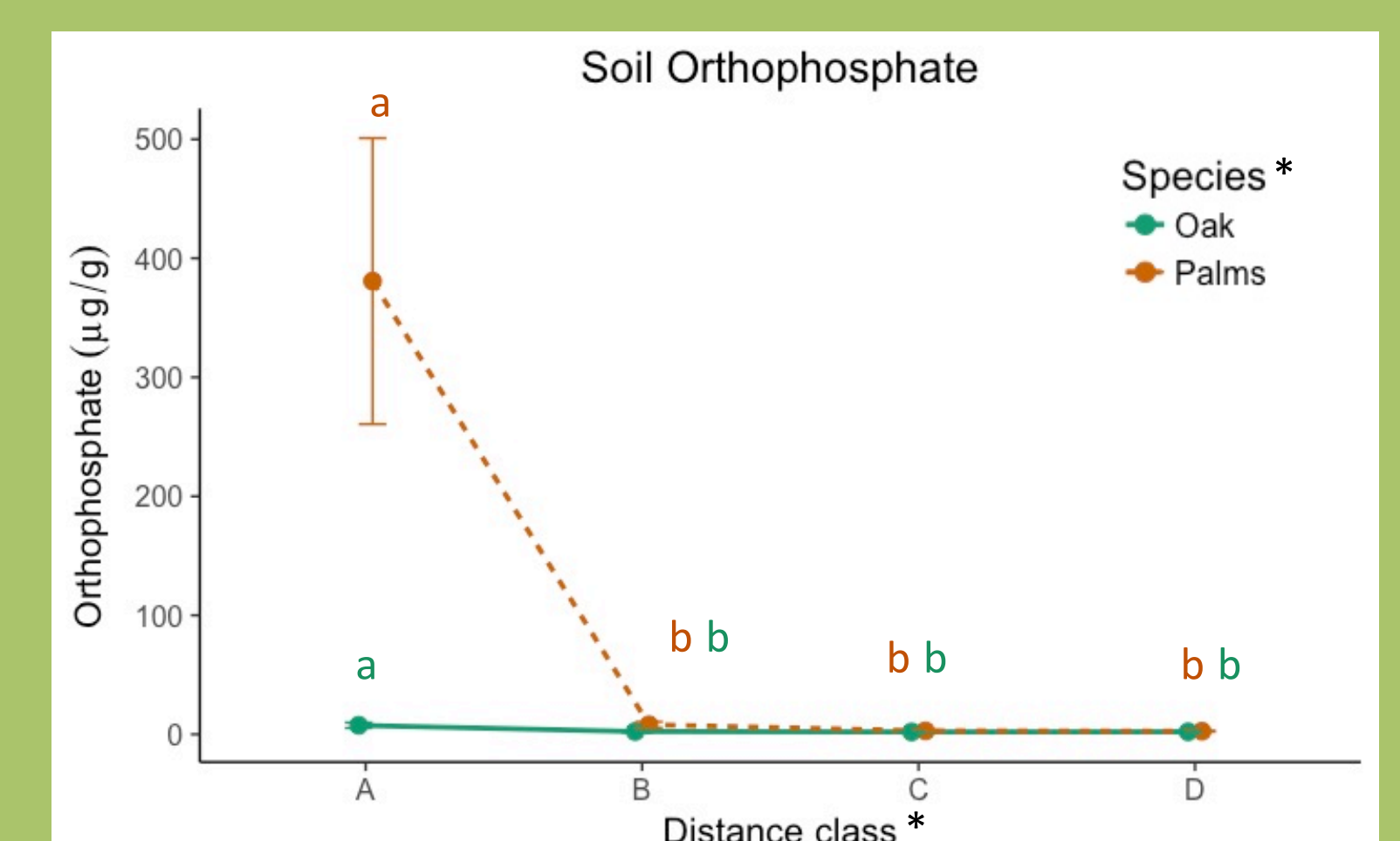
Interaction non-significant—Distance significant in Palms—Species significant



