Adam WM, Dos Santos Rodrigues V, Magri E, Motta Vargas AC, Prior SA, Moraes Zambon L, Lima RLD (2021). **Mid-rotation fertilization and liming of *Pinus taeda*: growth, litter, fine root mass, and elemental composition**
iForest – Biogeosciences and Forestry – doi: 10.3832/ifor3626-014

# Supplementary Material

**Tab. S1** - Mineral concentration (nutrients, Al, and Na) of forest floor fractions from a *Pinus taeda* L. stand subjected to fertilizer and lime treatments in Paraná state, southern Brazil. Averages followed by the same letter do not differ statistically after Student-Newman-Keuls test. Lower case letters compare treatments and upper case letters compare layers. (CV): coefficient of variation.

| Treatments | C | N | C:N | Ca | Mg | P | K | Mn | Fe | Na | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ------- % ------- | | | ---------- g kg$^{-1}$ ---------- | | | ---------- mg kg$^{-1}$ ---------- | | | | g kg$^{-1}$ |
| | | | | | | *New litter* | | | | | |
| Complete | 49.5 $^{aA}$ | 0.65 | 76 | 3.32 $^{aB}$ | 0.81 $^{bC}$ | 0.37 $^{aD}$ | 257 $^{aB}$ | 245 $^{aB}$ | 148 | 30 $^{bcC}$ | 0.9 |
| - Macro | 49.3 $^{aA}$ | 0.63 | 79 | 2.96 $^{aB}$ | 0.82 $^{bB}$ | 0.45 $^{aC}$ | 295 $^{a}$ | 313 $^{aB}$ | 109 | 28 $^{bcB}$ | 0.9 |
| - Micro | 49.3 $^{aA}$ | 0.67 | 73 | 2.76 $^{aB}$ | 0.79 $^{bB}$ | 0.47 $^{aC}$ | 286 $^{a}$ | 246 $^{aB}$ | 129 | 25 $^{bcC}$ | 0.7 |
| - K | 49.4 $^{aA}$ | 0.63 | 78 | 3.75 $^{aA}$ | 1.15 $^{aB}$ | 0.40 $^{aC}$ | 216 $^{aB}$ | 285 $^{aA}$ | 134 | 30 $^{bcC}$ | 0.9 |
| - Zn | 49.6 $^{aA}$ | 0.68 | 73 | 2.53 $^{aB}$ | 0.70 $^{bB}$ | 0.41 $^{aC}$ | 286 $^{a}$ | 233 $^{aB}$ | 141 | 22 $^{cC}$ | 0.8 |
| - Lime | 49.4 $^{aA}$ | 0.67 | 74 | 1.56 $^{bA}$ | 0.34 $^{cA}$ | 0.52 $^{aC}$ | 325 $^{a}$ | 321 $^{aA}$ | 151 | 47 $^{aC}$ | 0.8 |
| Control | 49.2 $^{aA}$ | 0.76 | 64 | 1.61 $^{bA}$ | 0.40 $^{cA}$ | 0.38 $^{aC}$ | 210 $^{b}$ | 390 $^{aA}$ | 154 | 42 $^{abC}$ | 1.1 |
| Average | 49.4 | 0.67 $^{C}$ | 74 $^{A}$ | 2.64 | 0.72 | 0.43 | 268 $^{aB}$ | 290 | 138 $^{D}$ | 32 | 0.8 $^{C}$ |
| | | | | | | *Old litter* | | | | | |
| Complete | 45.8 $^{aB}$ | 1.00 | 46 | 4.29 $^{aB}$ | 1.10 $^{aB}$ | 0.69 $^{aC}$ | 295 $^{aB}$ | 502 $^{aA}$ | 499 | 27 $^{aC}$ | 2.7 |
| - Macro | 46.1 $^{aB}$ | 1.06 | 44 | 3.88 $^{aB}$ | 0.93 $^{abB}$ | 0.68 $^{aB}$ | 289 $^{a}$ | 588 $^{aA}$ | 483 | 25 $^{aB}$ | 3.0 |
| - Micro | 47.1 $^{aA}$ | 1.06 | 45 | 3.55 $^{aB}$ | 0.79 $^{bB}$ | 0.69 $^{aB}$ | 318 $^{a}$ | 493 $^{aA}$ | 356 | 32 $^{aC}$ | 2.2 |
| - K | 45.8 $^{aB}$ | 1.04 | 44 | 4.02 $^{aA}$ | 0.96 $^{abB}$ | 0.69 $^{aB}$ | 287 $^{aB}$ | 521 $^{aA}$ | 418 | 27 $^{aC}$ | 3.4 |
