Soil phosphorus distributions in the Calhoun CZO landscape

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INTRODUCTION

- Land use and soil management practices influence soil phosphorus (P) through processes such as erosion, overland flow, oxidation, mineralization, and leaching (Fig. 1; Liu et al., 2010).
- Historical land use impacts are evident in the long-term elevation of soil P in sites that have been fertilized (Richter et al, 2006; Falkengren-grerup et al., 2006) as well as the transformation of P forms after forest clearing (Garcia-Montel et al, 2001).
- Over decades, slow cycling of organic and occluded P fractions contribute to soil P availability.
- Objectives: quantify P pools in different hillslope positions of small watersheds with varying land use histories and evaluate the current and redistributed P fractions.

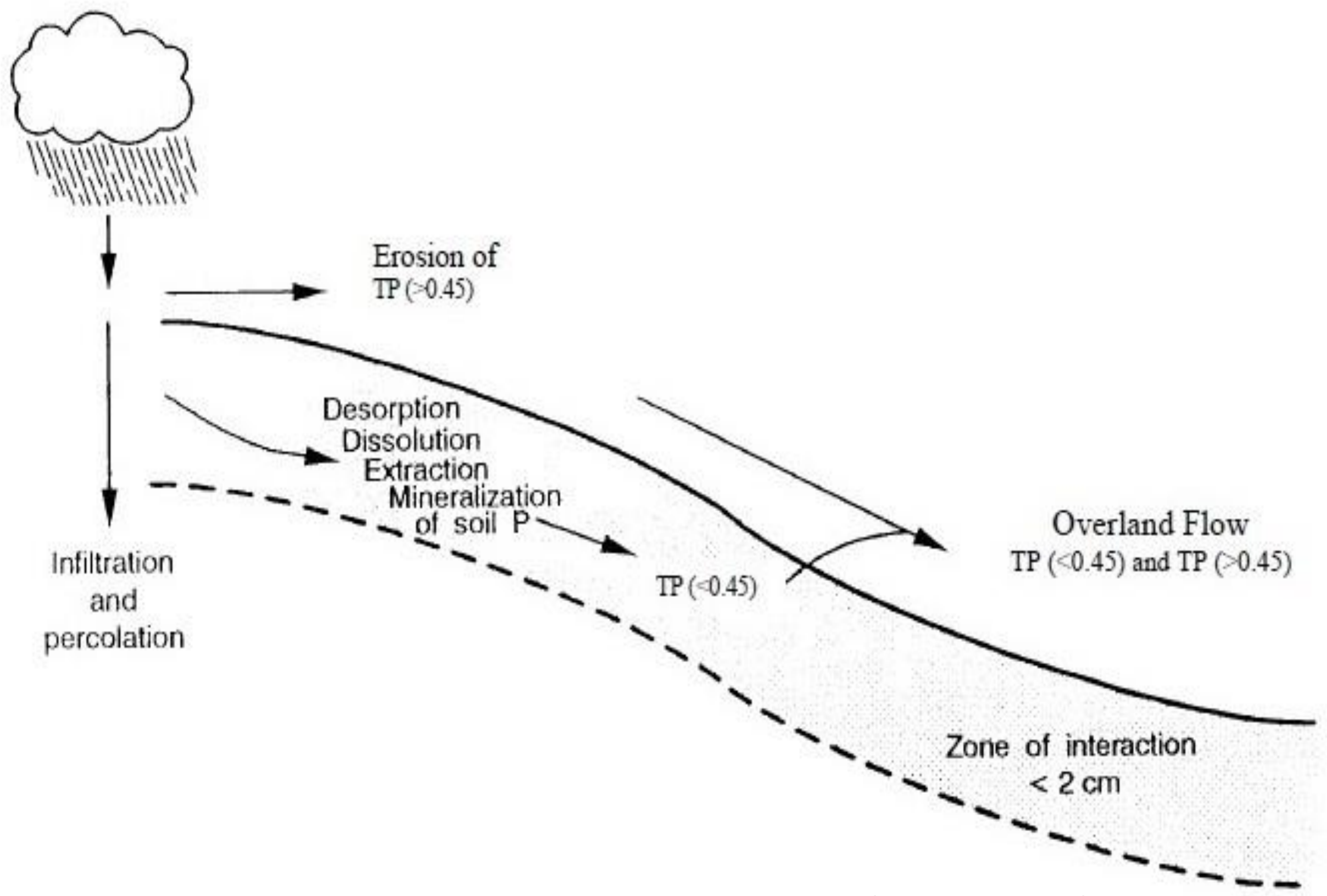


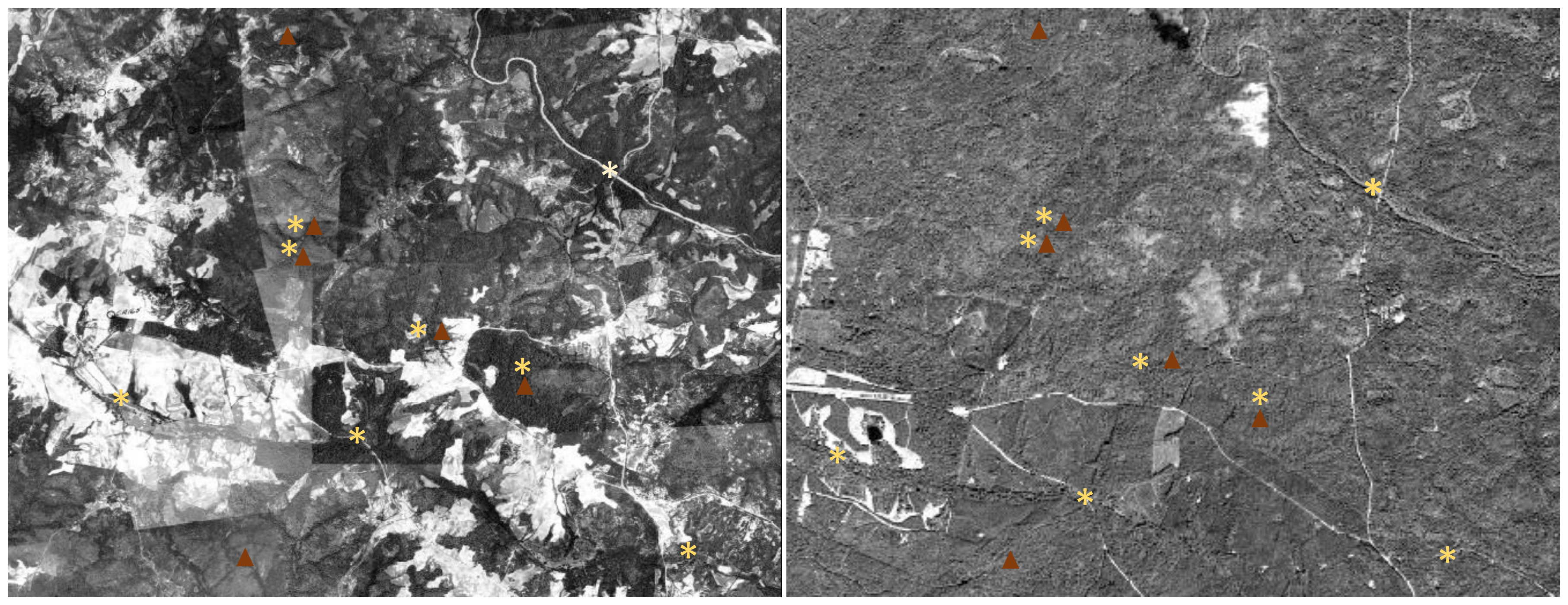
Fig. 1. P transportation mechanisms along hillslopes (Daniel, 1994). 0.45 µm= filter pore size that defines dissolved P vs. particulate P.

STUDY AREA & METHODS

- The Calhoun Critical Zone Observatory (CZO), within the Sumter National Forest, South Carolina (SC), has a history of severe surface erosion (~17 cm of soil eroded between 1750 and 1950; Hayes et al. 2014).
- The forest was cleared and burned, and in some cases fertilized with lime and P for crop production (Fig. 2; Gray and Thompson 1933).
- This combination of land use practices (agriculture, abandonment and regrowth/recovery) affords a unique opportunity to consider the landscape scale redistribution of P in response to current land uses.

