

# Calibration Report: Low N Sedimentary Site Base Case

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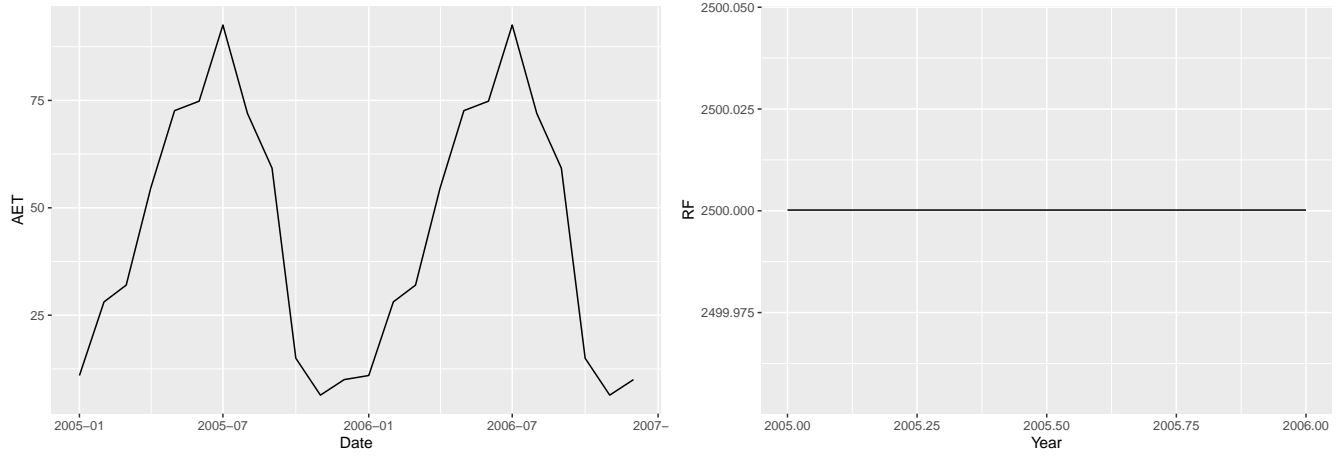
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## Hydrology



## Soil Solution Results

Table 1: Average Soil Solution Concentrations of Reliable Months (2005-2006)

| Soil Layer | $\mu\text{mol/L}$ |      |       |      |       |      |       |      |       |       |       |      |       |      |      |       |
|------------|-------------------|------|-------|------|-------|------|-------|------|-------|-------|-------|------|-------|------|------|-------|
|            | Ca                | Mg   | K     | Na   | NO3   | NH4  | SO4   | Cl   | PO4   | DOC   | Al    | Si   | H+    | pH   | R    | HR    |
| Layer 1    | 15.8              | 19.0 | 10.77 | 53.9 | 1.677 | 3.61 | 6.29  | 49.6 | 0.683 | 122.5 | 0.462 | 62.6 | 14.44 | 4.84 | 89.4 | 33.10 |
| Layer 2    | 16.6              | 20.1 | 10.98 | 71.0 | 1.419 | 3.50 | 6.70  | 47.5 | 0.275 | 126.6 | 0.288 | 70.5 | 9.91  | 5.00 | 97.8 | 28.75 |
| Layer 3    | 15.5              | 18.7 | 10.59 | 82.4 | 1.264 | 3.49 | 9.64  | 47.2 | 0.265 | 113.5 | 0.461 | 70.9 | 6.26  | 5.20 | 91.7 | 21.76 |
| Layer 4    | 13.1              | 20.3 | 6.85  | 82.8 | 1.095 | 2.82 | 12.24 | 50.4 | 0.209 | 85.3  | 0.335 | 71.9 | 5.02  | 5.30 | 71.1 | 14.26 |
| Layer 5    | 14.7              | 22.9 | 7.18  | 87.8 | 0.973 | 2.55 | 10.92 | 57.2 | 0.143 | 87.7  | 0.383 | 75.5 | 5.42  | 5.27 | 73.1 | 14.61 |
| Layer 6    | 15.1              | 23.5 | 7.26  | 89.5 | 0.881 | 2.27 | 10.84 | 65.3 | 0.162 | 63.8  | 0.180 | 79.1 | 3.03  | 5.52 | 56.2 | 7.62  |
| Layer 7    | 16.1              | 24.9 | 7.48  | 92.4 | 0.802 | 2.07 | 11.45 | 71.2 | 0.161 | 60.6  | 0.249 | 82.6 | 3.94  | 5.40 | 52.2 | 8.38  |
| Layer 8    | 15.7              | 24.6 | 7.37  | 94.0 | 0.754 | 1.95 | 11.94 | 74.5 | 0.137 | 48.6  | 0.145 | 85.1 | 2.50  | 5.60 | 43.0 | 5.58  |

Table 2: Lysimeter Measured Soil Solution Concentrations of Reliable Months (2005)

| Layer | $\mu\text{mol/L}$ |       |    |       |    |      |     |       |     |        |     |        |     |        |     |       |       |       |     |        |        |       |        |       |        |
|-------|-------------------|-------|----|-------|----|------|-----|-------|-----|--------|-----|--------|-----|--------|-----|-------|-------|-------|-----|--------|--------|-------|--------|-------|--------|
|       | Ca                | Ca SD | Mg | Mg SD | K  | K SD | Na  | Na SD | NO3 | NO3 SD | NH4 | NH4 SD | SO4 | SO4 SD | Cl  | Cl SD | $P^a$ | P SD  | DOC | DOC SD | $Al^b$ | Al SD | $Si^c$ | Si SD | $pH^d$ |
| 1     | 29                | 12.9  | 30 | 20    | 32 | 17   | 131 | 71    | 2.3 | 2.14   | 1.1 | 0.25   | 18  | 2.20   | 167 | 109   | 0.07  | 0.038 | 123 | 28     | 0.98   | 0.42  | 82     | 16    | 5.6    |
| 2     | 29                | 12.9  | 30 | 20    | 32 | 17   | 131 | 71    | 2.3 | 2.14   | 1.1 | 0.25   | 18  | 2.20   | 167 | 109   | 0.07  | 0.038 | 123 | 28     | 0.98   | 0.42  | 82     | 16    | 5.3    |
| 3     | 29                | 12.9  | 30 | 20    | 32 | 17   | 131 | 71    | 2.3 | 2.14   | 1.1 | 0.25   | 18  | 2.20   | 167 | 109   | 0.07  | 0.038 | 123 | 28     | 0.98   | 0.42  | 82     | 16    | 5.4    |
| 4     | 14                | 3.3   | 24 | 12    | 12 | 20   | 133 | 58    | 1.9 | 0.73   | 1.2 | 0.27   | 12  | 0.73   | 152 | 87    | 0.05  | 0.032 | 63  | 30     | 0.37   | 0.17  | 84     | 15    | 5.5    |
| 5     | 14                | 3.3   | 24 | 12    | 12 | 20   | 133 | 58    | 1.9 | 0.73   | 1.2 | 0.27   | 12  | 0.73   | 152 | 87    | 0.05  | 0.032 | 63  | 30     | 0.37   | 0.17  | 84     | 15    | 5.6    |
| 6     | 14                | 3.3   | 24 | 12    | 12 | 20   | 133 | 58    | 1.9 | 0.73   | 1.2 | 0.27   | 12  | 0.73   | 152 | 87    | 0.05  | 0.032 | 63  | 30     | 0.37   | 0.17  | 84     | 15    | 5.7    |
| 7     | 14                | 3.3   | 24 | 12    | 12 | 20   | 133 | 58    | 1.9 | 0.73   | 1.2 | 0.27   | 12  | 0.73   | 152 | 87    | 0.05  | 0.032 | 63  | 30     | 0.37   | 0.17  | 84     | 15    | 5.8    |
| 8     | 14                | 3.3   | 24 | 12    | 12 | 20   | 133 | 58    | 1.9 | 0.73   | 1.2 | 0.27   | 12  | 0.73   | 152 | 87    | 0.05  | 0.032 | 63  | 30     | 0.37   | 0.17  | 84     | 15    | 5.8    |

<sup>a</sup> Average based on TP annual average  
<sup>b</sup> Does not distinguish between organic-Al and free Al  
<sup>c</sup> Model does not simulate Si uptake  
<sup>d</sup> From Hynicka et al., 2017 (10-50cm) extrapolated to 1m

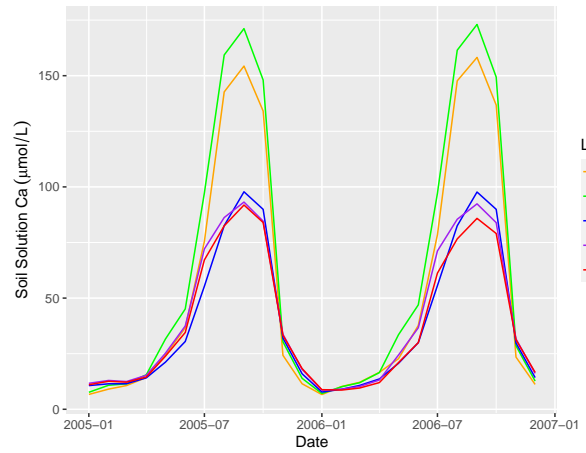
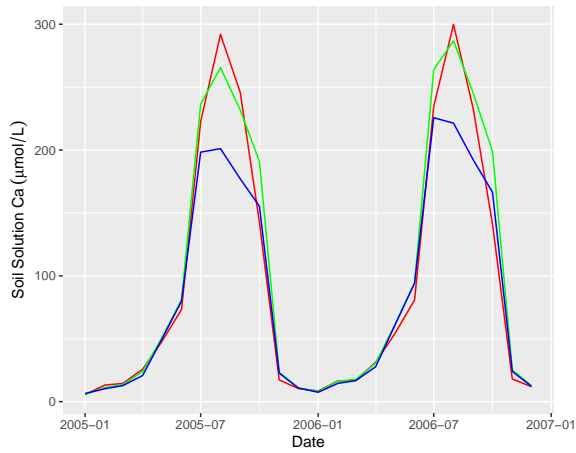


Figure 1: Monthly Calcium Concentrations by Soil Layer

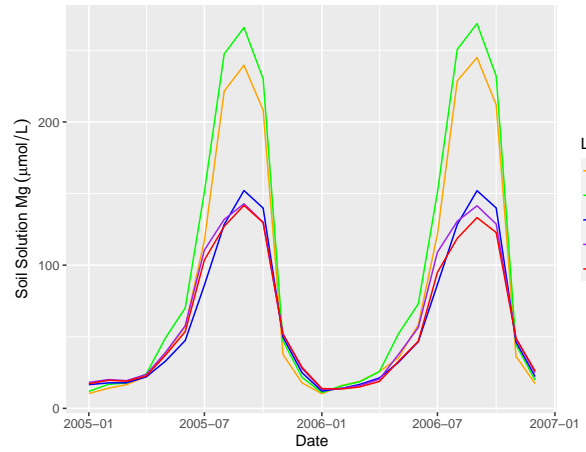
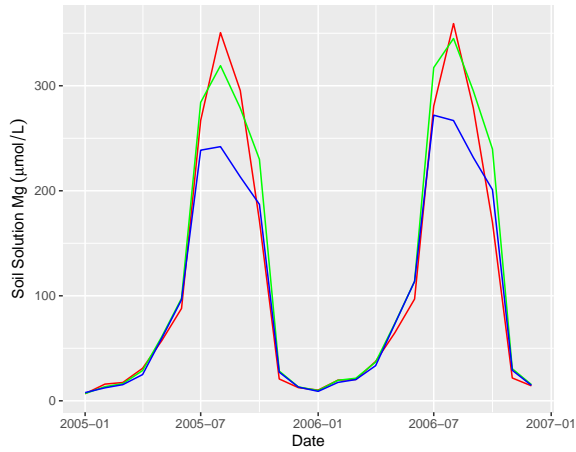


Figure 2: Monthly Magnesium Concentrations by Soil Layer

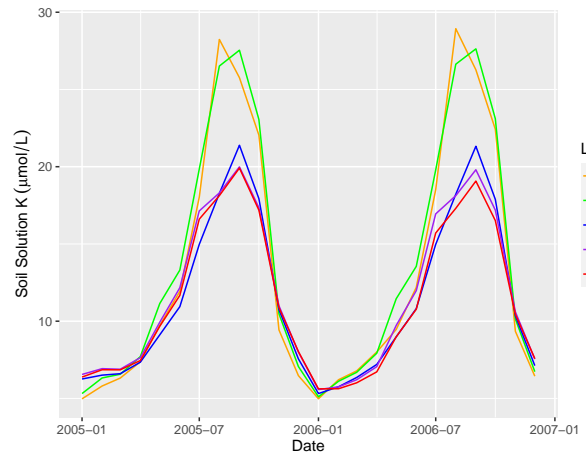
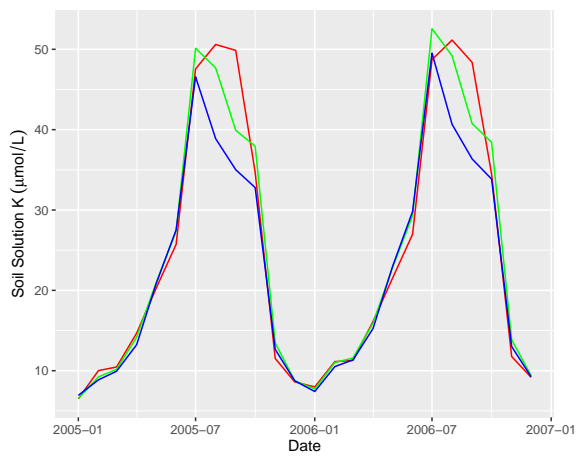


Figure 3: Monthly Potassium Concentrations by Soil Layer

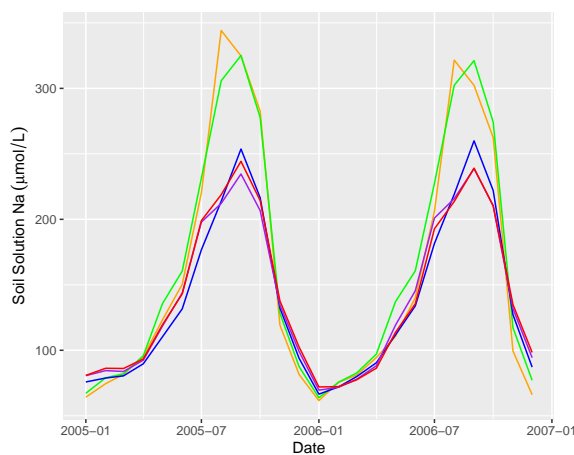
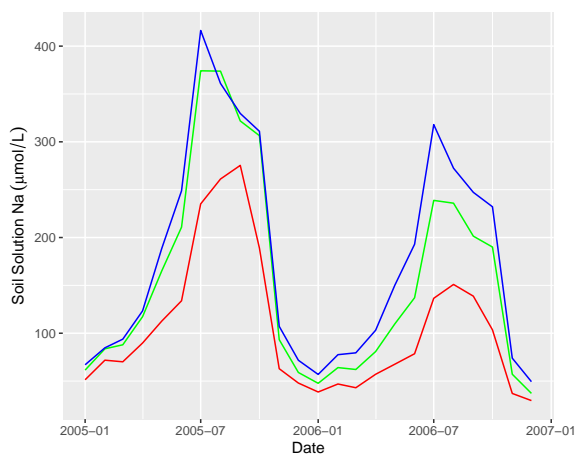