| - Zn | 45.8 $^{aB}$ | 1.05 | 44 | 3.32 $^{aB}$ | 0.75 $^{bB}$ | 0.68 $^{aB}$ | 306 $^{a}$ | 527 $^{aA}$ | 487 | 29 $^{aC}$ | 3.3 |
| - Lime | 46.2 $^{aB}$ | 1.02 | 45 | 1.78 $^{bA}$ | 0.38 $^{cA}$ | 0.64 $^{abC}$ | 388 $^{a}$ | 380 $^{aA}$ | 396 | 32 $^{aD}$ | 2.5 |
| Control | 45.3 $^{aB}$ | 1.01 | 45 | 1.58 $^{bA}$ | 0.30 $^{cB}$ | 0.43 $^{bC}$ | 217 $^{b}$ | 394 $^{aA}$ | 478 | 30 $^{aC}$ | 2.7 |
| Average | 46.0 | 1.03 $^{B}$ | 45 $^{B}$ | 3.20 | 0.74 | 0.64 | 300 $^{A}$ | 486 | 445 $^{C}$ | 29 | 2.8 $^{B}$ |
| | | | | | | *Coarse fragmented layer* | | | | | |
| Complete | 41.4 $^{bcC}$ | 1.06 | 39 | 9.9 $^{aA}$ | 2.9 $^{aA}$ | 0.90 $^{aB}$ | 233 $^{aB}$ | 439 $^{a\ aB}$ | 920C | 85 $^{bB}$ | 5.8 |
| - Macro | 40.5 $^{bcD}$ | 0.96 | 41 | 14 $^{aA}$ | 3.1 $^{aA}$ | 1.02 $^{aA}$ | 261 $^{a}$ | 479 $^{a\ aB}$ | 772 | 119 $^{aA}$ | 5.8 |
| - Micro | 41.0 $^{bcC}$ | 1.05 | 39 | 10 $^{aA}$ | 2.8 $^{aA}$ | 1.14 $^{aA}$ | 238 $^{a}$ | 362 $^{a\ aB}$ | 847 | 78 $^{bB}$ | 4.6 |
| - K | 43.2 $^{abB}$ | 1.10 | 39 | 8.8 $^{aB}$ | 2.6 $^{aA}$ | 1.13 $^{aA}$ | 248 $^{aB}$ | 411 $^{aA}$ | 744 | 95 $^{bB}$ | 5.7 |
| - Zn | 40.5 $^{bcC}$ | 1.07 | 38 | 12.7 $^{aA}$ | 3.0 $^{aA}$ | 1.15 $^{aA}$ | 260 $^{a}$ | 446 $^{aA}$ | 902 | 86 $^{bB}$ | 3.9 |
| - Lime | 46.1 $^{aB}$ | 1.15 | 40 | 0.6 $^{bC}$ | 0.2 $^{bB}$ | 0.68 $^{bB}$ | 248 $^{a}$ | 60 $^{bB}$ | 762 | 88 $^{bB}$ | 4.9 |
| Control | 45.5 $^{aB}$ | 1.18 | 39 | 0.3 $^{cB}$ | 0.1 $^{bC}$ | 0.63 $^{bB}$ | 207 $^{b}$ | 36 $^{bB}$ | 782 | 79 $^{bB}$ | 4.6 |
| Average | 42.6 | 1.08 $^{B}$ | 39 $^{C}$ | 8.0 | 2.1 | 0.95 | 242 $^{bC}$ | 319 | 818 $^{C}$ | 90 | 5 $^{A}$ |
| | | | | | | *Fine fragmented layer* | | | | | |
| Complete | 44.5 $^{abB}$ | 1.32 | 34 | 11.2 $^{aA}$ | 3.0 $^{aA}$ | 1.12 $^{aA}$ | 223 $^{aB}$ | 309 $^{a\ aB}$ | 970 $^{A}$ | 114 $^{aA}$ | 5.1 |
| - Macro | 43.2 $^{bC}$ | 1.33 | 33 | 15.9 $^{aA}$ | 3.2 $^{aA}$ | 0.98 $^{aA}$ | 255 $^{a}$ | 391 $^{a\ aB}$ | 925 | 136 $^{aA}$ | 4.1 |
| - Micro | 44.0 $^{abB}$ | 1.31 | 34 | 11.8 $^{aA}$ | 2.9 $^{aA}$ | 1.03 $^{aA}$ | 237 $^{a}$ | 247 $^{aB}$ | 937 | 99 $^{aA}$ | 5.0 |
| - K | 44.8 $^{abB}$ | 1.34 | 33 | 10.7 $^{aB}$ | 2.8 $^{aA}$ | 1.06 $^{aA}$ | 187 $^{b}$ | 330 $^{aA}$ | 838 | 123 $^{aA}$ | 4.0 |
| - Zn | 42.9 $^{bC}$ | 1.33 | 32 | 12.6 $^{aA}$ | 3.0 $^{aA}$ | 1.02 $^{aA}$ | 215 $^{b}$ | 338 $^{a\ aB}$ | 993 | 111 $^{aA}$ | 6.1 |
| - Lime | 47.1 $^{aAB}$ | 1.36 | 35 | 1.0 $^{bB}$ | 0.3 $^{bA}$ | 1.04 $^{aA}$ | 243 $^{a}$ | 42 $^{bB}$ | 893 | 116 $^{aA}$ | 4.7 |
| Control | 46.7 $^{abAB}$ | 1.45 | 32 | 0.6 $^{cC}$ | 0.3 $^{bB}$ | 0.85 $^{aA}$ | 220 $^{b}$ | 29 $^{bB}$ | 932 | 126 $^{aA}$ | 5.0 |
| Average | 44.7 | 1.35 $^{A}$ | 33 $^{D}$ | 9.1 | 2.2 | 1.01 | 225 $^{C}$ | 241 | 927 $^{A}$ | 118 | 4.9 $^{A}$ |

