Continental-scale Consequences of Tree die-offs in North America: Identifying Where Forest Loss Matters Most

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Supplemental Information

Supplemental Tables S1 – S5

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**Table S1.** Table of Domain abbreviations, Domain names, area and forest information. From left to right, columns show the number of the Domain, as specified by NEON, followed by the abbreviation for the full Domain name, and the full name. The fourth column shows the total area of the Domain in km$^2$, and the fifth shows the forest density in km$^2$ of trees per km$^2$ of total area. The sixth column shows the area of forest removed in each experiment in km$^2$, and the seventh column shows the area of grass added in each experiment in km$^2$. The two differ by the area of bare ground. The right most column shows the average change in annual mean GPP for the US outside of the modified Domain following forest loss in that Domain in units of gC/m$^2$/yr.

| Domain Name                  | Area of domain (km$^2$) | Forest density (km$^2$/km$^2$) | Forest Area removed (km$^2$) | Grass Area added (km$^2$) | ΔGPP US (gC/m$^2$/yr) |
|-----------------------------|-------------------------|---------------------------------|-----------------------------|--------------------------|------------------------|
| 1 NE Northeast              | 424,910                 | 0.67                            | 283,146                     | 286,361                  | 11.86                  |
| 2 MA Mid Atlantic           | 422,202                 | 0.66                            | 280,480                     | 281,124                  | 27.65                  |
| 3 SE Southeast              | 401,944                 | 0.56                            | 224,494                     | 225,553                  | 3.43                   |
| 5 GL Great Lakes            | 582,484                 | 0.44                            | 254,744                     | 266,327                  | 11.91                  |
| 6 PP Prairie Peninsula      | 702,920                 | 0.09                            | 62,417                      | -                        | -                      |
| 7 AP Appalachians / Cumberland Plateau | 325,359 | 0.53                            | 171,703                     | 171,703                  | 23.53                  |
| 8 OZ Ozarks Complex         | 673,028                 | 0.42                            | 279,533                     | 288,081                  | 47.11                  |
| 9 NP Northern Plains        | 854,989                 | 0.07                            | 57,345                      | -                        | -                      |
| 10 CP Central Plains        | 412,947                 | 0.05                            | 20,321                      | -                        | -                      |
| 11 SP Southern Plains       | 545,657                 | 0.06                            | 33,944                      | -                        | -                      |
| 12 NR Northern Rockies      | 283,238                 | 0.57                            | 160,301                     | 192,047                  | -12.94                 |
| 13 SR Southern Rockies / Colorado Plateau | 697,179 | 0.11                            | 75,402                      | 385,040                  | 7.07                   |
| 14 DS Desert Southwest      | 437,748                 | 0.05                            | 22,419                      | 282,892                  | 8.61                   |
| 15 GB Great Basin           | 777,428                 | 0.21                            | 164,203                     | 431,695                  | -3.51                  |
| 16 PN Pacific Northwest     | 288,511                 | 0.91                            | 263,847                     | 268,332                  | -7.38                  |
| 17 PS Pacific Southwest     | 279,605                 | 0.45                            | 126,095                     | 141,330                  | -27.14                 |
| 18 TU Tundra                | 961,616                 | 0.05                            | 48,407                      | -                        | -                      |
| 19 TA Taiga                 | 830,962                 | 0.31                            | 254,160                     | 351,419                  | -12.00                 |
Table S2. Matrix of GPP response to forest loss for all Domains. Change in annual mean GPP in each Domain (rows) due to tree removal in a Domain (columns) in units of gC/m²/yr. Bold italicized values pass a statistical significance test at 95% confidence. For a key of Domain abbreviations see Table S1, and for a map of Domain locations see Fig. 5.