Figure 4: Monthly Sodium Concentrations by Soil Layer

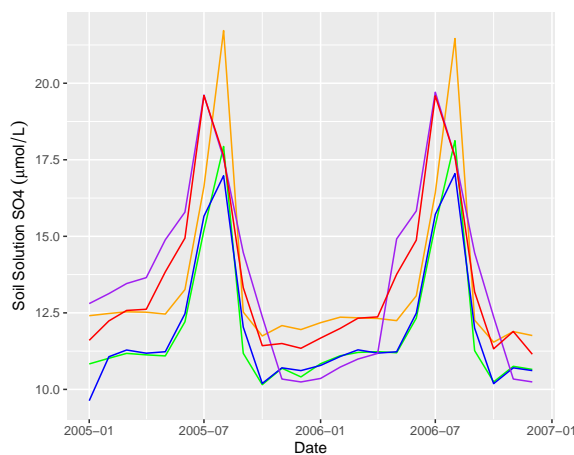
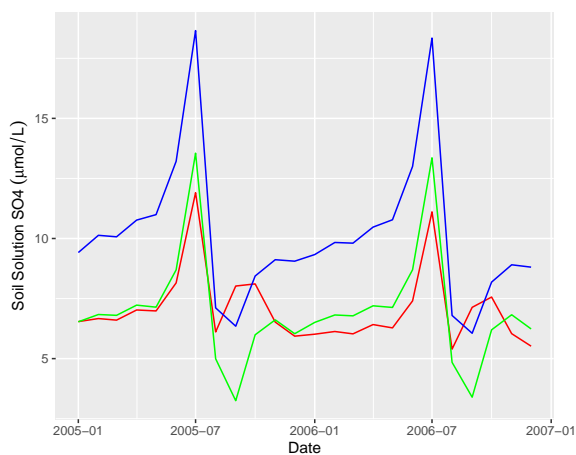


Figure 5: Monthly Sulfate Concentrations by Soil Layer

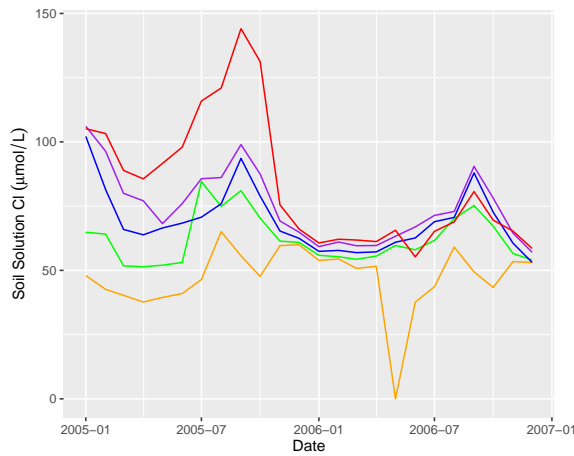
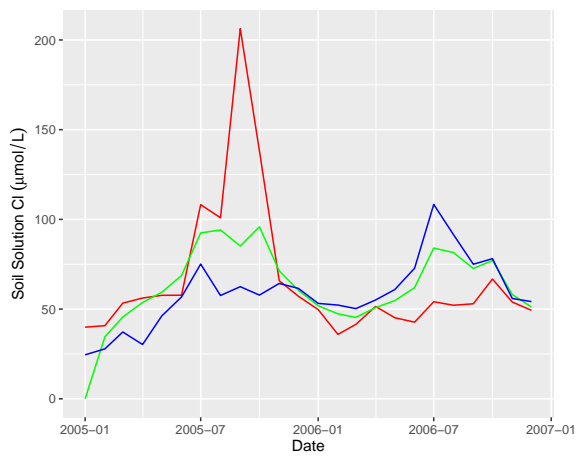


Figure 6: Monthly Chloride Concentrations by Soil Layer

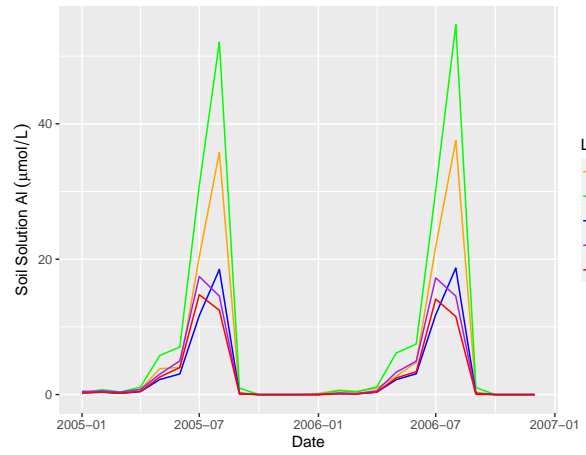
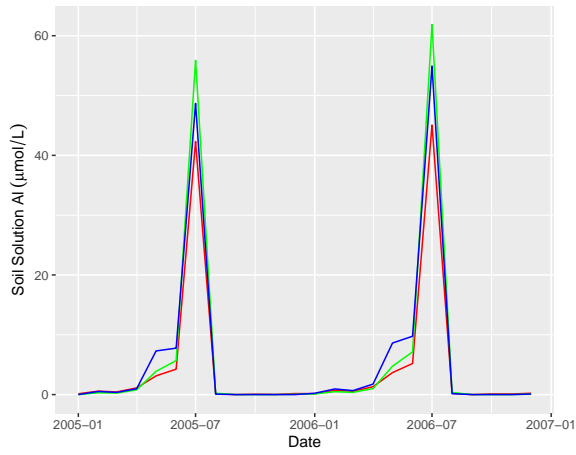


Figure 7: Monthly Aluminum Concentrations by Soil Layer

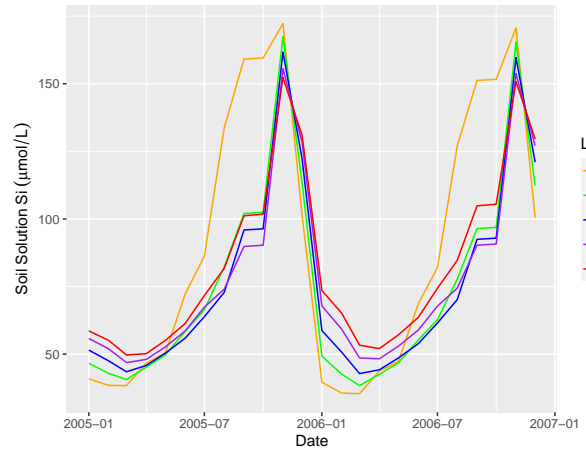
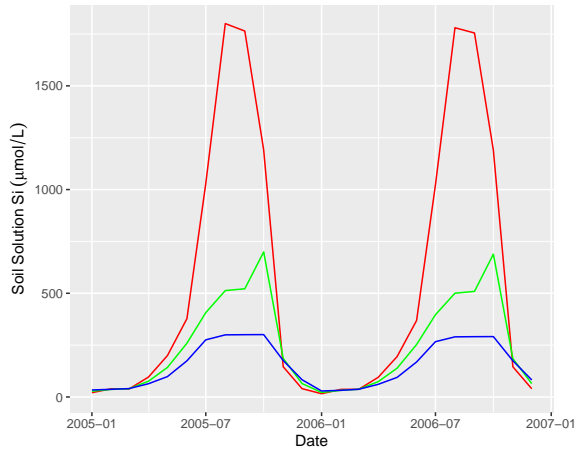


Figure 8: Monthly SiO<sub>2</sub> Concentrations by Soil Layer

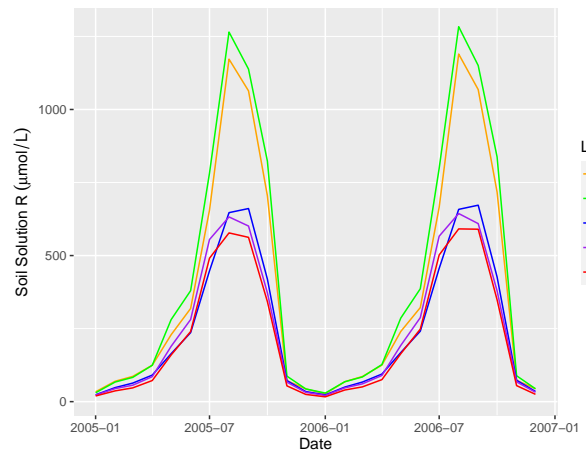
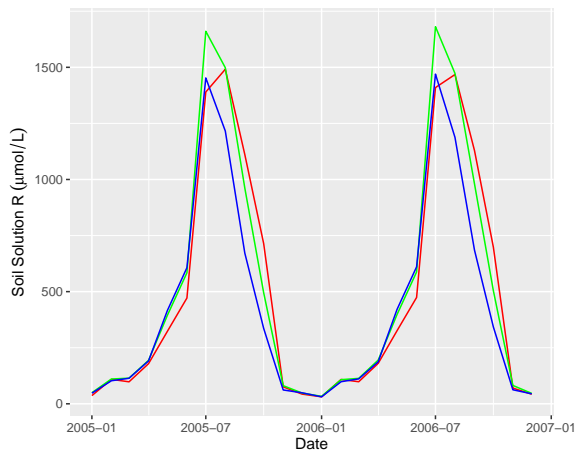


Figure 9: Monthly Organic Acid Base (R-) Concentrations by Soil Layer



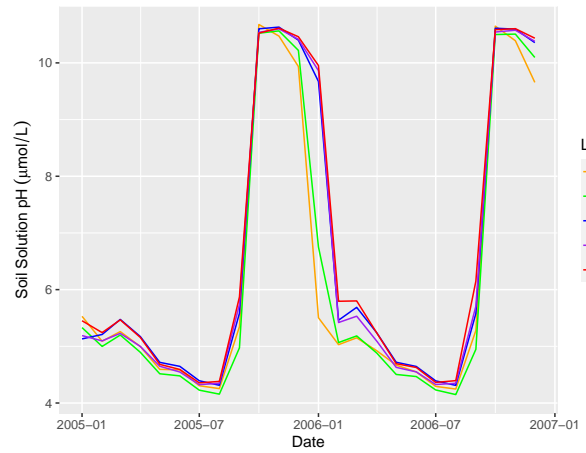
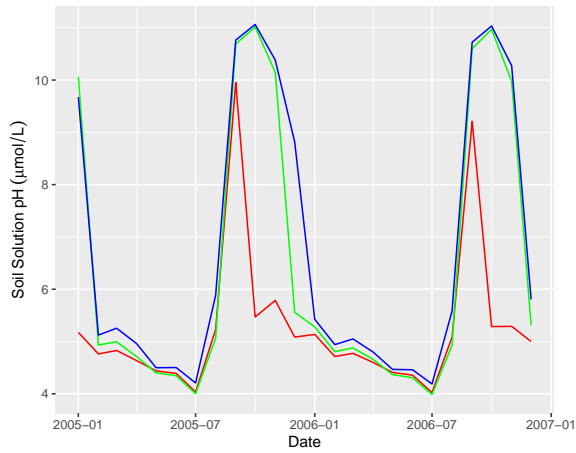


Figure 10: Monthly pH by Soil Layer

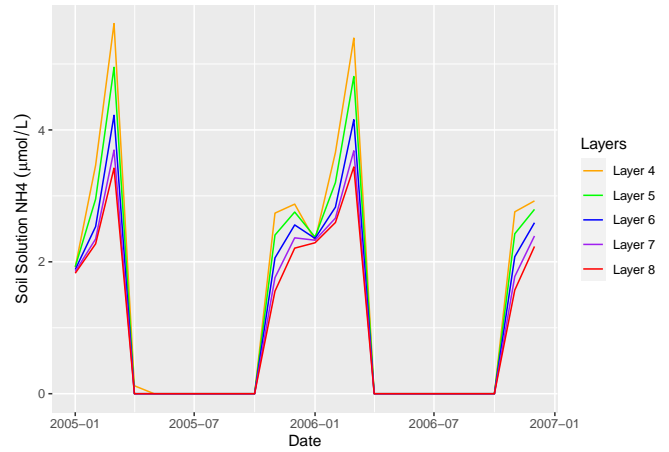
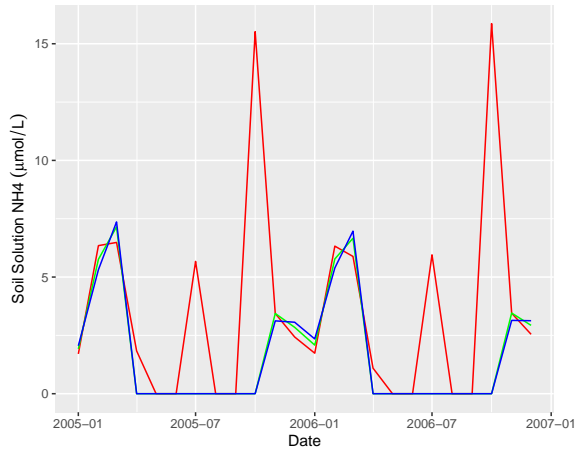


Figure 11: Yearly Ammonium concentration by Soil Layer

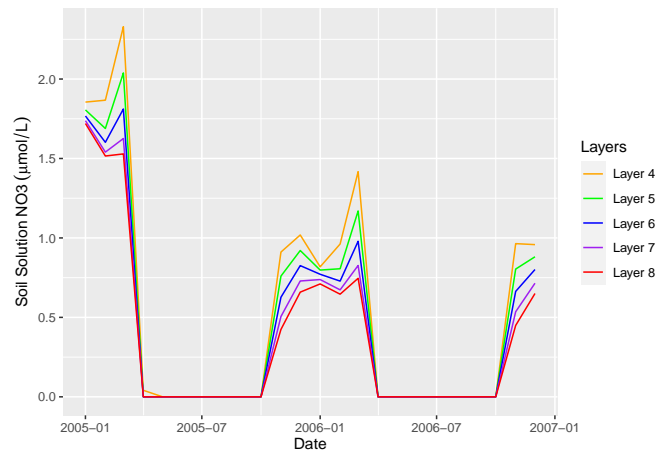
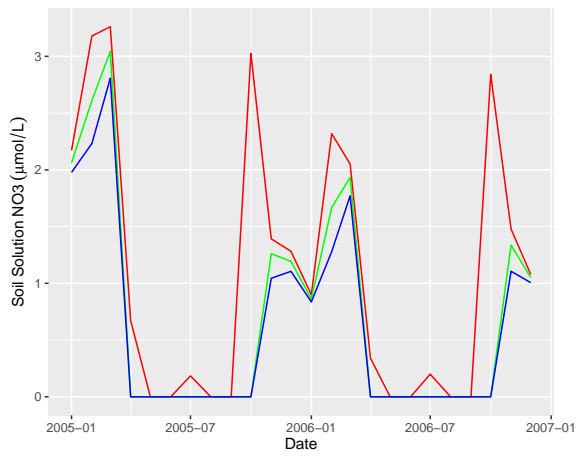