| **Treatments** | **C** | **N** | **C:N** | **Ca** | **Mg** | **P** | **K** | **Mn** | **Fe** | **Na** | **Al** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **------- % -------** | | | **---------- g kg$^{-1}$ ----------** | | | **---------- mg kg$^{-1}$ ----------** | | | | **g kg$^{-1}$** |
| | | | | | | *F-test results* | | | | | |
| Treatments | p<0.01 | p=0.07 | p=0.58 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p=0.06 | p=0.01 | p=0.21 |
| Layer | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 | p<0.01 |
| T X L | p<0.01 | p=0.64 | p=0.96 | p<0.01 | p<0.01 | p<0.01 | p=0.89 | p<0.01 | p=0.89 | p<0.01 | p=0.17 |
| CV Treatments | 7.1 | 25.7 | 5.8 | 44.8 | 13.9 | 18.8 | 30.4 | 53 | 21.4 | 23.2 | 29.8 |
| CV Layers | 4.7 | 9.4 | 1.8 | 32.8 | 9.7 | 11.8 | 21.6 | 29.1 | 18.8 | 20.9 | 29.8 |

**Tab. S2 -** Results of principal component analysis of litter layer elemental compositions and C:N ratios for a *Pinus taeda* L. stand subjected to fertilizer and lime treatments in Paraná state, southern Brazil.

| Variable | CP1 | | CP2 | |
|---|---|---|---|---|
| | Eigenvector | $\sigma^2$ (%) | Eigenvector | $\sigma^2$ (%) |
| Fe | 0.43 | 18 | 0.14 | 2 |
| P | 0.42 | 18 | -0.02 | 0 |
| Al | 0.40 | 16 | 0.13 | 2 |
| Na | 0.38 | 14 | 0.19 | 4 |
| Mg | 0.31 | 10 | -0.43 | 19 |
| Ca | 0.23 | 5 | -0.56 | 31 |
| Mn | 0 | 0 | -0.61 | 37 |
| K | -0.14 | 2 | -0.18 | 3 |
| C:N | -0.41 | 17 | -0.14 | 2 |
| Eigenvalues | 2.34 | - | 1.63 | - |
| % explained | 53.7 | - | 24.5 | - |
| % accumulated | 53.7 | - | 78.2 | - |

**Tab. S3 -** Total nutrients (C, N, Ca, Mg, P, K, Mn, and Fe), Al, and Na in forest floor litter layers (new litter, old litter, coarse fragmented layer, and fine fragmented layer) from a *Pinus taeda* L. stand subjected to fertilizer and lime treatments in Paraná state, southern Brazil.