- Soil samples were collected from upper, middle, and lower landscape positions at three reforested and three “reference” sites (Fig. 3, example of Calhoun CZO soil).
- Samples were extracted with Mehlich III (“Readily soluble and exchangeable P_i”; Carter 1993) and fractionated (Hedley et al. 1982).
- Water samples were collected monthly from local streams and rivers.
- Soil solutions were collected every 10-14 days from ceramic cup lysimeters located at two depths in the same hillslope positions from January-July 2017.

Fig. 3. Typical soil profile in Calhoun CZO, SC



Calhoun CZO (1933) **Calhoun CZO (2017)**

* Stream sample locations (8 of 17 shown) ▲ Soil sample and lysimeter locations

Fig. 2. Time comparison of the Calhoun Experimental Forest (SC) land cover. US Forest Service 1933 photograph obtained from the Photographic Archive of the Calhoun Experimental Forest. (http://criticalzone.org/calhoun/data/dataset/4324/)

RESULTS

Table1. Mean (± SD) of readily available and exchangeable P_i (mg/kg) in three hillslope positions within two land cover classes in Calhoun Experimental Forest (SC). Readily available and exchangeable P_i in Reforested hillslope are greater than Reference hillslope throughout much of the landscape positions and soil profiles.

Land cover	Hillslope position	Profile depth (cm)						
		0-7.5	7.5-15	15-35	35-60	60-100	100-150	150-200
Reforested	*Up-slope*	5.7(3.4)	5.2(3.1)	3.3(0.6)	3.0(0.5)	3.0(0.5)	3.1(0.7)	4.4(2.3)
Reference		4.9(2.7)	4.3(2.7)	1.8(0.4)	1.0(0.4)	0.8(0.2)	0.9(0.3)	0.8(0.3)
Reforested	*Mid-slope*	11.5(6.4)	5.1(4.1)	3.0(2)	2.9(1.4)	2.6(1.2)	3.3(2.3)	4.2(0.9)
Reference		9.5(1.2)	4.6(0.3)	2.0(0.7)	1.9(1)	1.9(3.6)	3.7(1.3)	2.8(1.6)
Reforested	*Low-slope*	10.4(5.6)	5.4(3)	4.4(3.1)	3.0(1.6)	2.8(1.7)	6.0(7.3)	5.8(6)
Reference		12.1(0.6)	4.8(1)	2.1(3.4)	2.6(2.4)	1.7(6)	1.7(2.4)	3.9(0.3)