Figure 12: Yearly Nitrate concentration by Soil Layer

## Lysimeter Comparisons

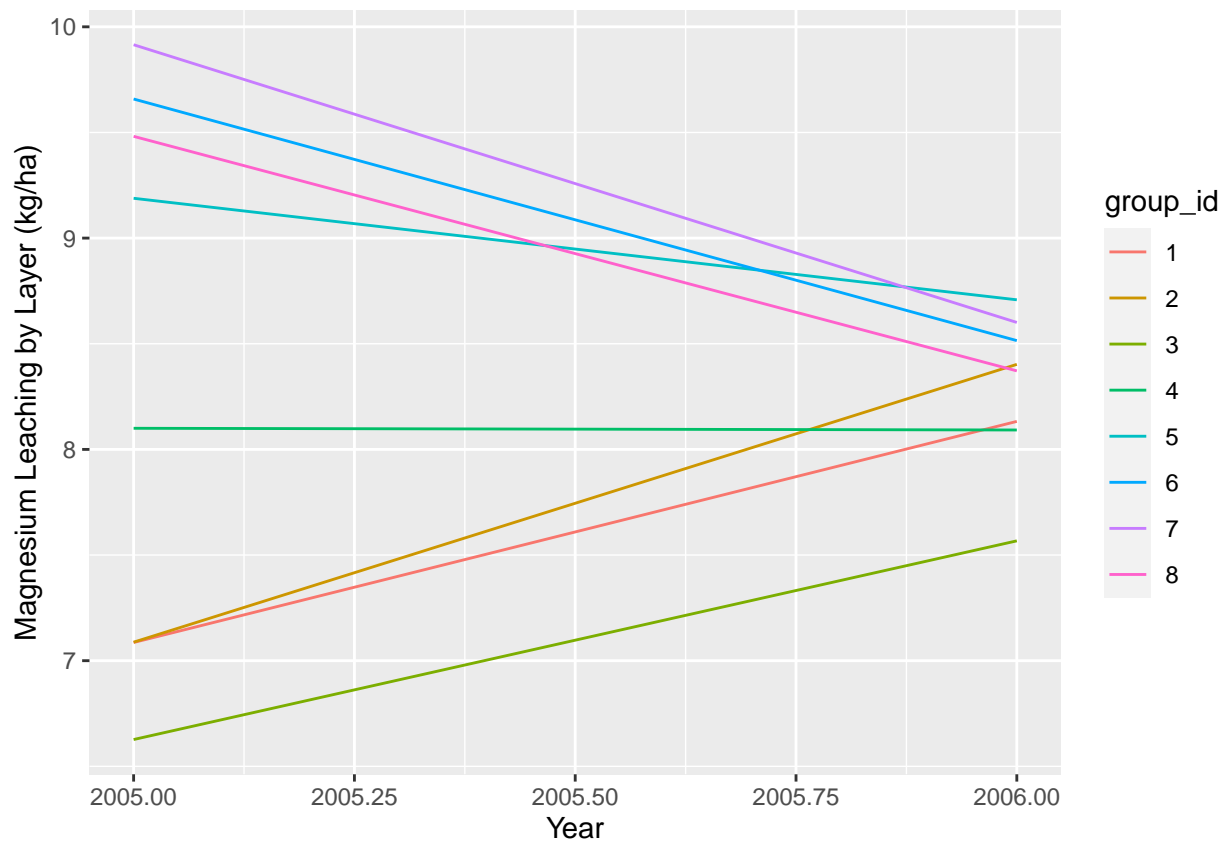
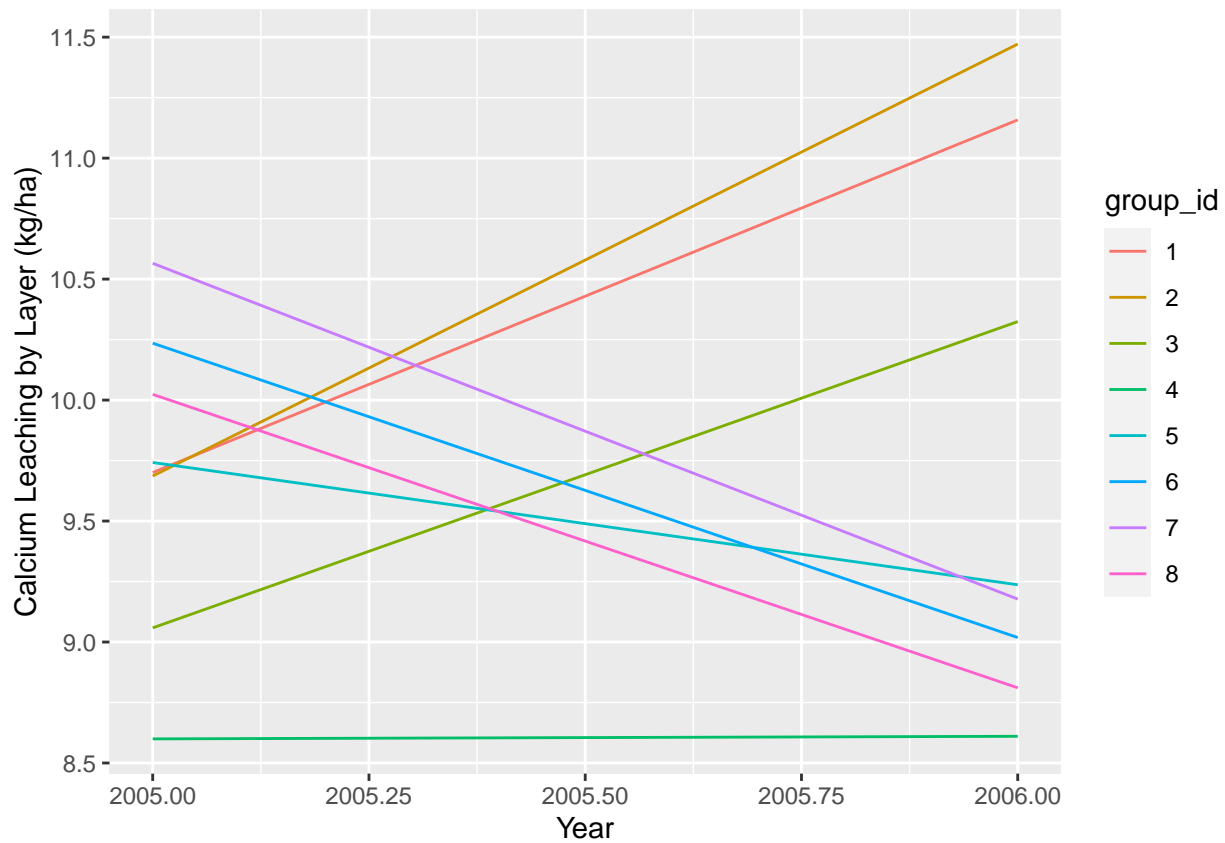


Table 3: Simulated Lysimeter Fluxes by Depth (2005-2006)

| Depth | YEAR | kg/ha |     |     |    |      |      |     |    |       |     |        |    |
|-------|------|-------|-----|-----|----|------|------|-----|----|-------|-----|--------|----|
|       |      | Ca    | Mg  | K   | Na | NO3  | NH4  | SO4 | Cl | P     | DOC | Al     | Si |
| 2     | 2005 | 9.7   | 7.1 | 6.4 | 29 | 0.37 | 0.71 | 3.3 | 24 | 0.13  | 19  | 0.018  | 40 |
| 2     | 2006 | 11.5  | 8.4 | 6.9 | 20 | 0.26 | 0.72 | 3.4 | 30 | 0.13  | 19  | 0.021  | 39 |
| 8     | 2005 | 10.0  | 9.5 | 4.3 | 32 | 0.21 | 0.39 | 5.2 | 42 | 0.061 | 6.3 | 0.0095 | 37 |
| 8     | 2006 | 8.8   | 8.4 | 3.9 | 30 | 0.12 | 0.42 | 5.2 | 30 | 0.062 | 6.1 | 0.0087 | 39 |

Table 4: Actual Average Lysimeter Fluxes (2005)

|                         |       | kg/ha       |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
|-------------------------|-------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Shallow.and.Deep.fluxes | Depth | NH4         | NH4.SD      | NO3         | NO3.SD      | TN          | TN.SD       | DOC         | DOC.SD      | TP          | TP.SD       | Cl          | Cl.SD       | SO4         | SO4.SD      | Ca          | Ca.SD       | Mg          | Mg.SD       | K           | K.SD        | Na          | Na.SD       | Al          | Al.SD       |
| NA                      | 20    | 0.210049416 | 0.018413539 | 0.29063369  | 0.903104016 | 2.584976176 | 1.323438247 | 22.79330337 | 3.780780556 | 0.045545328 | 0.013708415 | 48.12893782 | 44.34049409 | 3.239059723 | 6.167872501 | 20.40967405 | 9.071287806 | 8.894951811 | 5.785746495 | 9.522967189 | 6.371362223 | 27.29467076 | 18.51377501 | 0.340716918 | 0.126564555 |
| NA                      | 100   | 0.18482098  | 0.037686163 | 0.058428056 | 0.56180591  | 0.782891773 | 1.207801926 | 7.454929603 | 2.86204934  | 0.02941534  | 0.012838737 | 38.85767377 | 30.20293147 | 4.342785568 | 2.358188679 | 7.924881994 | 1.716262595 | 6.693254137 | 3.118581853 | 2.39035473  | 6.086366362 | 27.76582547 | 13.72230984 | 0.162624321 | 0.037249254 |

## Weathering Results

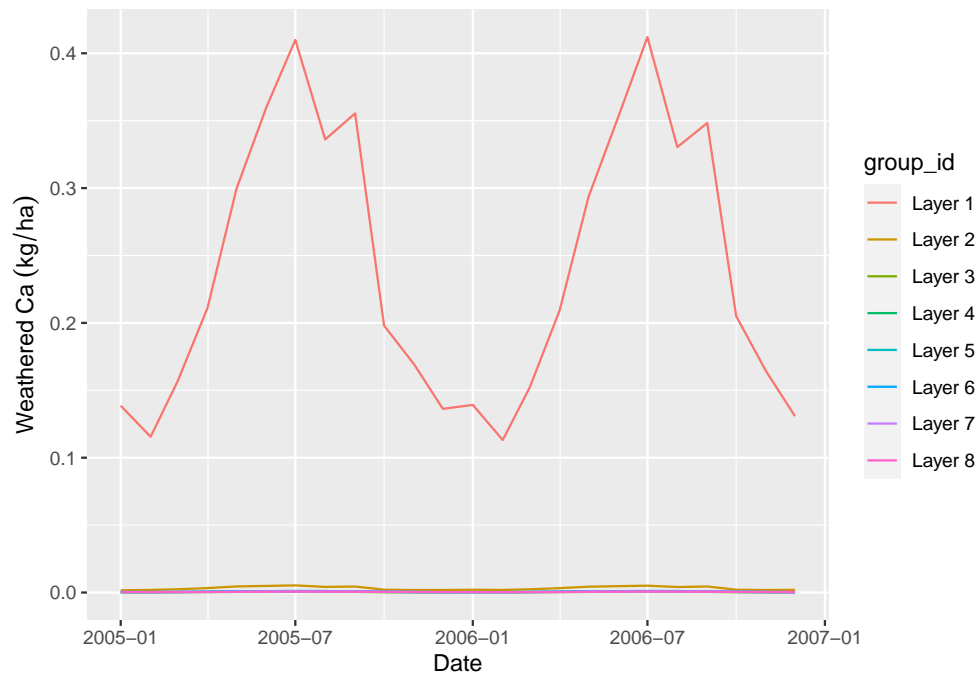


Figure 13: Calcium Weathering (All Layer)

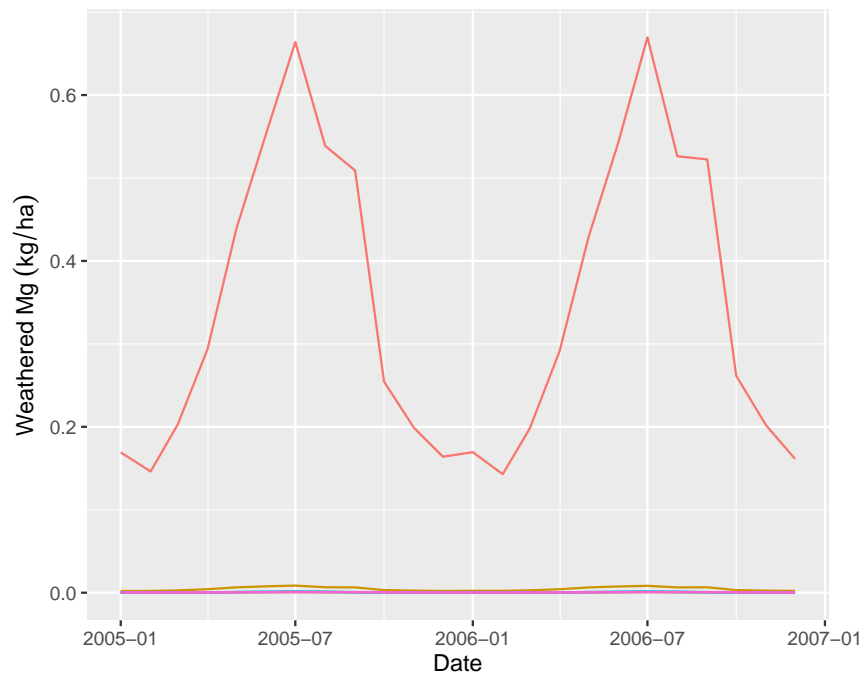


Figure 14: Magnesium Weathering (All Layer)

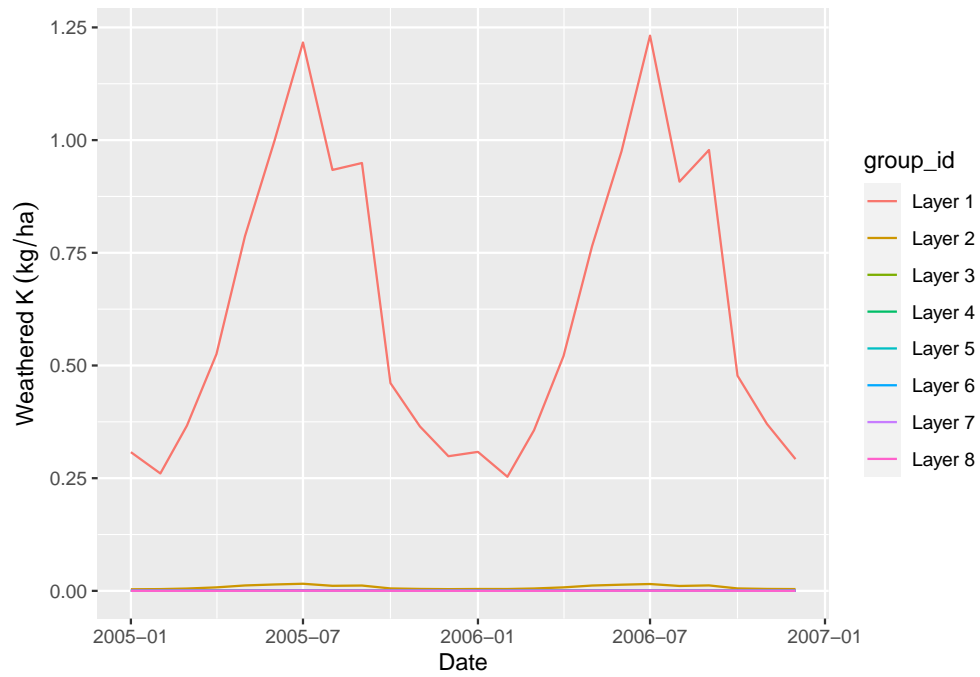


Figure 15: Potassium Weathering (All Layer)