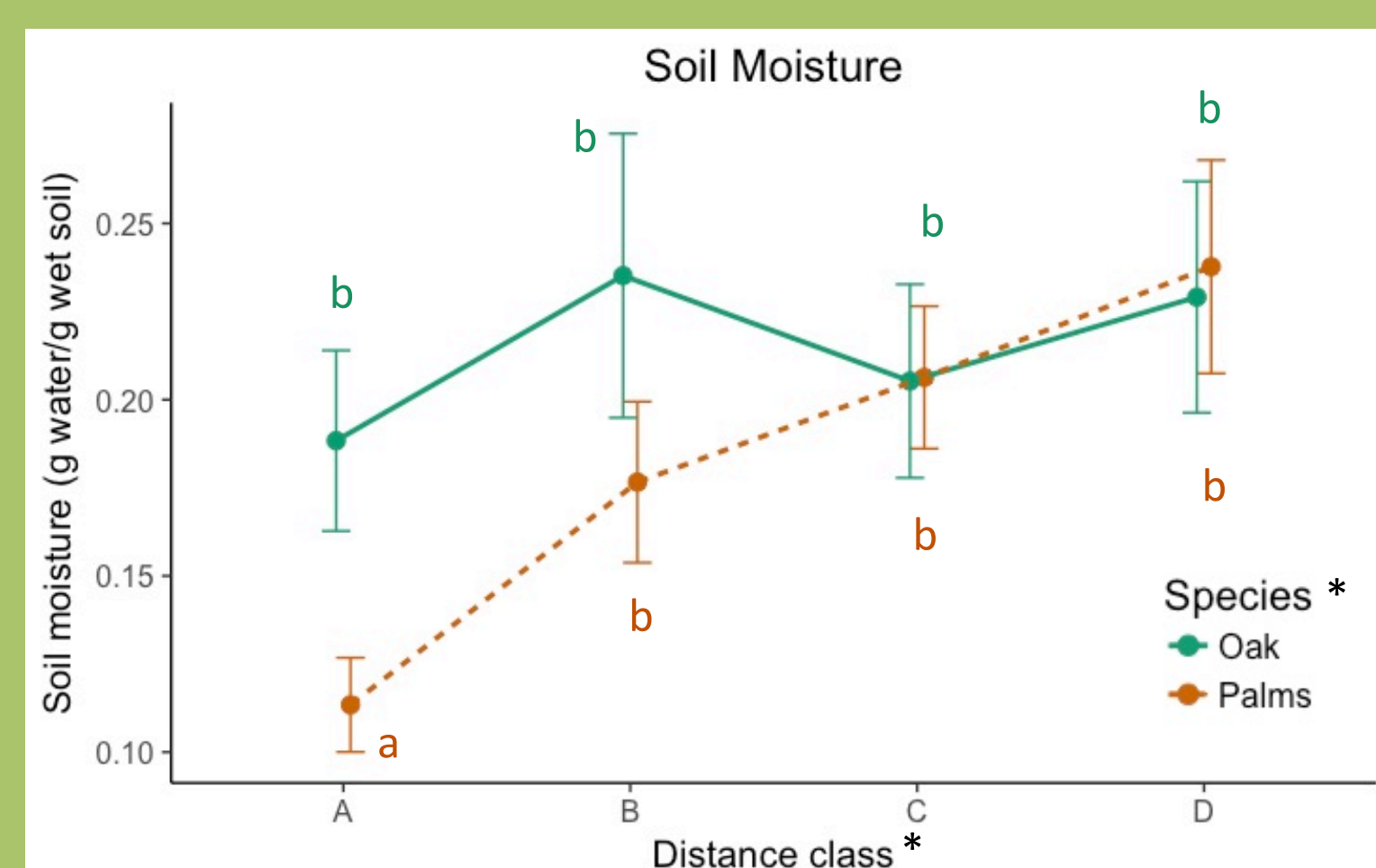
Interaction non-significant—Distance significant—Species non-significant