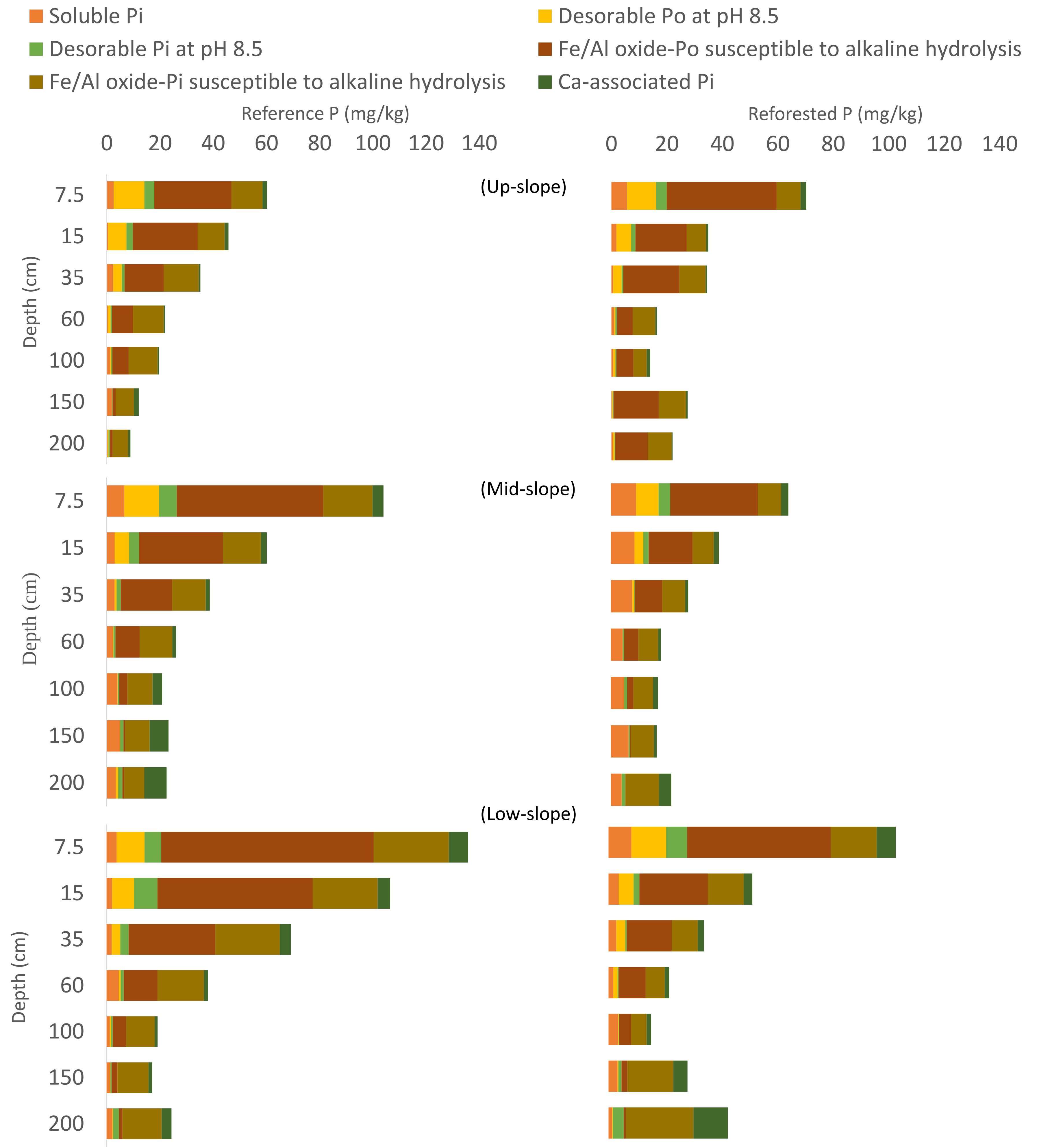
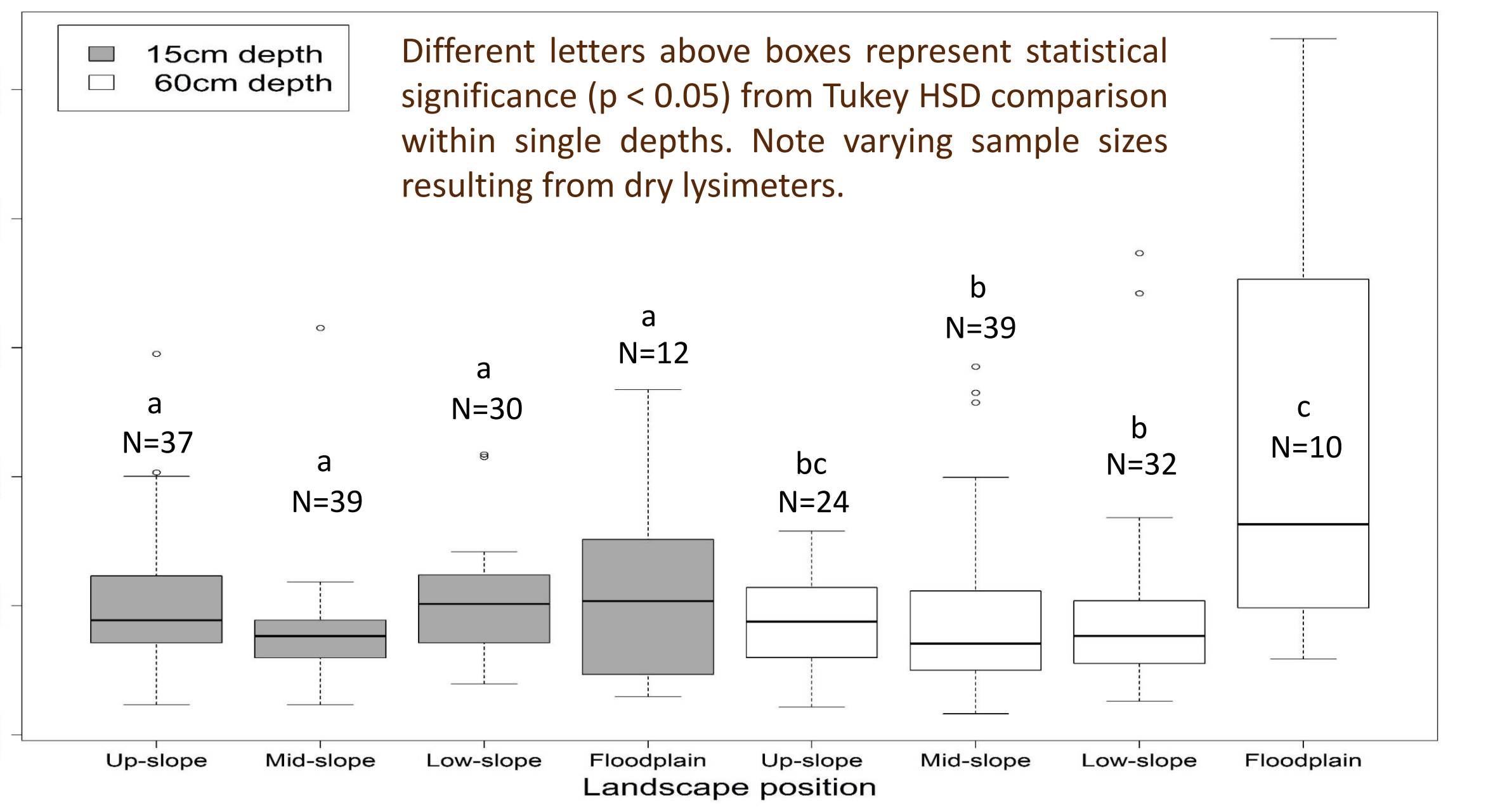