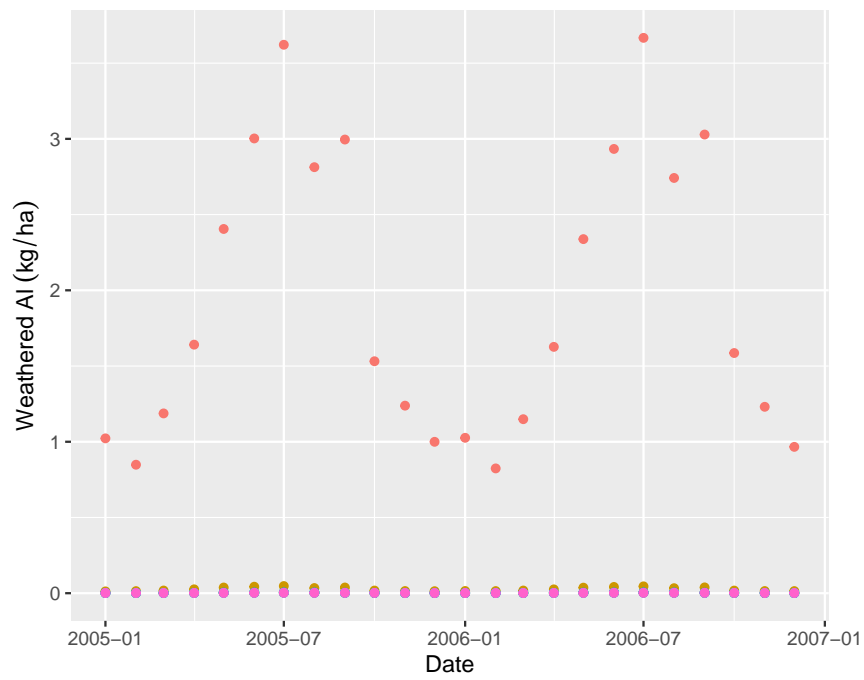


Figure 16: Aluminum Weathering (All Layer)

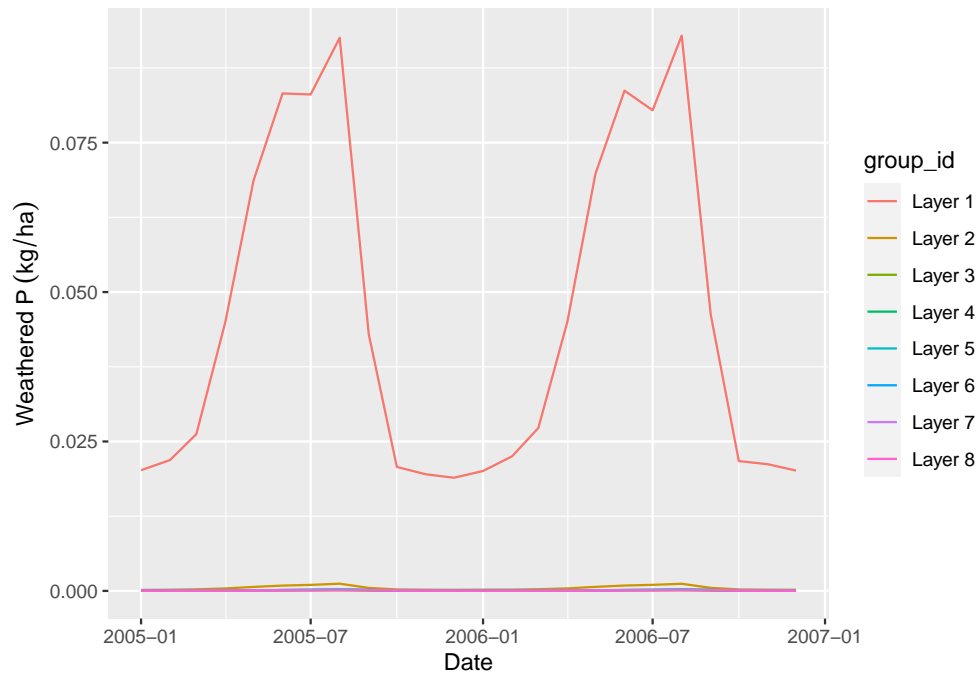


Figure 17: Phosphate Weathering (All Layer)

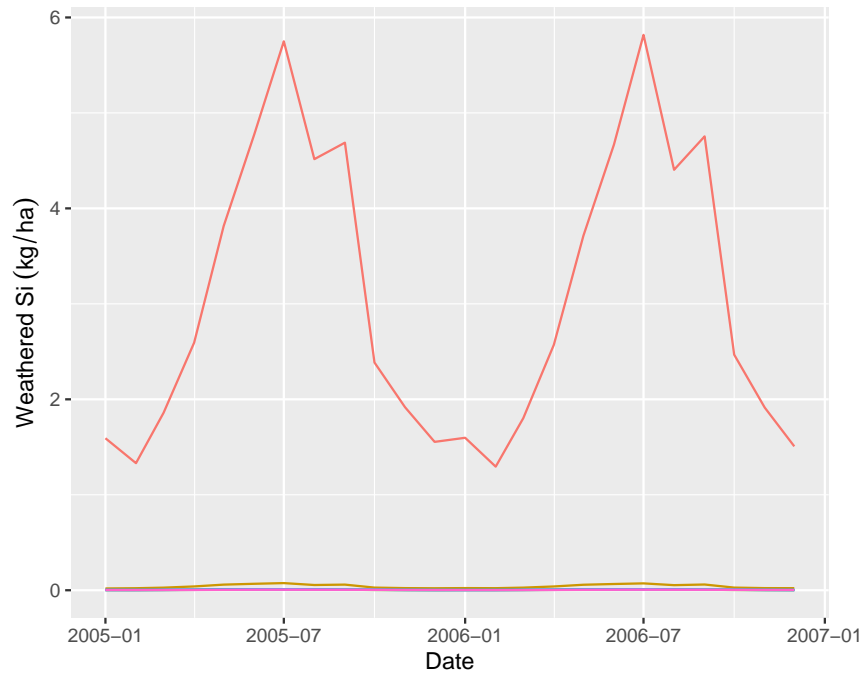


Figure 18: Silica Weathering (All Layer)

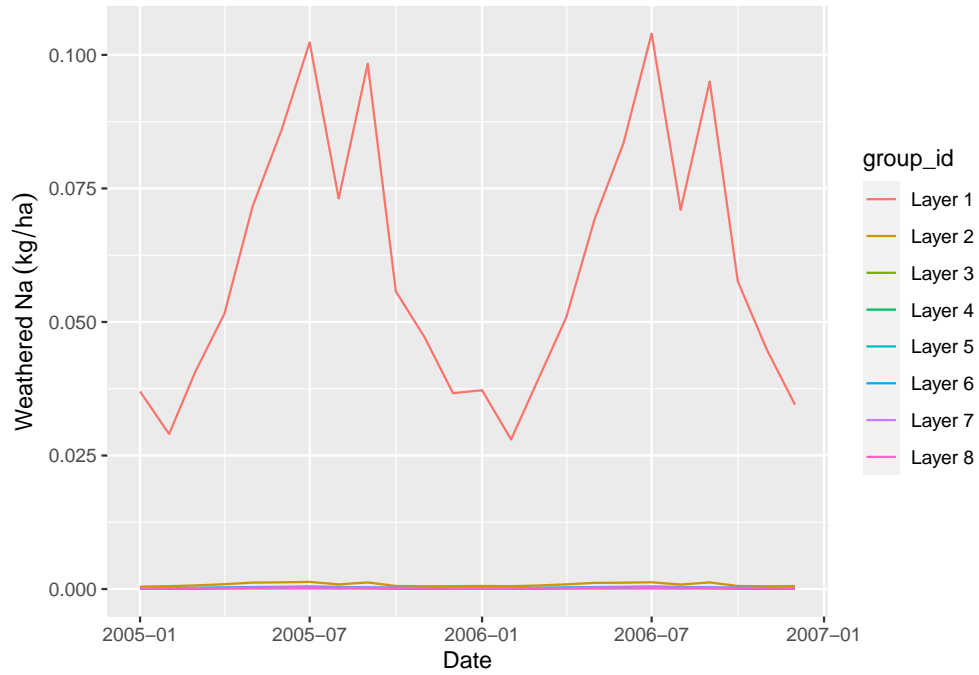


Figure 19: Sodium Weathering (All Layer)

## Litter Pool Results

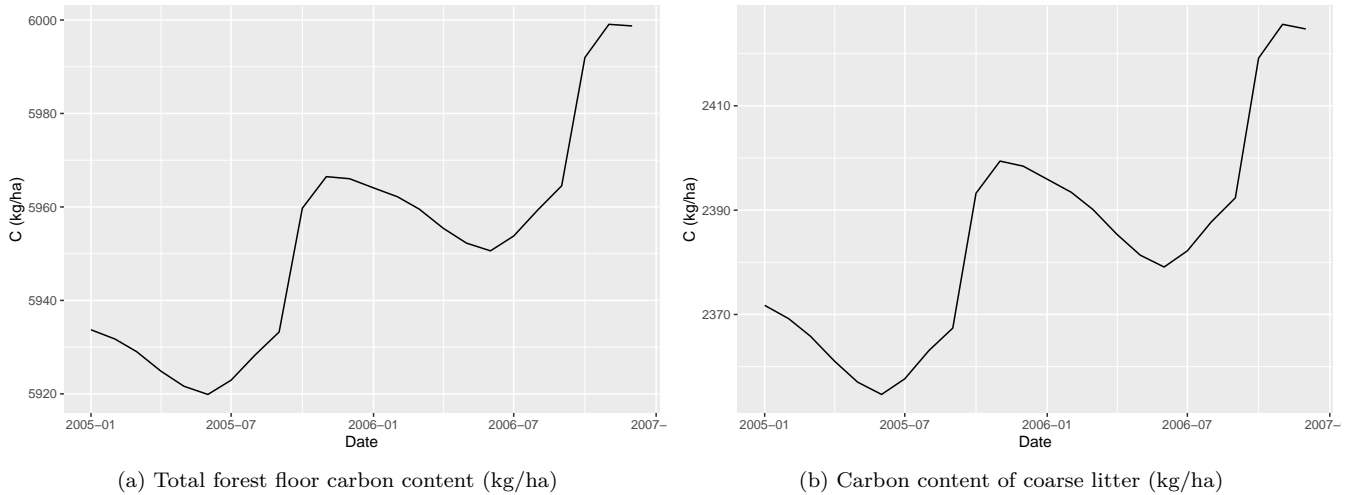


Figure 20: Forest Floor (O-Layer) Carbon Content Over Simulation Period

Looking at a range of soil carbon studies in Douglas-fir forests of the Pacific Northwest, forest floor (defined as non-mineral OM) C content goes from a lower bound of 3,700 kg C/ha in a 9-yr old stand (Cromack et al. 1999) to 8200 kg C/ha in an average 38 year old stand [edmondsRelationshipsSoilOrganic1994]. These stands were notably N rich compared to the site simulated for the low N site, the soil C should be lower in the simulations as there is about half as much soil N in the low N simulated site as in the sites described in [edmondsRelationshipsSoilOrganic1994]. The high N site has about 21,000 kg N/ha at 1m depth, so it should be modeled to be at the higher end of organic and litter C buildup.



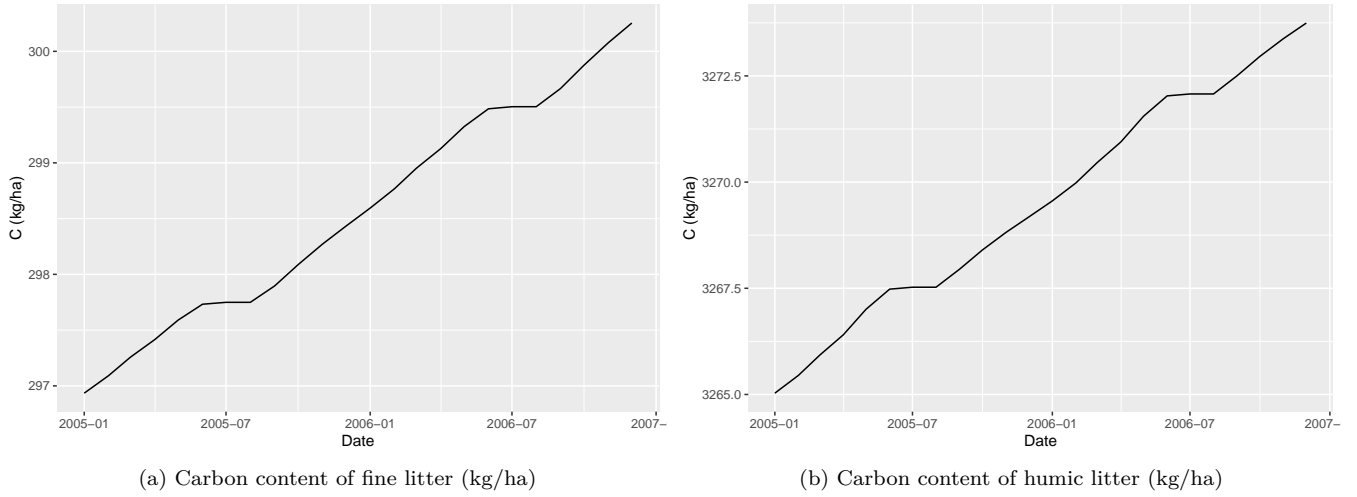


Figure 21: Forest Floor (O-Layer) Carbon Content Over Simulation Period

Note that the fine litter pool (the stage between humus and fresh/coarse litter) is growing in this model. This might deviate from observed behavior.