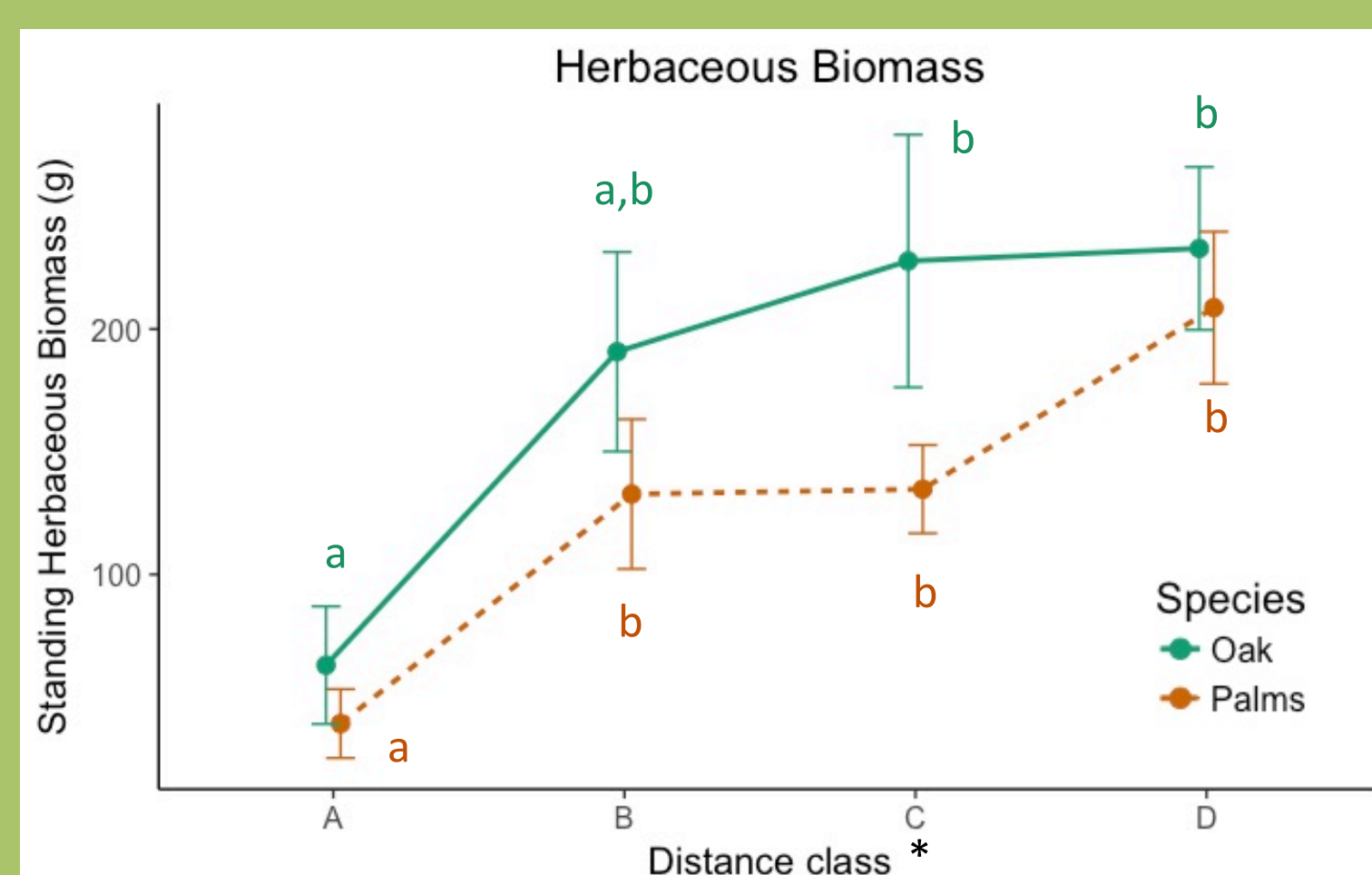
Interaction non-significant—Distance significant in Palms—Species non-significant