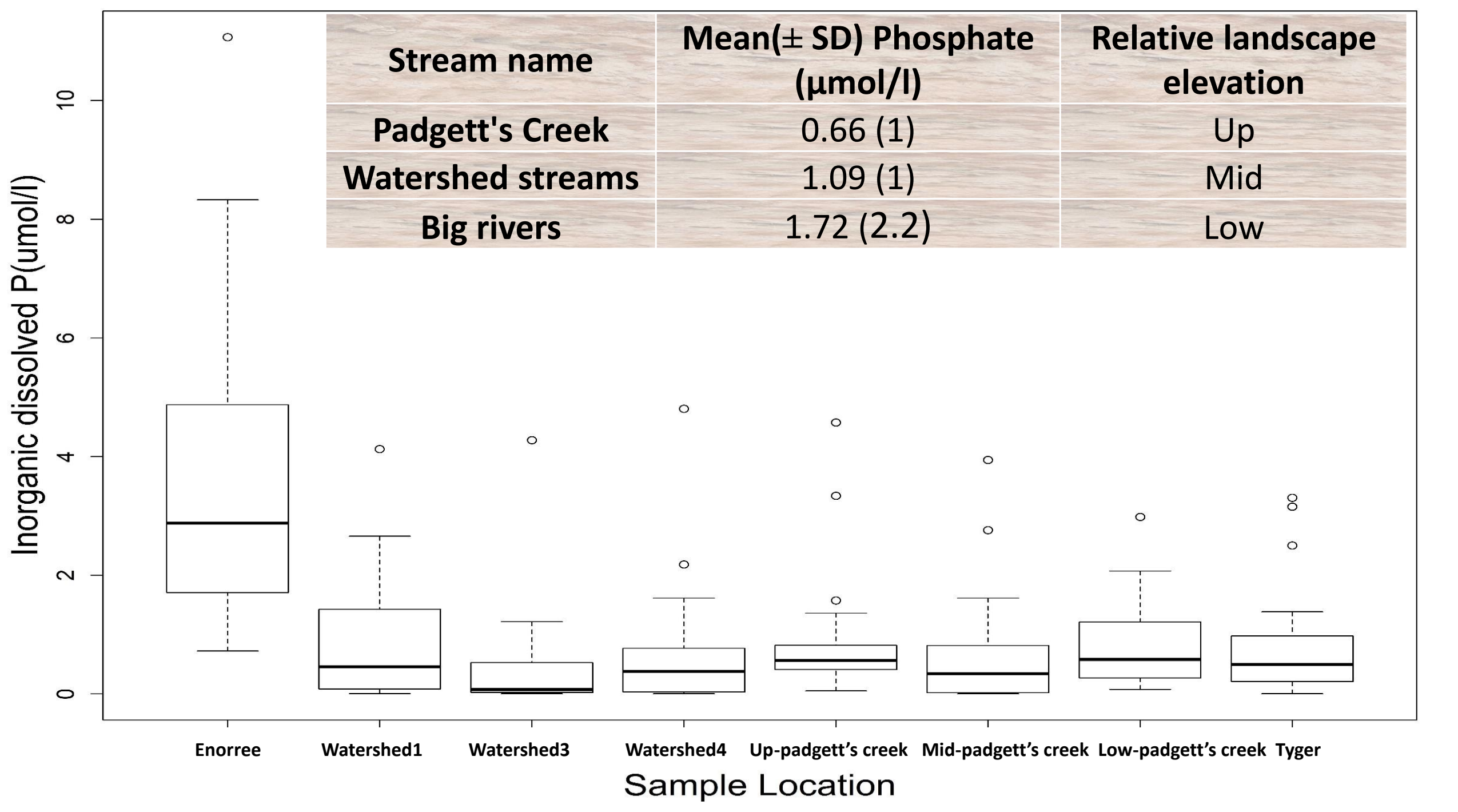