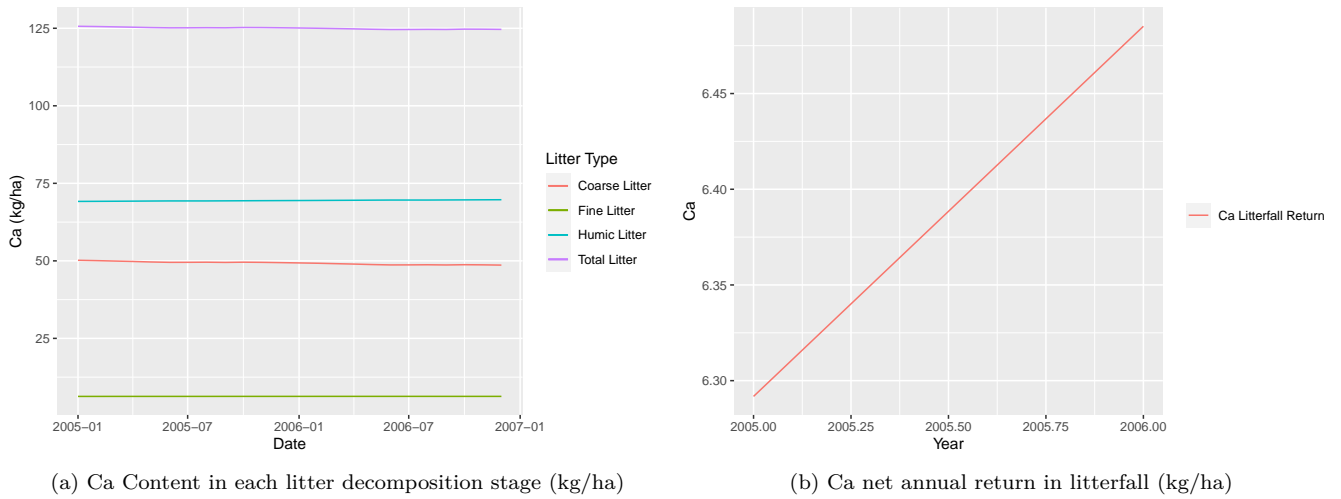
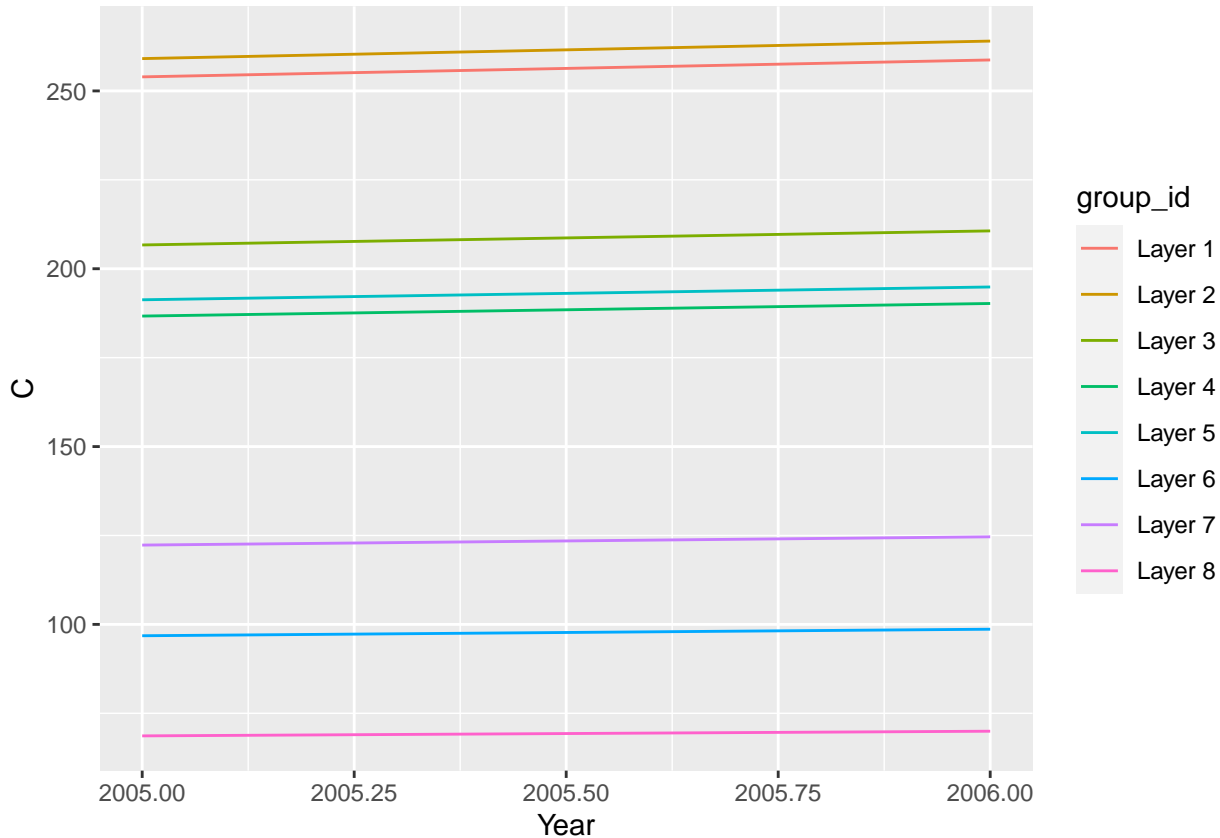


Figure 22: Forest Floor/O-horizon Ca content over time (a). and net annual Ca return in litterfall (b).

## Soil Organic Matter Results



Mineral soil SOM C content is very high compared to other pools of carbon in the ecosystem, soil carbon should buildup over time assuming available surfaces exist for soil carbon “stabilization”. In NutsFor, the SOM pool is represented by an active microbial pool, so there are issues with building up SOM in the soil as one might expect from a real stand. Microbial growth is limited by soil moisture and nutrient availability like the tree pool, so it is not a wholly adequate representation of C stabilization. Instead of calibrating this output to show buildup, I calibrated it such that it was “level”, thus, soil carbon additions to the mineral soil are dictated by DOC percolation with water flow.

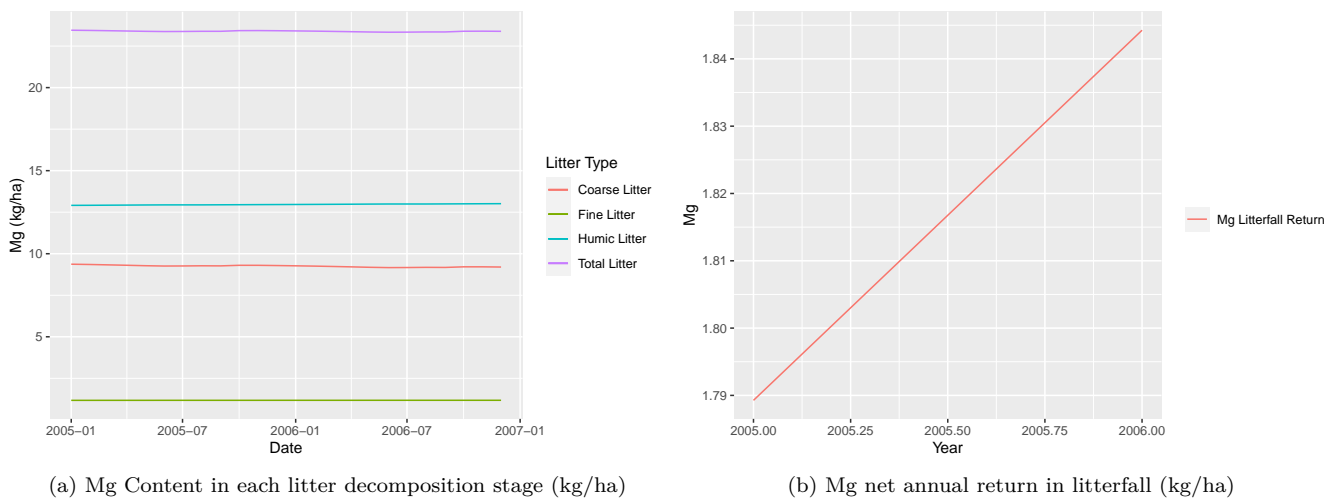
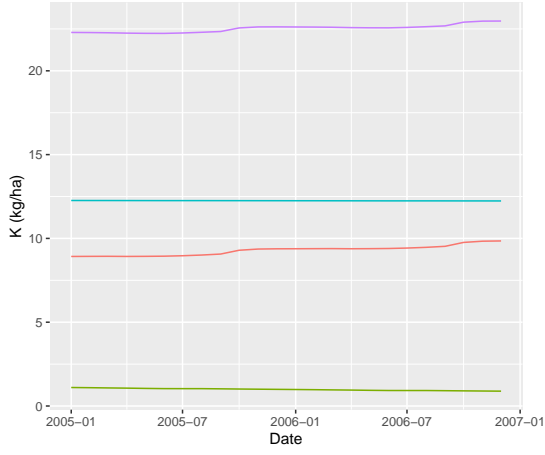
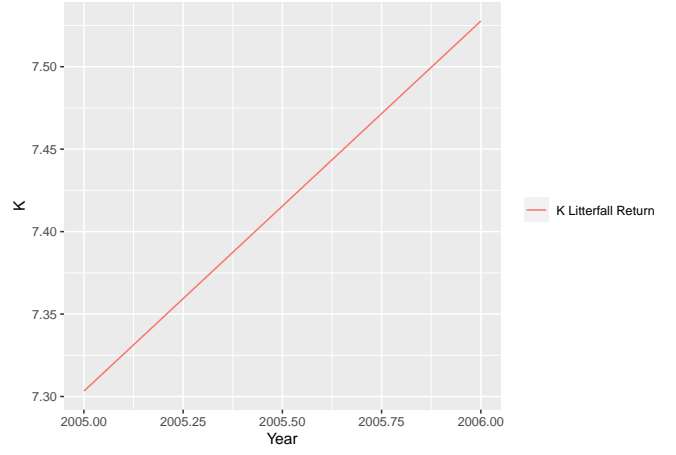


Figure 23: Forest Floor/O-horizon Mg content over time (a). and net annual Mg return in litterfall (b).

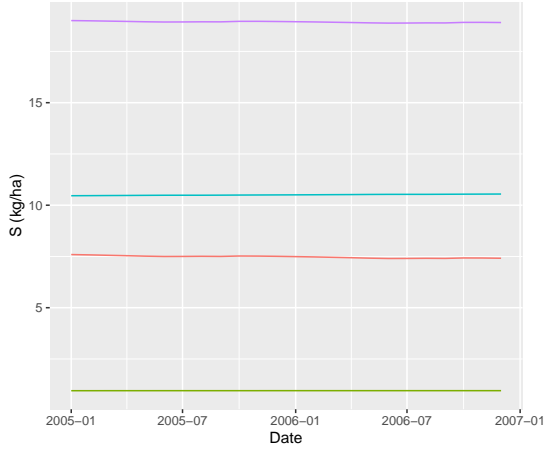


(a) K Content in each litter decomposition stage (kg/ha)

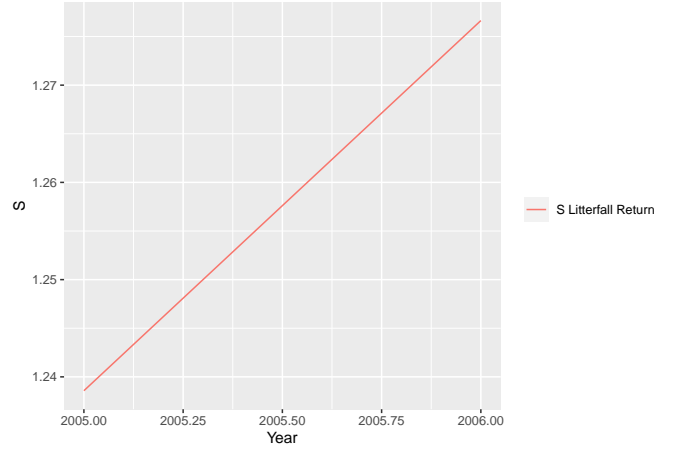


(b) K net annual return in litterfall (kg/ha)

Figure 24: Forest Floor/O-horizon K content over time (a). and net annual K return in litterfall (b).

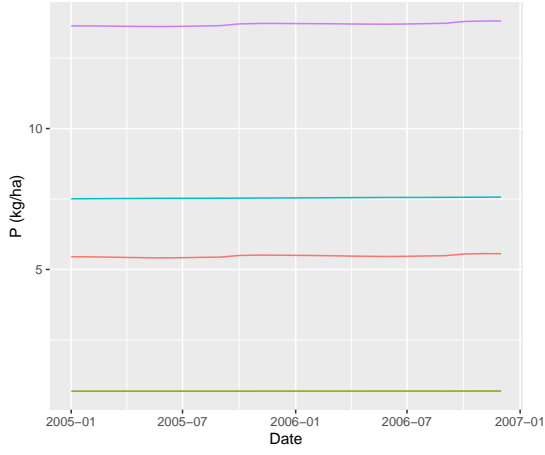


(a) S Content in each litter decomposition stage (kg/ha)

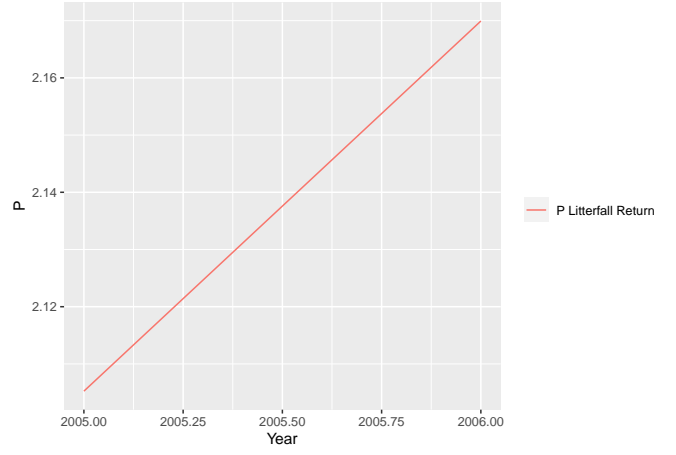


(b) S net annual return in litterfall (kg/ha)

Figure 25: Forest Floor/O-horizon S content over time (a). and net annual S return in litterfall (b).

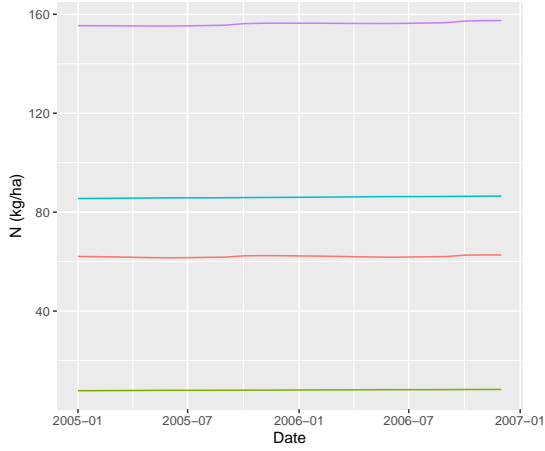


(a) P Content in each litter decomposition stage (kg/ha)

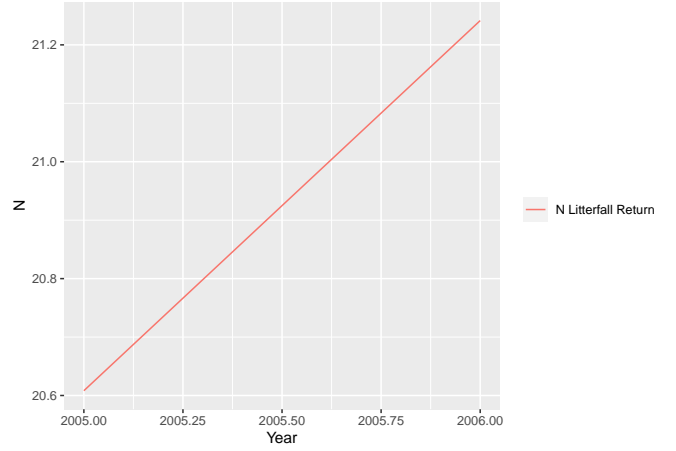


(b) P net annual return in litterfall (kg/ha)

Figure 26: Forest Floor/O-horizon P content over time (a). and net annual P return in litterfall (b).