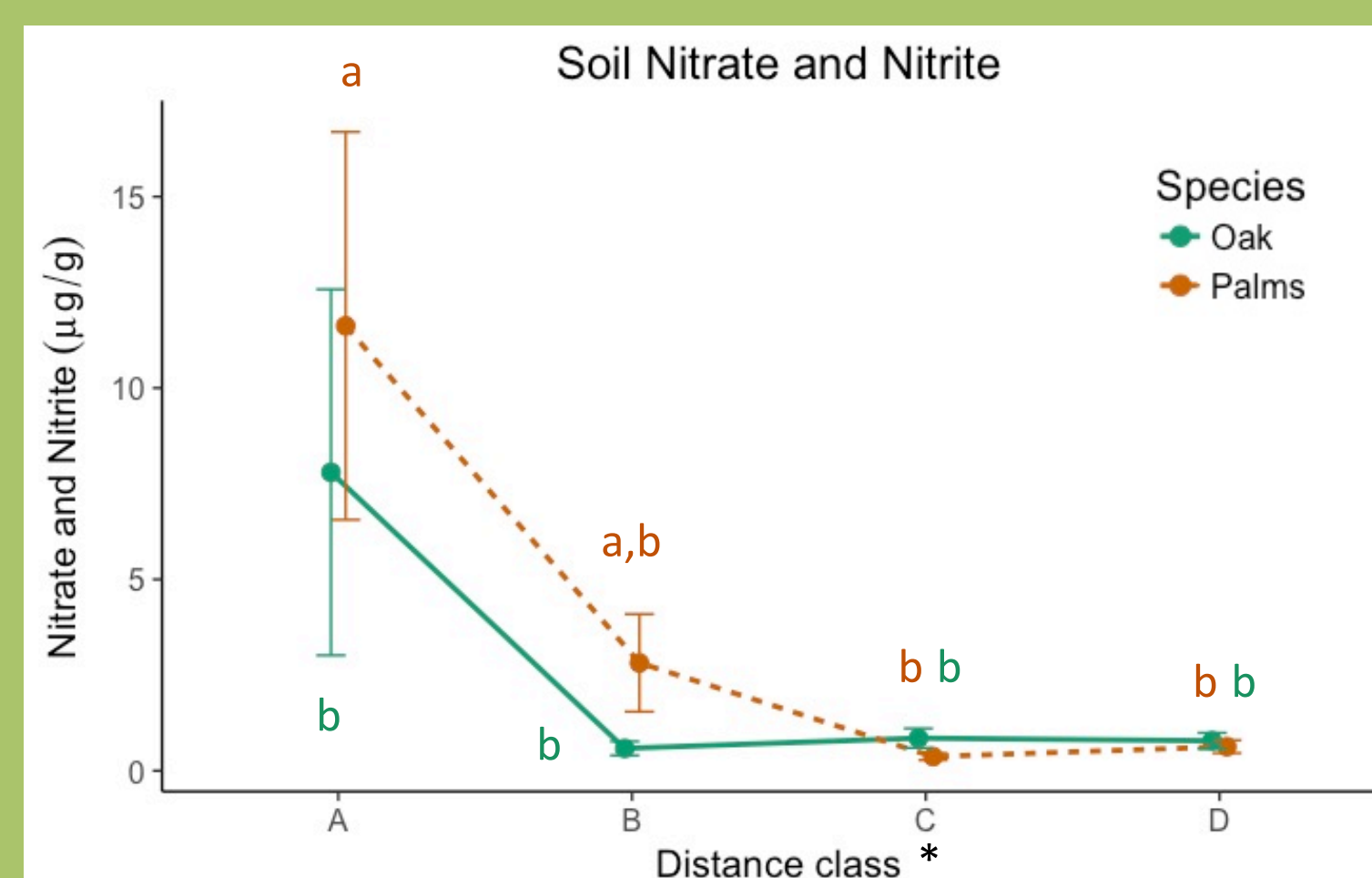
Interaction significant—Distance significant (in both species)—Species significant