| Treatments | C | N | Ca | Mg | P | K | Mn | Fe | Al | Na |
|---|---|---|---|---|---|---|---|---|---|---|
| | kg ha$^{-1}$ | | | | | | | | | |
| *New litter* | | | | | | | | | | |
| Complete | 2,226 | 29.1 | 15.1 | 3.64 | 1.67 | 1.15 | 1.12 | 0.67 | 4.2 | 0.13 |
| - Macro | 1,911 | 24.4 | 11.5 | 3.17 | 1.79 | 1.13 | 1.22 | 0.42 | 3.2 | 0.11 |
| - Micro | 2,034 | 27.7 | 11.4 | 3.27 | 1.93 | 1.18 | 1.03 | 0.53 | 3.1 | 0.10 |
| - K | 1,854 | 23.7 | 14.1 | 4.33 | 1.49 | 0.81 | 1.07 | 0.50 | 3.4 | 0.11 |
| - Zn | 2,145 | 29.3 | 10.9 | 3.03 | 1.77 | 1.24 | 1.00 | 0.61 | 3.5 | 0.10 |
| - Lime | 1,962 | 26.8 | 6.2 | 1.36 | 2.06 | 1.29 | 1.28 | 0.59 | 3.3 | 0.19 |
| Control | 1,953 | 29.9 | 6.5 | 1.60 | 1.54 | 0.82 | 1.61 | 0.61 | 4.4 | 0.16 |
| *Old litter* | | | | | | | | | | |
| Complete | 2,886 | 63.2 | 26.7 | 6.84 | 4.29 | 1.84 | 3.22 | 3.18 | 17.4 | 0.17 |
| - Macro | 2,743 | 63.8 | 23.4 | 5.71 | 3.91 | 1.74 | 3.61 | 2.95 | 17.9 | 0.15 |
| - Micro | 2,832 | 63.7 | 21.5 | 4.67 | 4.07 | 1.91 | 2.97 | 2.14 | 13.6 | 0.19 |
| - K | 2,733 | 62.1 | 24.3 | 5.90 | 4.23 | 1.74 | 3.17 | 2.54 | 21.0 | 0.16 |
| - Zn | 2,753 | 63.3 | 20.5 | 4.59 | 4.19 | 1.87 | 3.21 | 2.97 | 19.6 | 0.17 |
| - Lime | 2,367 | 52.3 | 9.2 | 1.94 | 3.21 | 2.02 | 1.94 | 2.04 | 13.1 | 0.16 |
| Control | 1,946 | 42.2 | 7.3 | 1.21 | 1.88 | 0.94 | 1.73 | 2.10 | 11.8 | 0.12 |
| *Coarse fragmented layer* | | | | | | | | | | |
| Complete | 10,811 | 275.5 | 259.9 | 76.52 | 23.72 | 6.03 | 11.28 | 24.45 | 157.1 | 2.22 |
| - Macro | 9,533 | 229.2 | 342.9 | 74.95 | 23.86 | 6.59 | 11.27 | 18.62 | 135.2 | 2.85 |
| - Micro | 11,019 | 279.6 | 282.9 | 76.53 | 31.58 | 6.31 | 10.28 | 23.49 | 124.8 | 2.13 |
| - K | 9,232 | 232.4 | 186.5 | 55.35 | 24.09 | 4.98 | 9.22 | 15.77 | 117.7 | 2.07 |
| - Zn | 8,801 | 233.0 | 256.2 | 63.55 | 25.49 | 5.86 | 9.91 | 19.55 | 84.2 | 1.83 |
| - Lime | 10,840 | 267.2 | 13.6 | 3.53 | 15.86 | 5.51 | 1.48 | 17.75 | 120.5 | 2.08 |
| Control | 10,816 | 279.5 | 6.8 | 3.61 | 14.94 | 4.91 | 0.95 | 18.72 | 109.0 | 1.88 |
| *Fine fragmented layer* | | | | | | | | | | |
| Complete | 7,207 | 209.6 | 173.4 | 47.67 | 18.02 | 3.68 | 4.32 | 16.20 | 89.7 | 1.86 |
| - Macro | 6,836 | 207.8 | 183.9 | 50.72 | 13.97 | 3.85 | 5.70 | 14.25 | 65.4 | 2.11 |
| - Micro | 9,223 | 269.2 | 229.3 | 59.49 | 20.90 | 4.77 | 4.91 | 18.77 | 93.6 | 2.04 |
| - K | 6,582 | 197.0 | 151.4 | 41.49 | 15.77 | 2.80 | 4.59 | 12.16 | 57.7 | 1.82 |
| - Zn | 5,211 | 160.6 | 152.5 | 36.24 | 12.44 | 2.60 | 4.01 | 11.88 | 72.4 | 1.36 |
| - Lime | 7,993 | 231.7 | 17.0 | 4.66 | 17.62 | 4.15 | 0.72 | 15.16 | 78.3 | 1.98 |
| Control | 7,550 | 232.7 | 10.6 | 4.04 | 13.44 | 3.59 | 0.49 | 15.31 | 79.7 | 2.04 |