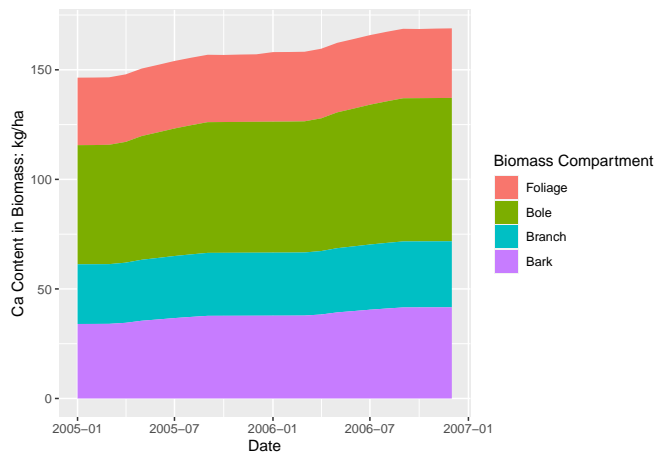
(a) N Content in each litter decomposition stage (kg/ha)



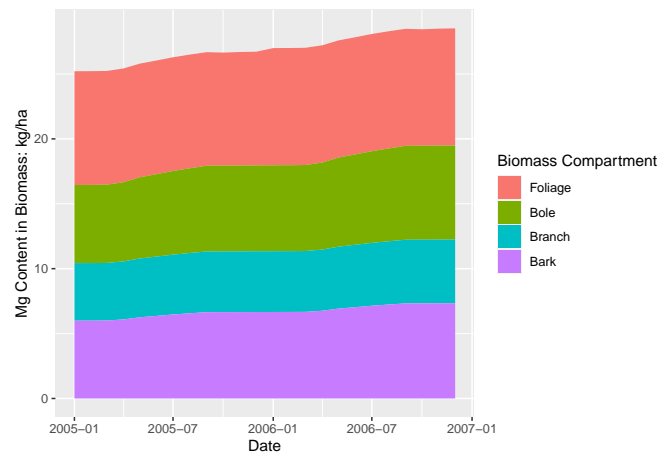
(b) N net annual return in litterfall (kg/ha)

Figure 27: Forest Floor/O-horizon N content over time (a). and net annual N return in litterfall (b).

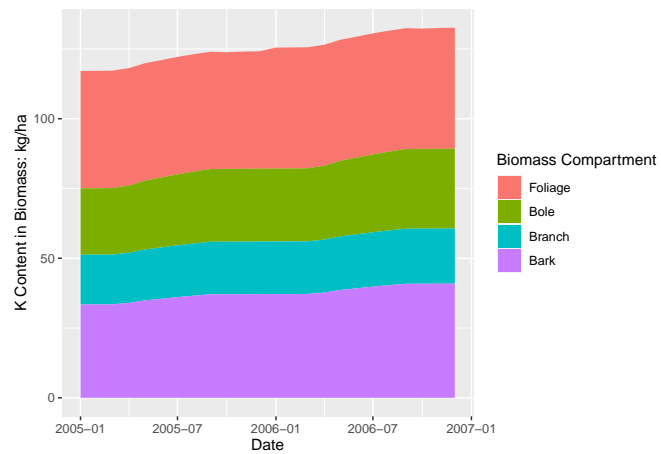
## Tree Nutrient Content



(a) Calcium content in each biomass compartment

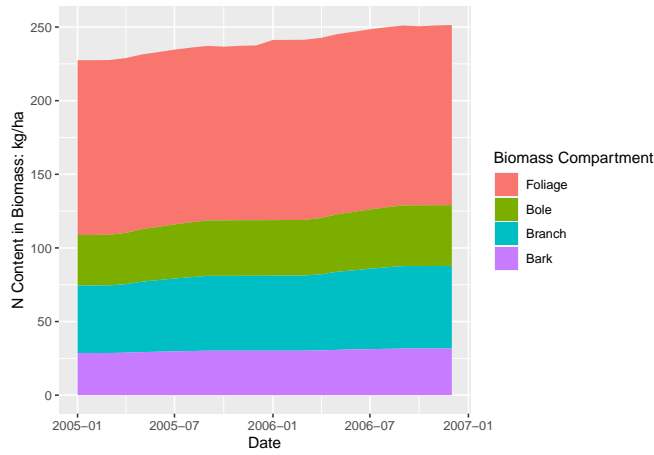


(b) Magnesium content in each biomass compartment

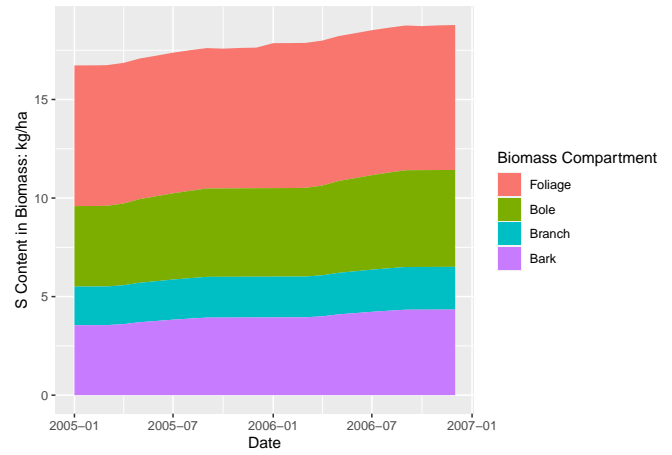


(c) Potassium content in each biomass compartment

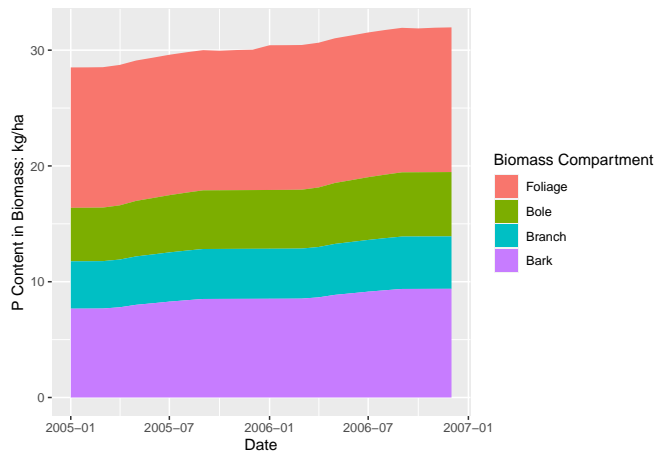
Figure 28: Base Cation Nutrient Content in Simulated Forest



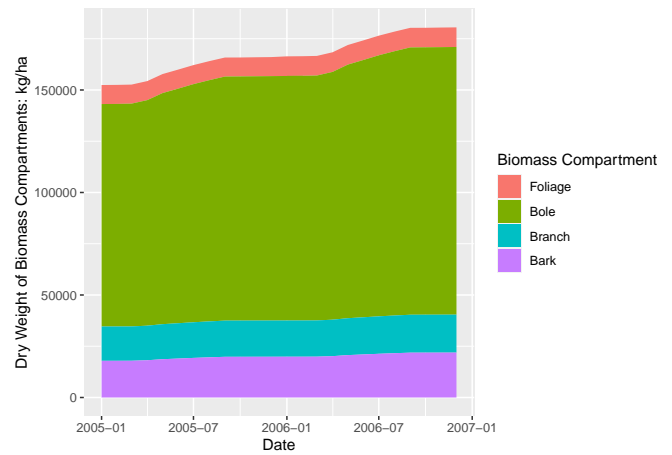
(a) Nitrogen content in each biomass compartment



(b) Sulfur content in each biomass compartment



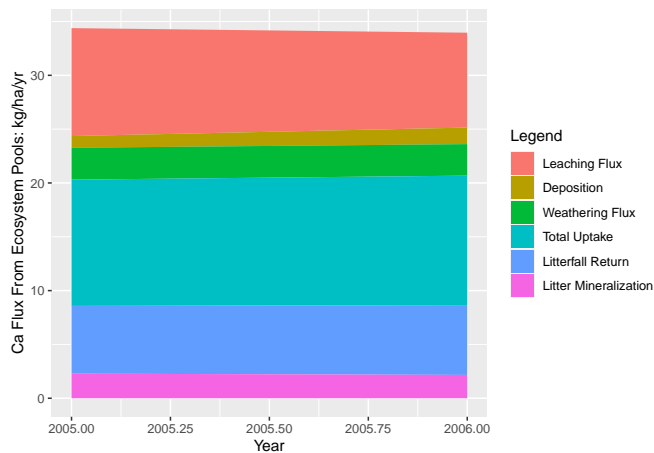
(c) Phosphorous content in each biomass compartment



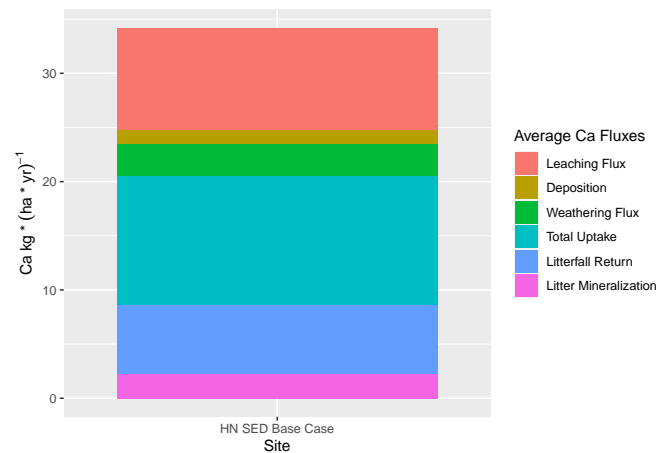
(d) Biomass of each compartment

Figure 29: N, S, and P Nutrient Contents and biomass per compartment

## Analysis 1: Stack Flux Data

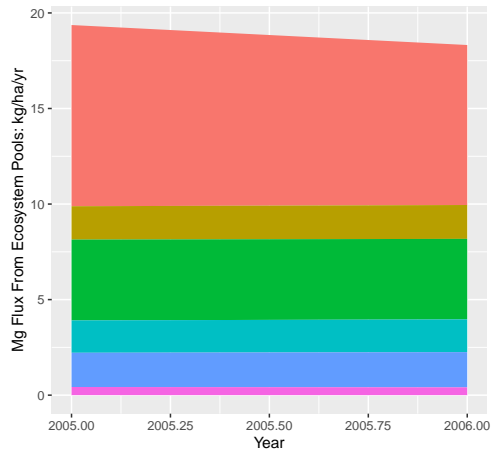


(a) Ca input and output fluxes over time

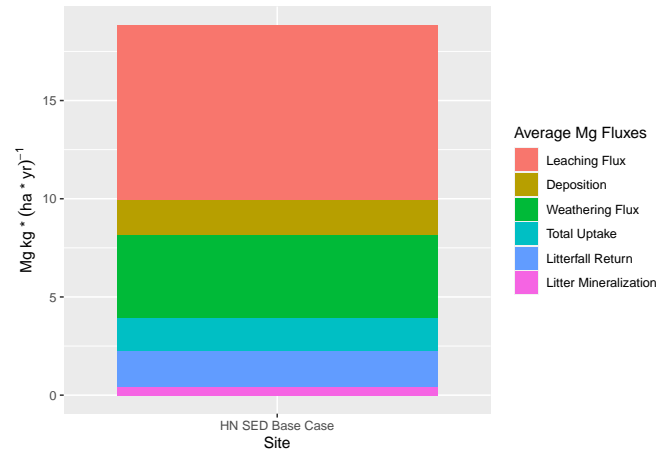


(b) Total Average Ca input and output fluxes

Figure 30: Calcium input and output comparison graphs

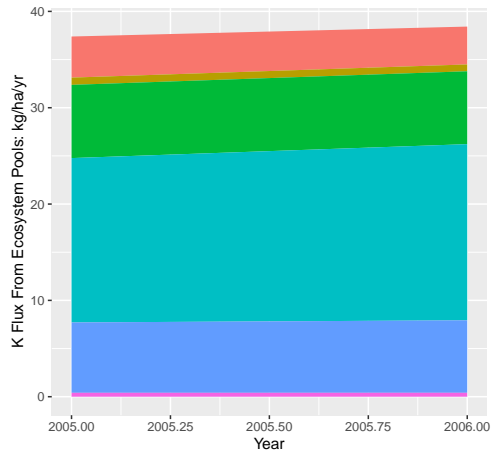


(a) Mg input and output fluxes over time

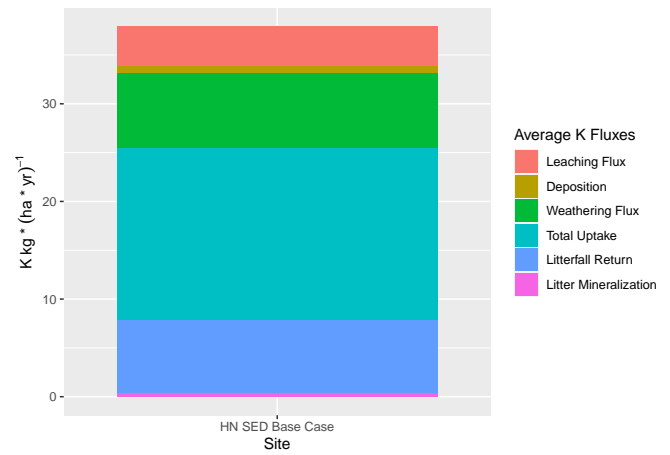


(b) Total Average Mg input and output fluxes

Figure 31: Magnesium input and output comparison graphs



(a) K input and output fluxes over time



(b) Total Average K input and output fluxes

Figure 32: Potassium input and output comparison graphs

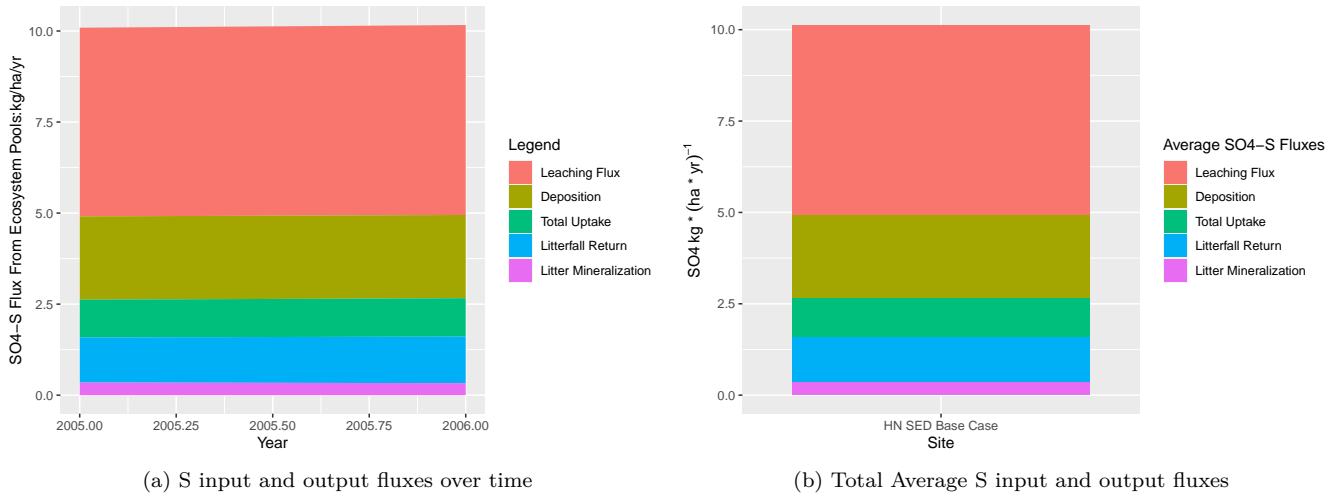


Figure 33: Sulfur input and output comparison graphs

The sulfate adsorbed pool depletes itself, the organic sulfur pool becomes increasingly dominant. This behavior is not unreasonable, however I would expect higher sulfate adsorption.

