

# Nutrient retention in forest soils: Role of reactive aluminum and iron phases



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## 1 Highlights

- Soil nutrient distribution was strongly affected by short-range order (SRO) Al and Fe mineral phases :
  - The effective cation exchange capacity ( $CEC_e$ ) decreased with increasing amounts of SRO phases
  - Phosphorus lability decreased with increasing amounts of SRO phases
- The influence of SRO phases can explain the observed, seemingly anomalous influence of pH on  $CEC_e$  and P lability.
- This study shows that understanding the peculiar chemistry of some forest soils requires the explicit consideration of the sorptive properties of SRO Al and Fe phases.

## 2 Study objectives

- To describe nutrient distribution in forested Spodosols in southwestern Canada
- To determine the influence of SRO Al and Fe phases on nutrient availability

## 3 Study sites

The study was conducted at the Roberts Creek Study Forest on southern coastal British Columbia, Canada (Fig. 1). The area lies within the Coastal Western Hemlock biogeoclimatic zone.

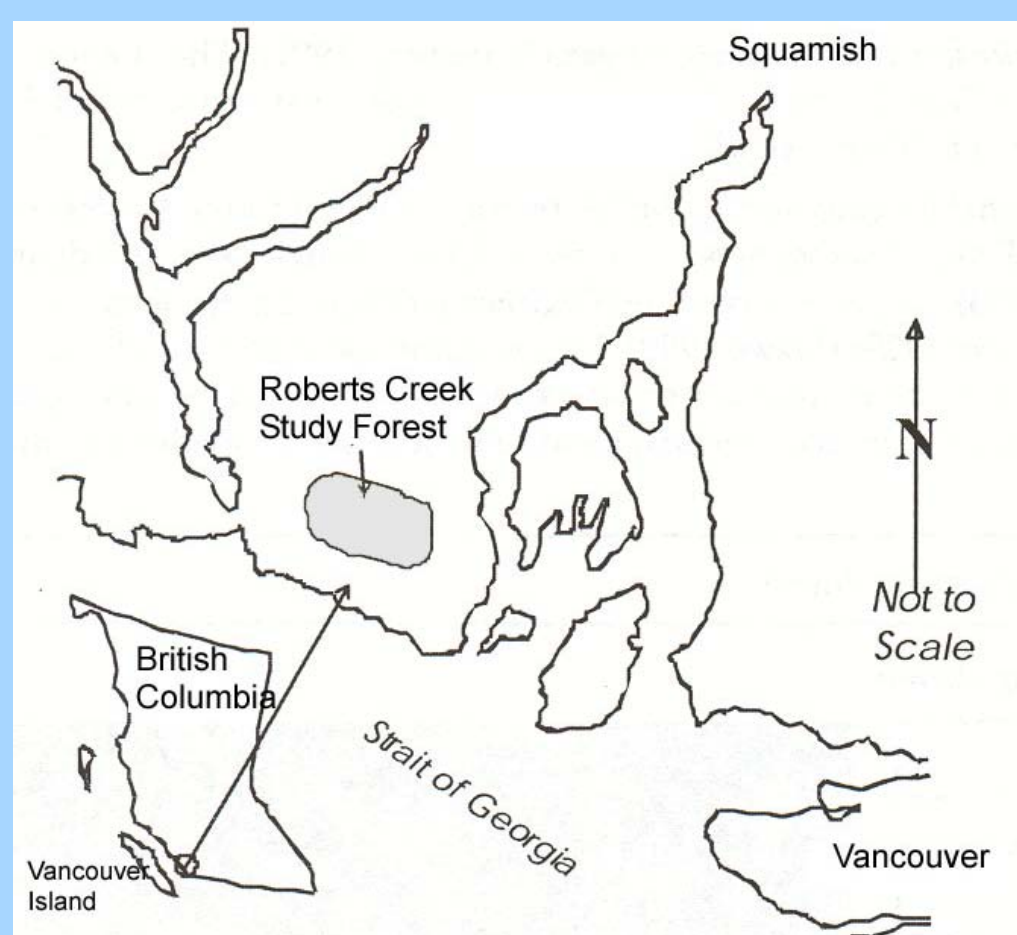


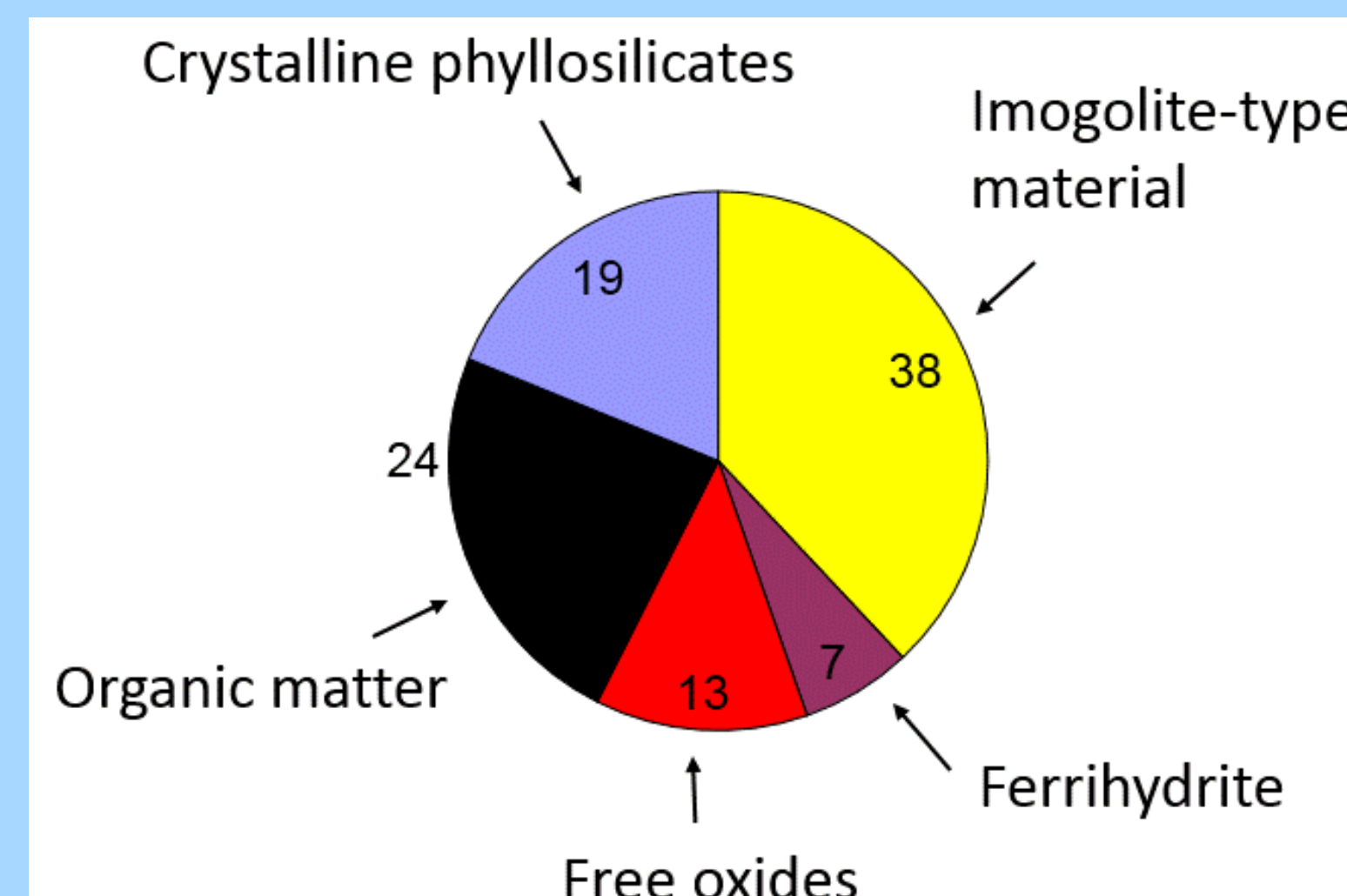
Figure 1: Field site location



Figure 2: A typical soil profile

Soils of Roberts Creek are Aquentic Haplorthods of sandy loam to loamy sand texture (Fig. 2). In the subsoil, SRO mineral phases such as imogolite-type material and ferrihydrite account for nearly half of the colloidal fraction (Fig. 3).