Fig. 4. P fraction distribution across depths and position in Reference (left) and Reforested (right) hillslopes. Labile and moderately labile pools in mid and low slope of reference hillslopes are greater than reforested hillslopes. In contrast, P pools in up-slope, reforested hillslopes are greater than reference hillslopes.



Different letters above boxes represent statistical significance ($p < 0.05$) from Tukey HSD comparison within single depths. Note varying sample sizes resulting from dry lysimeters.

Fig. 5. Total dissolved P (µmol/l) in Reforested hillslopes Calhoun CZO soil solution from January – July 2017. (Three outliers deleted for image clarity.)



Stream name	Mean(± SD) Phosphate (µmol/l)	Relative landscape elevation
Padgett's Creek	0.66 (1)	Up
Watershed streams	1.09 (1)	Mid
Big rivers	1.72 (2.2)	Low

Fig. 6. Inorganic dissolved P (µmol/) in select Calhoun CZO rivers and streams. The heavy line in each boxplot represents the median.

Table 2. P-values of factors related to different fractionation pools estimated through multiple regression analysis.

Fractionation pools	Depth	Land cover	pH_w	pH_{Cacl_2}	Clay%
Mehlich III extracted P	NS	0.095 (-)	NS	0.01 (+)	0.024 (-)
Soluble P_i	NS	0.02 (+)	NS	NS	0.06 (+)
Desorbable P_i at pH 8.5	<0.001 (-)	0.025 (-)	0.08(+)	NS	<0.001 (-)
Desorbable P_o at pH 8.5	<0.001 (-)	0.09 (-)	NS	NS	<0.001 (-)
Fe/Al oxide-P_i susceptible to Alkaline hydrolysis	NS	0.003 (-)	NS	NS	0.02 (-)
Fe/Al oxide-P_o susceptible to Alkaline hydrolysis	<0.001 (-)	0.011 (-)	0.02 (+)	0.03 (+)	<0.001 (+)
Ca-associate P_i	NS	NS	NS	0.05 (+)	<0.001 (-)

NS represents p-values >0.1, (+) and (-) reflect positive and negative relationships, respectively.

CONCLUSIONS

- All soils analyzed in reforested hillslopes had greater labile P pools (Soluble and exchangeable P_i and Desorbable P_i & P_o at pH 8.5) relative to reference hillslopes throughout the soil profile, suggesting past fertilization increased P in the system.
- Fe/Al oxide-P pools in lower slopes are greater than other landscape positions in both land uses likely from erosion delivering material down slope. Also Fe/Al oxide-P_o is greater than Fe/Al oxide-P_i which may reflect C eroded with clay.
- P availability increased with higher pH because of lower Fe/Al oxide – phosphate binding capacity; thus, P is more available for biota and potential movement in solution.
- Increasing soil clay content was associated with more soluble P_i possibly due to increased anion exchange capacity. In contrast, increasing clay resulted in less desorbable P_i & P_o at pH 8.5 possibly because clay minerals such as Fe oxyhydroxides bind P irreversibly.
- Although the amount of P in surface water and soil solution is currently low, concentrations may have been higher in the past and integrating fluxes over the time of forest recovery may partly explain higher P concentrations in deeper soils.

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