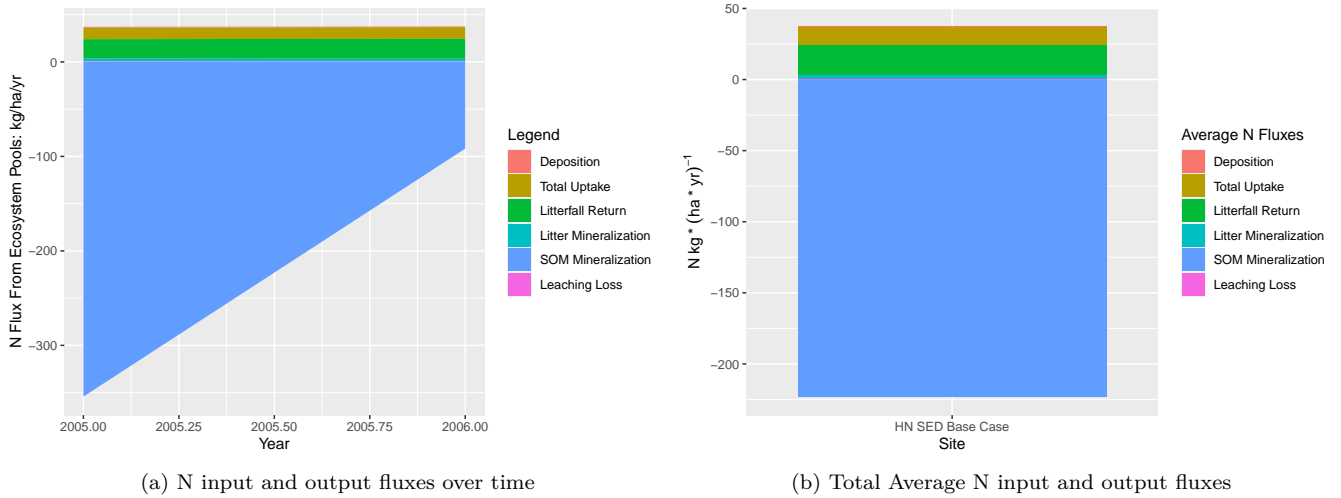


Figure 34: Nitrogen input and output comparison graphs

There looks to be a SOM reporting bug which causes a large negative spike in N mineralization, it does not seem to affect the simulation in terms of N flux or nutrient uptake, which tells me it is likely a reporting error.



## Cation Exchange Capacity

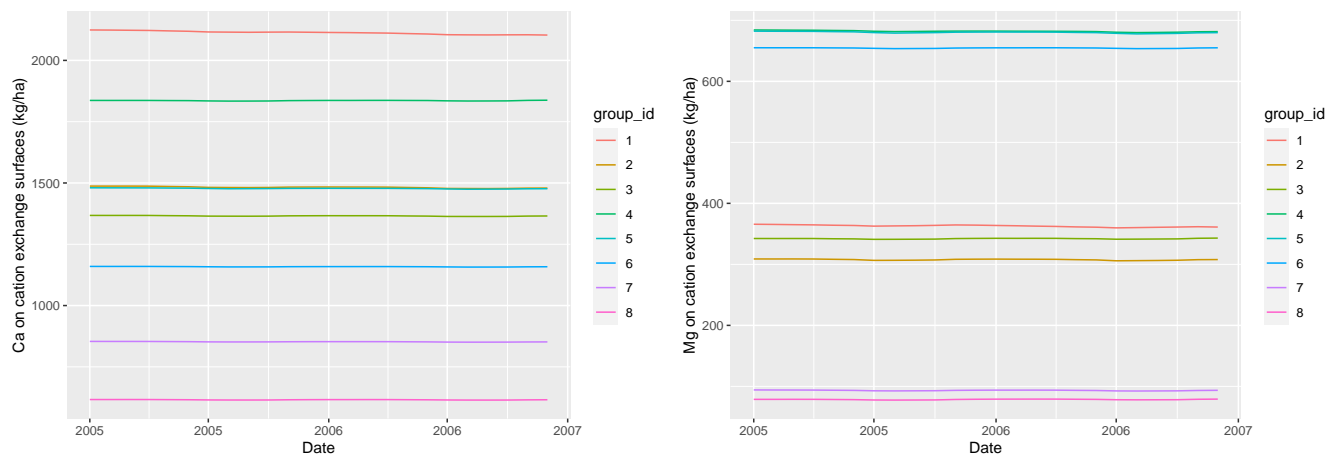


Figure 35: Calcium and Magnesium on exchangerover time

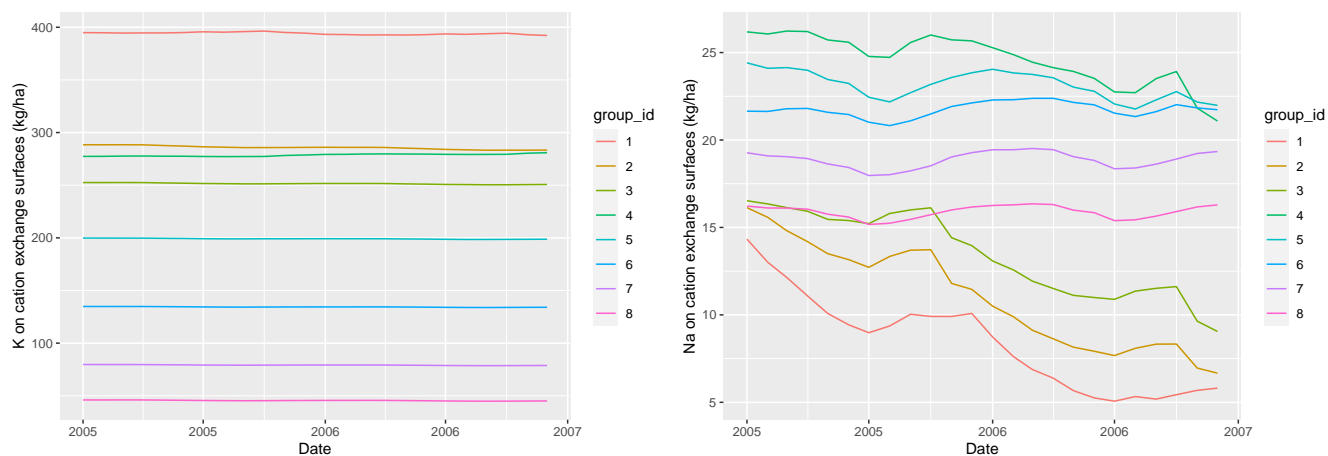


Figure 36: Potassium and Sodium on exchangerover time

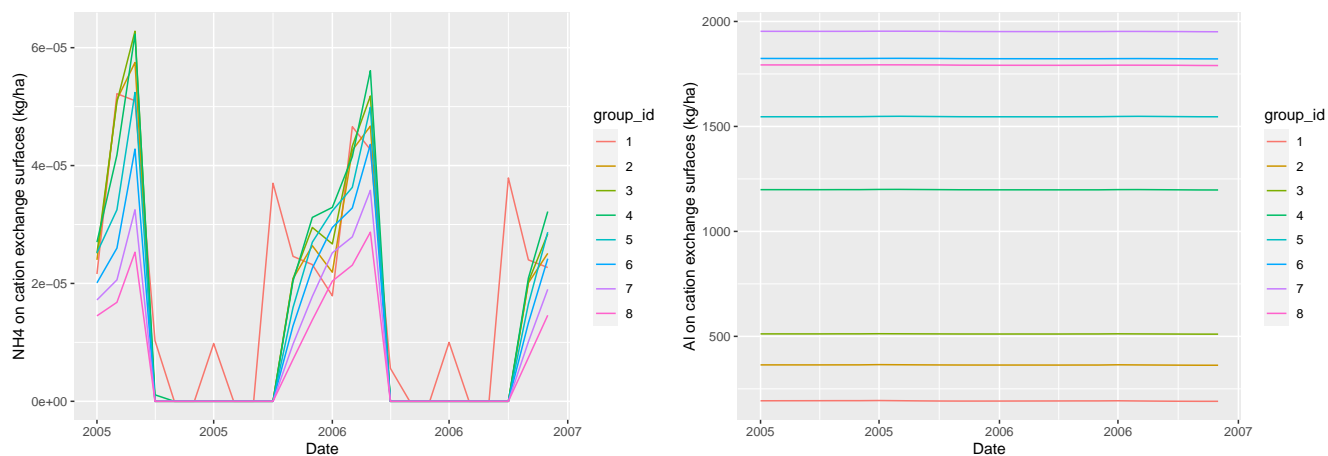
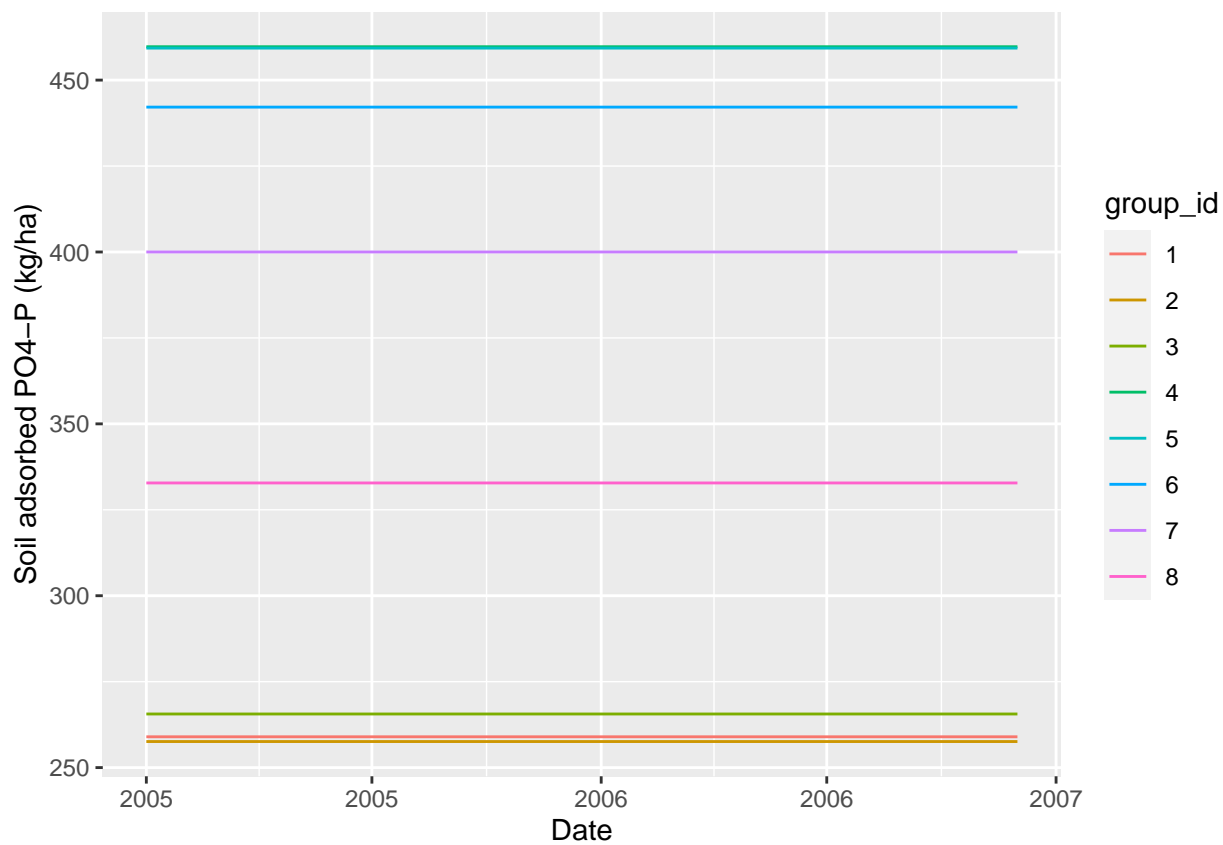
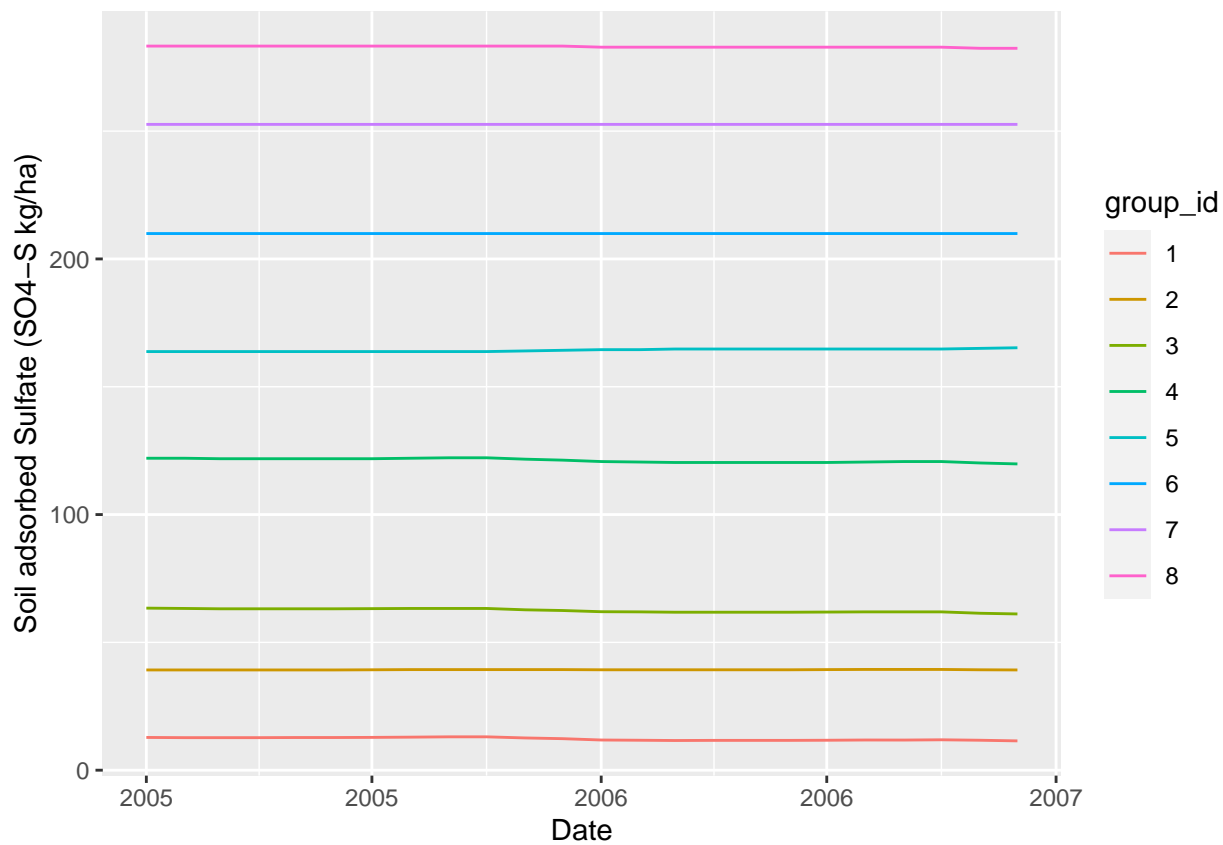
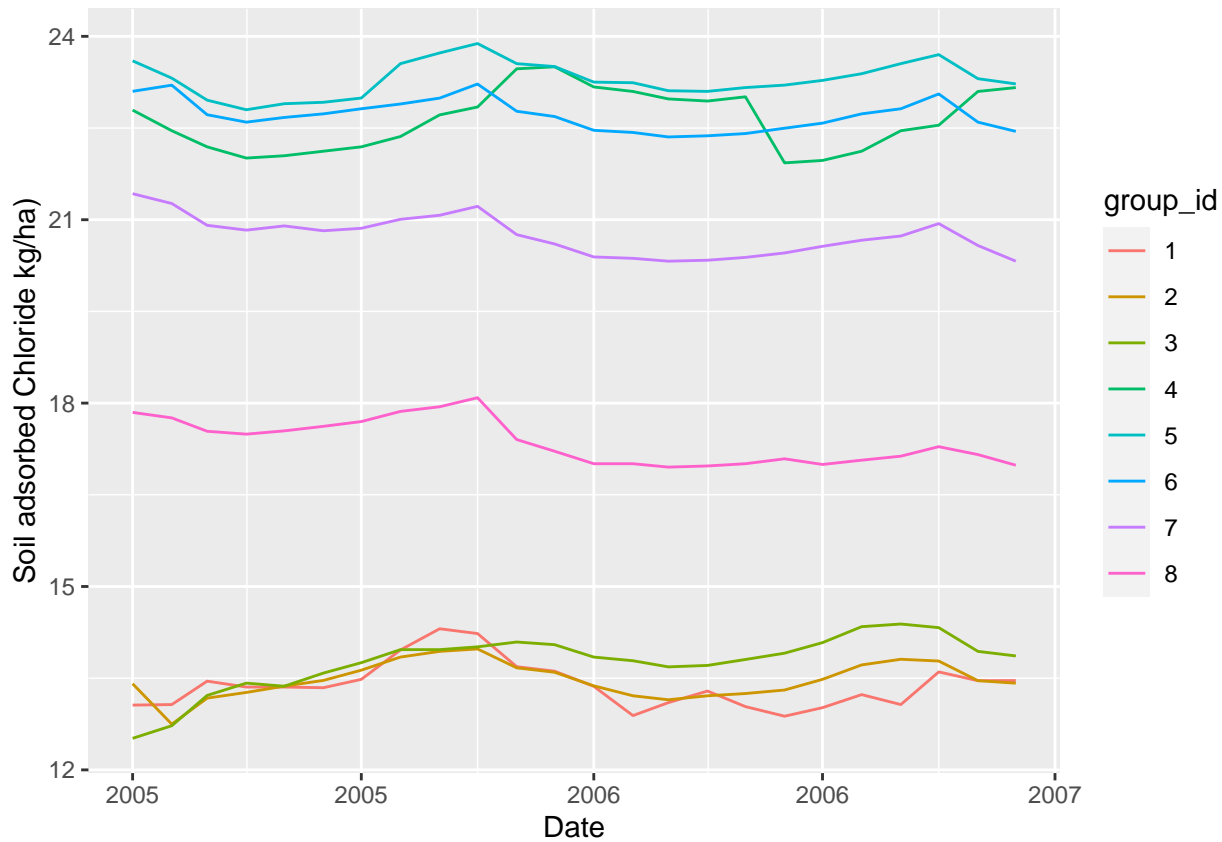