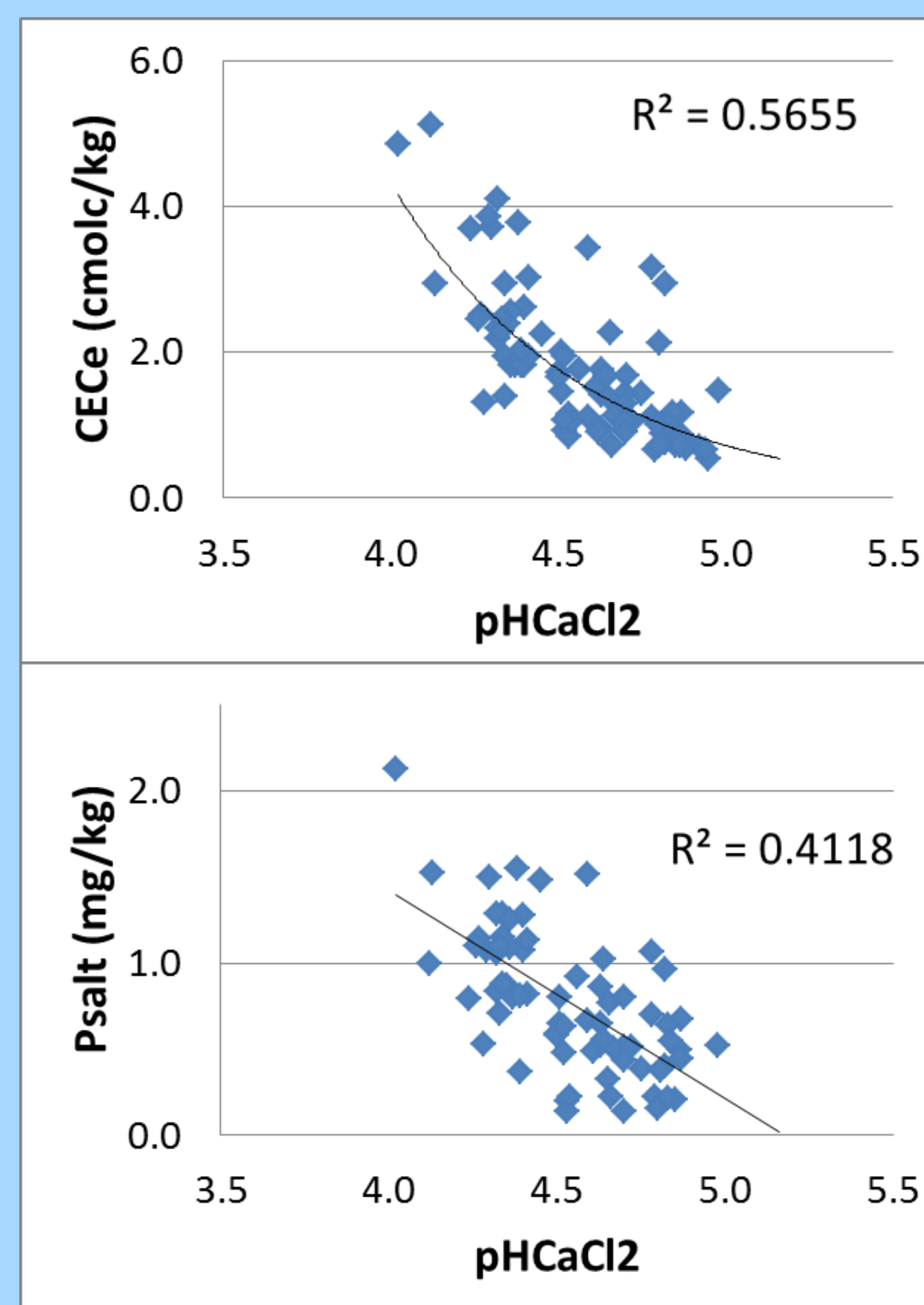
Figure 3: Composition of the colloidal fraction in the subsoil (Bs) horizon, expressed as a percentage of the total clay content (54 g clay / kg soil)



## 4 Some unexpected geochemical relations

Initial investigations of nutrient distribution in B horizons of Roberts Creek soils revealed that contrary to generally expected geochemical behavior, both the  $CEC_e$  and P availability decreased as pH increased (Fig. 4).

Figure 4: The  $CEC_e$  and salt-extractable P ( $P_{salt}$ ) decrease as pH measured in salt ( $pH_{CaCl2}$ ) increases.