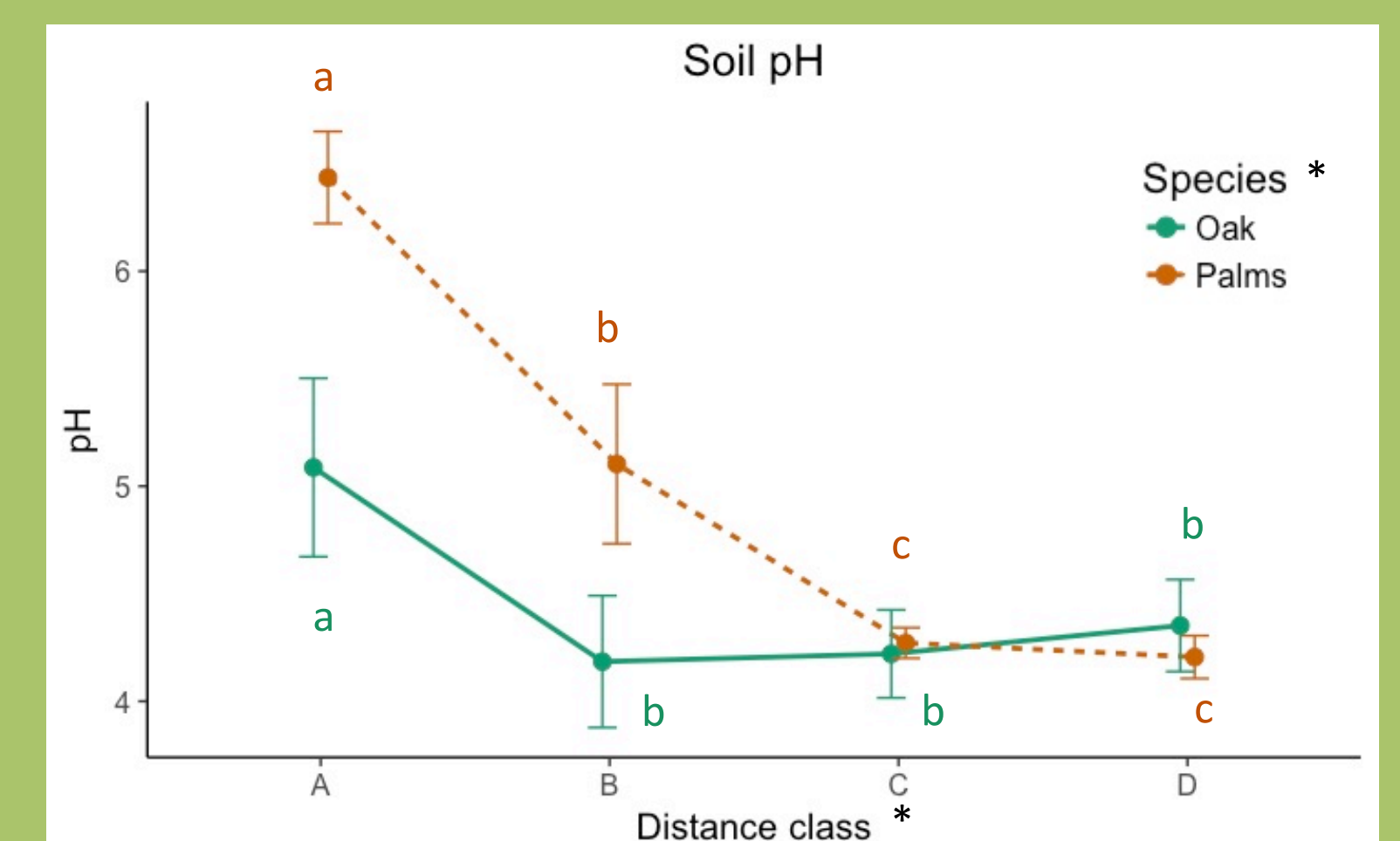
Interaction non-significant—Distance significant in Palms—Species significant



Interaction non-significant—Distance significant—Species non-significant



Interaction non-significant—Distance significant—Species non-significant



Interaction significant—Distance significant—Species significant

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 inputs⁷ 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 ranchers¹⁰, 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 tested⁹.
- 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.



Satellite view of scattered oaks and palm clusters in semi-native pasture at MAERC.

References

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