Figure 37: Ammonium and Aluminum on exchangerover time

## Anion Exchange Capacity





The phosphate adsorption is set from the original parameterization I received from Gregory. It tends to build up, which implies a high soil solution concentration (adsorption is determined by concentration).

Sulfate adsorption is weak and drains easily, I set a low adsorbed sulfate pool following IFS data from the Thompson site (glacial outwash, inceptisol). According to the book *Atmospheric Sulfur Deposition: Environmental and Health Impacts*, sulfur is mostly locked in organic compartments rather than on the adsorption surfaces. We might expect that sulfate, like phosphate, would increase on the AEC, however the input of sulfate relative to the adsorption and uptake of sulfate is likely too low to facilitate adsorption. This is well supported by IFS data that show low sulfate adsorption on potentially high capacity adsorbing soils. The higher sulfate concentrations observed at the high N site could well be due to a higher inherent sulfur pool, possibly a condition of higher sulfate-mineral weathering, or due to a competitive response with phosphate.

Other

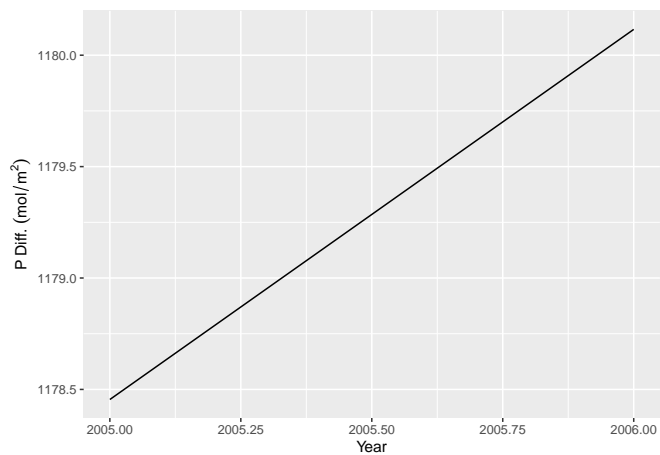
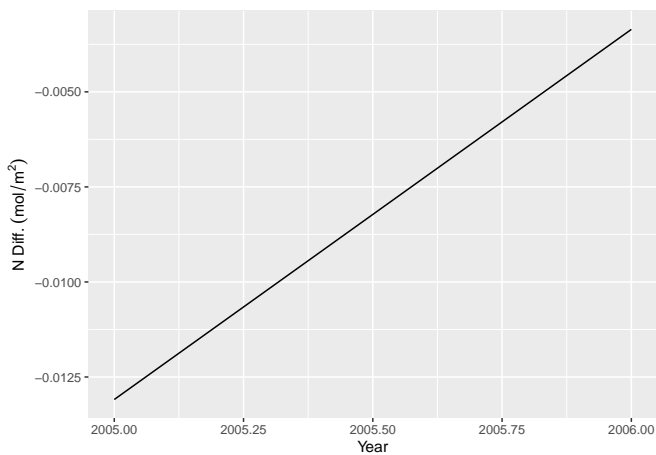
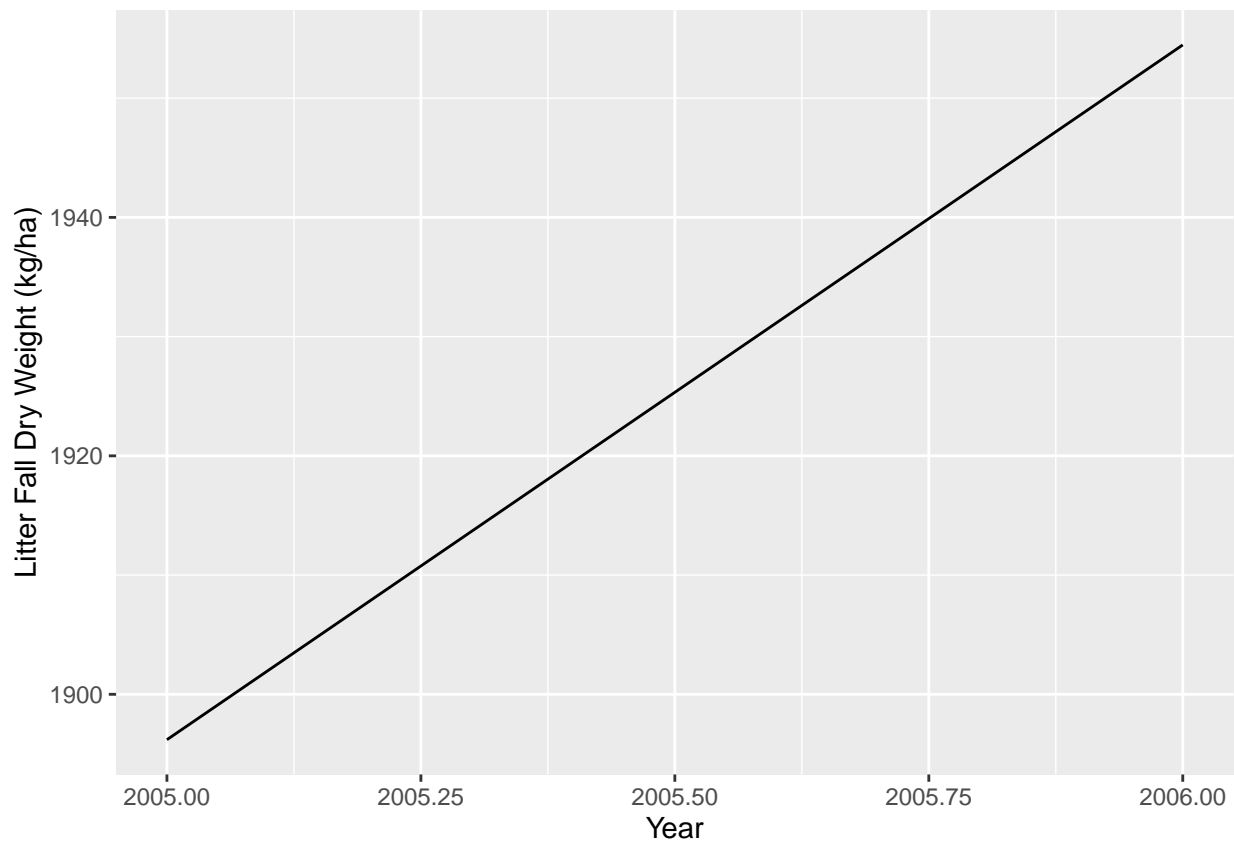


Figure 38: N and P Potential Uptake to Actual Uptake Difference

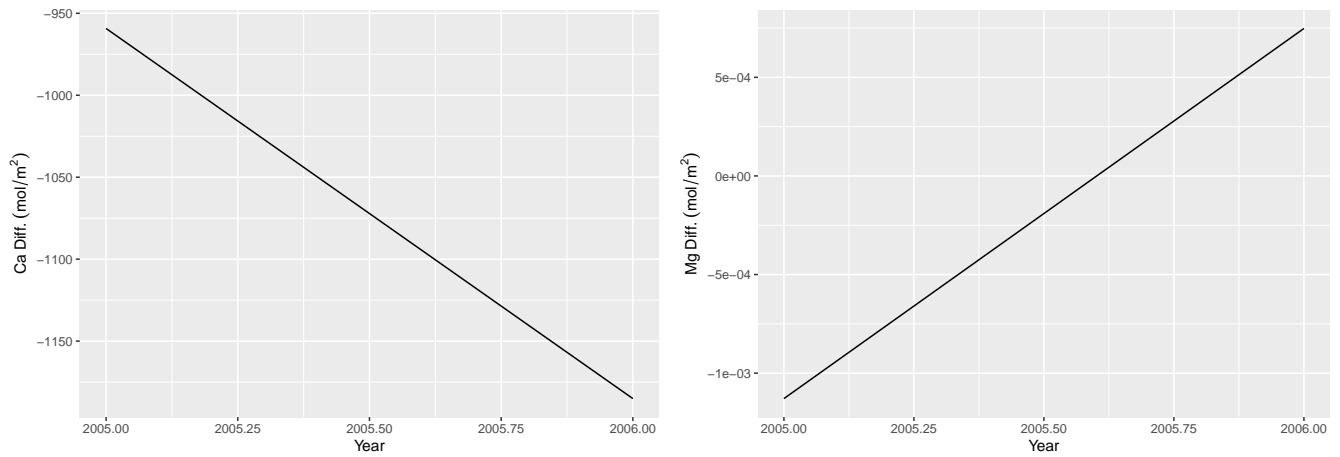


Figure 39: Ca and Mg Potential Uptake to Actual Uptake Difference

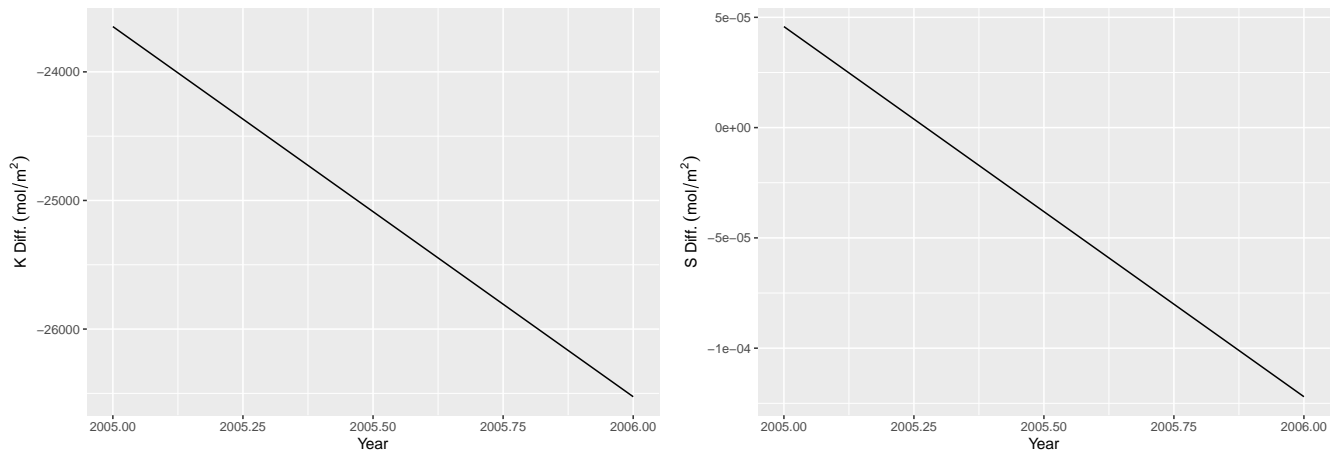


Figure 40: K and S Potential Uptake to Actual Uptake Difference

What I get from this calculation is that for all nutrients except N and P, the stand is able to extract near exactly the required amount of each nutrient for growth. For K, foliar leaching causes excessive total uptake, however the mineral pool is rich enough in K to facilitate this excess uptake. These graphs do not take into consideration that uptake can vary by 20% before growth limitation is induced.

Cromack, Kermit, Richard E. Miller, Harry W. Anderson, Ole T. Helgersen, and Robert B. Smith. 1999. "Soil Carbon and Nutrients in a Coastal Oregon Douglas-Fir Plantation with Red Alder." *Soil Science Society of America Journal* 63 (1): 232–39. <https://doi.org/10.2136/sssaj1999.03615995006300010034x>.