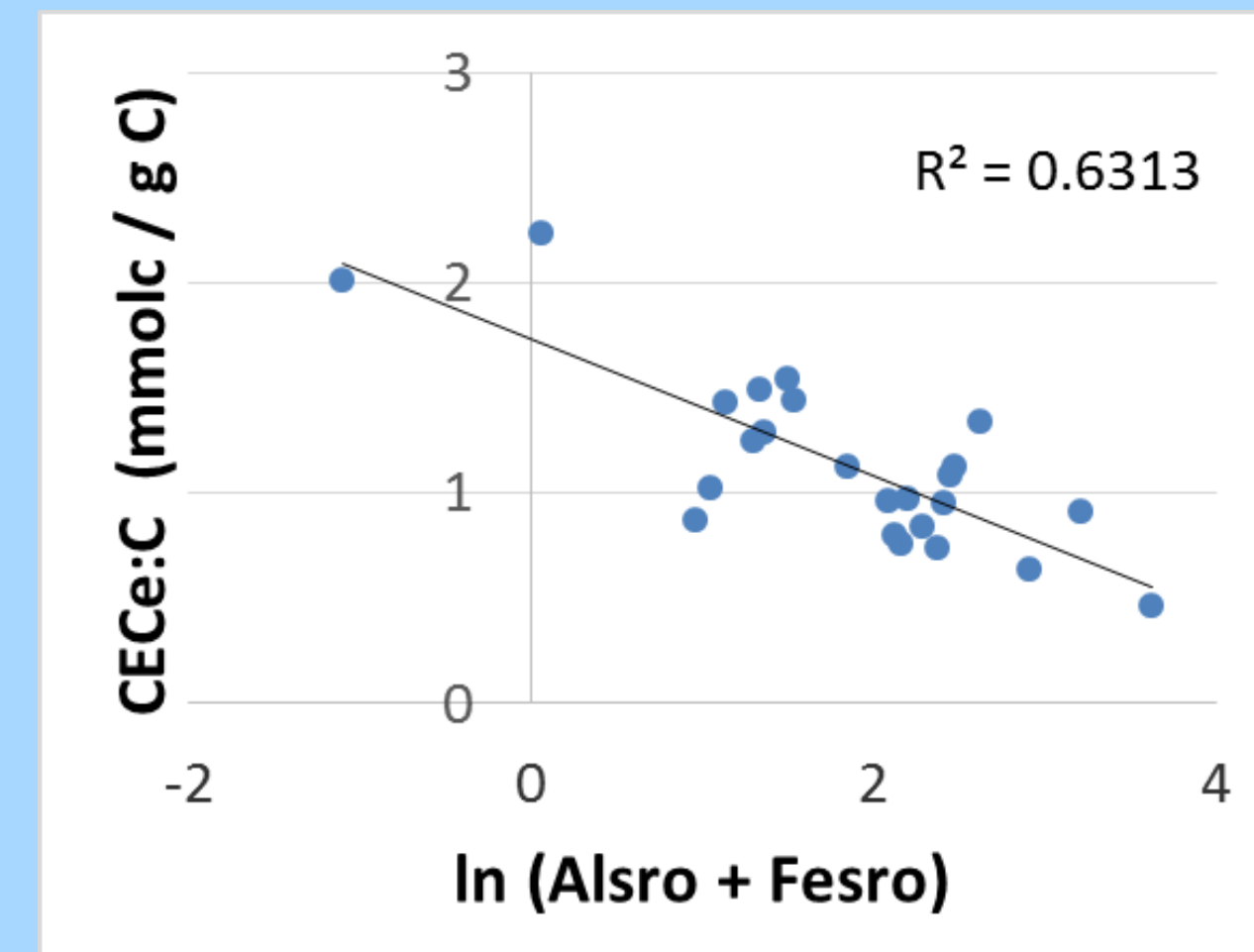


The next section explores the hypothesis that this divergent geochemical property is linked to the effects of SRO mineral phases.

## 5 Influence of SRO Al and Fe phases

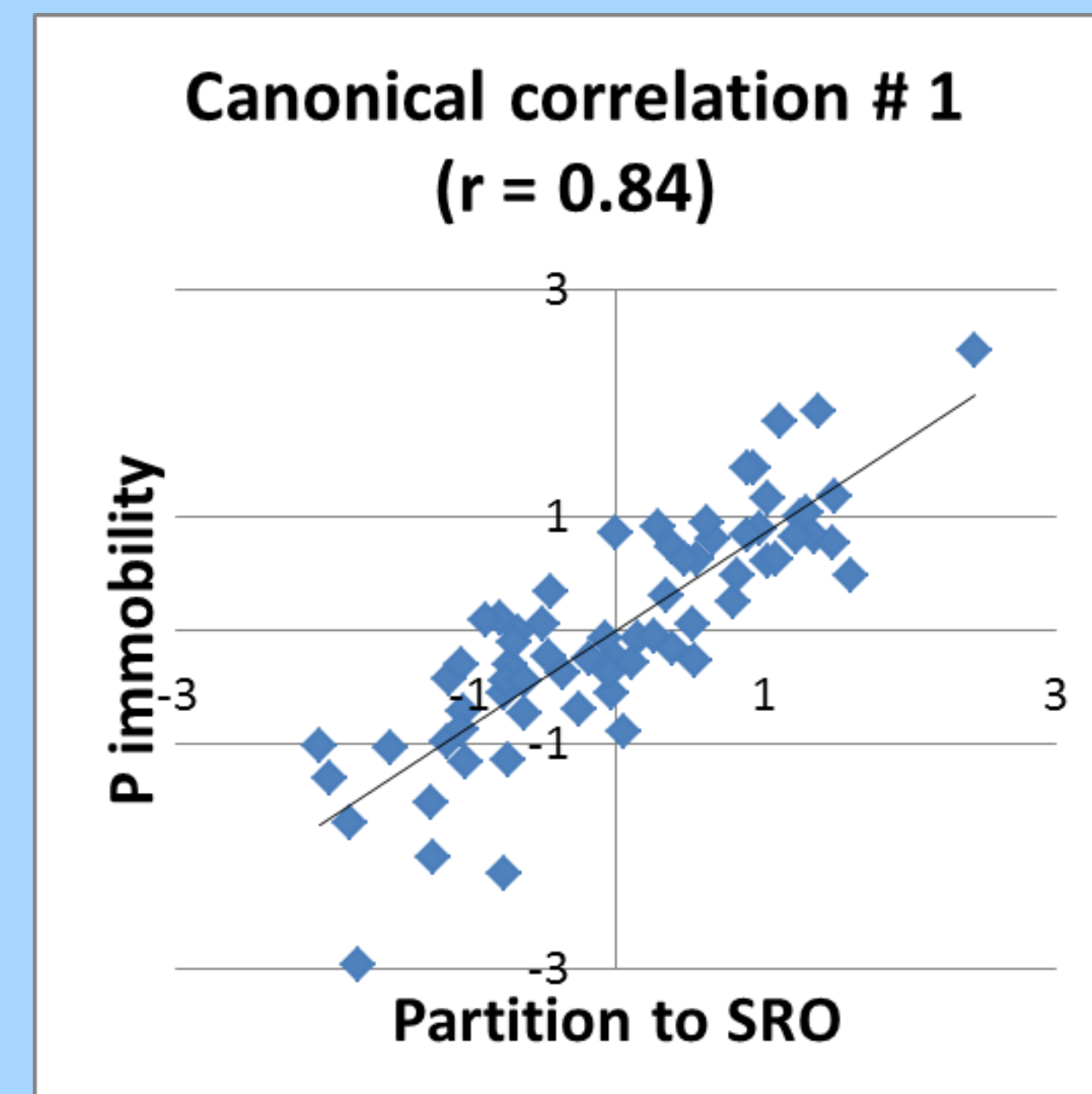
The decline in  $CEC_e$  in higher pH soils was concomitant with an increase in the amount of SRO and increased partition of Al to SRO minerals, at the expense of organic complexes (Fig. 5). The decrease in  $CEC_e$  is thus attributable to an increase in the amount and specific affinity of SRO phases for organic anionic sorption sites at higher pH (Grand & Lavkulich 2013, EJSS 64:651-660).

Figure 5: The decline in  $CEC_e$  is associated with an increase in SRO phases at higher pH. We present the variations in the  $CEC_e:C$  ratio (an indicator of the charge density of organic matter) in order to correct for the potential influence of soil organic matter on  $CEC_e$  and pH.



The decline in P availability with pH was also linked to an increased partition to SRO phases, as shown by canonical correlation analysis (Fig. 6).

Figure 6: Graphical representation of the multivariate relation between soil factors and P forms, as calculated from canonical correlation analysis.



The structure of the canonical axes is given in Table 1.

Table 1: Correlation between canonical and input variables.

P form	Canonical variable 1 "P immobility"	Canonical variable 2	Canonical variable 3
$P_{salt}$	-0.78	0.62	-0.12
$P_{sro}$ (oxalate-extractable)	0.48	0.88	-0.04
Total P	0.33	0.71	0.63

Soil variable	Canonical variable 1 "Partition to SRO"	Canonical variable 2	Canonical variable 3
$pH_{CaCl2}$	0.77	-0.32	0.46
Silt + clay	-0.49	0.09	-0.12
Soil C	-0.61	0.74	0.26
$Al_{org}$ (pyr-extractable)	-0.49	0.64	-0.13
$Al_{sro}$ (ox-extractable)	0.53	0.84	0.14

## 6 Implications

Nutrient dynamics have been most extensively studied in agricultural soils with a predominance of crystalline phyllosilicates as surface-active components. This study shows that in some forest soils, much of the chemical reactivity is accounted for by SRO mineral and organo-mineral products, resulting in a divergent geochemical behavior. In particular, higher pH soils may exhibit lower nutrient availability due to an increase in the affinity of SRO Al and Fe phases for organic anions and oxyanions.

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