| Domain in which trees were removed | NE   | MA   | SE   | GL   | AP   | OZ   | NR   | SR   | DS   | GB   | PN   | PS   | TA   |
|-----------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| NE                                | 33.9 | -13.4| -15.0| -18.8| -25.9| -19.9| -24.8| -17.6| -12.6| -24.6| -20.4| -7.7 | -16.2|
| MA                                | -18.6| 222.9| 4.3  | -15.4| -21.1| -13.0| -25.1| -16.6| -3.9  | -25.8| -11.9| -10.4| -18.6|
| SE                                | 24.3 | -49.6| 108.2| 69.5 | -55.4| 24.5 | 28.9 | 50.3 | 14.0 | -88.5| -57.7| -98.7| -58.0|
| GL                                | -27.7| 9.4  | -17.5| 5.2  | -15.6| -20.5| -60.5| -25.9| -34.4| -25.6| -45.4| -21.6| -25.7|
| PP                                | 12.7 | 80.1 | 15.9 | 88.3 | 20.7 | 18.1 | -48.8| -27.8| 13.2 | -19.2| 45.8 | -58.4| 14.0 |
| AP                                | 6.3  | 25.8 | 20.2 | -8.8 | 248.2| 18.4 | -37.5| -17.5| 15.4 | -26.5| 10.4 | -10.3| 4.1  |
| OZ                                | 71.2 | 100.3| 10.7 | 22.3 | 75.0 | 467.3| 20.6 | 29.4 | 47.6 | -26.4| 54.6 | -73.2| 71.7 |
| NP                                | 3.0  | 6.1  | -5.6 | 46.1 | 5.7  | 18.8 | -44.8| -5.8  | -61.4| -14.4| 0.2  | -20.3| -43.1|
| CP                                | 1.4  | 17.1 | 9.3  | 7.8  | 23.7 | 12.6 | 9.3  | 16.1 | 3.0  | 20.2 | -2.4 | -12.3| 12.7 |
| SP                                | 13.3 | 44.3 | -15.2| 13.0 | 85.4 | 52.3 | -15.9| 25.6 | 36.1 | 50.2 | 9.4  | -73.6| 33.5 |
| NR                                | 14.6 | -14.5| -32.0| 11.2 | -41.3| -14.2| -112.1| -62.4| 32.0 | -43.1| -9.6 | -26.7| -5.1 |
| SR                                | -3.1 | -15.7| -15.0| -16.3| 30.2 | 6.3  | 2.0  | 57.6 | 2.4  | 31.1 | -28.1| -13.1| -3.3 |
| DS                                | 5.7  | -3.7 | -0.6 | -5.9 | 35.7 | 13.2 | 10.7 | 25.4 | 87.1 | 26.6 | -21.0| -12.2| 15.1 |
| GB                                | 15.7 | 12.9 | 1.1  | 8.8  | 21.3 | 18.9 | 7.4  | 15.0 | 16.8 | -23.9| 7.3  | 12.0 | 4.8  |
| PN                                | -2.1 | -3.9 | -8.8 | 3.1  | 6.5  | 7.8  | -8.9 | 5.4  | -10.0| -4.4 | -291.9| -8.0 | -24.3|
| PS                                | 9.7  | 38.1 | 3.5  | 49.8 | 66.3 | 17.4 | 37.1 | 71.8 | 24.2 | 42.0 | 8.9  | -161.6| 20.7 |
| TU                                | 5.2  | 12.2 | 6.1  | 13.4 | 8.6  | 15.8 | 8.9  | 23.6 | 11.9 | 24.2 | 2.5  | 2.2  | -8.2 |
| TA                                | 5.5  | 15.7 | 8.9  | 17.4 | 16.6 | 21.6 | 9.3  | 24.5 | 13.7 | 22.5 | 5.6  | -2.8 | -130.2|

Table S3. Matrix of Temperature response to forest loss for all Domains. Change in June-July-August average near surface air Temperature in each Domain (rows) due to tree removal in a Domain (columns) in units of degrees C. Bold italicized values pass a statistical significance test at 95% confidence. For a key of Domain abbreviations see Table S1, and for a map of Domain locations see Fig. 5.

| Domain in which trees were removed | NE  | MA  | SE  | GL  | AP  | OZ  | NR  | SR  | DS  | GB  | PN  | PS  | TA  |
|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NE                                | -0.16 | -0.12 | -0.06 | -0.11 | -0.12 | -0.01 | 0.05 | -0.08 | 0.02 | 0.01 | -0.09 | 0.13 | -0.09 |
| MA                                | -0.16 | -0.11 | 0.05 | 0.06 | -0.11 | -0.03 | 0.00 | -0.03 | -0.07 | 0.08 | -0.11 | 0.10 | 0.01 |
| SE                                | -0.05 | 0.03 | -0.05 | 0.19 | 0.06 | -0.03 | -0.08 | 0.15 | -0.02 | 0.18 | 0.03 | 0.15 | 0.12 |
| GL                                | -0.08 | -0.18 | -0.02 | -0.18 | -0.16 | -0.03 | 0.19 | -0.02 | 0.07 | 0.05 | -0.10 | 0.22 | -0.05 |
| PP                                | -0.16 | -0.29 | -0.02 | -0.27 | -0.24 | -0.20 | 0.11 | 0.03 | -0.14 | 0.11 | -0.28 | 0.26 | -0.14 |
| AP                                | -0.19 | -0.23 | -0.01 | 0.04 | -0.13 | -0.22 | 0.03 | -0.06 | -0.14 | 0.08 | -0.18 | 0.08 | -0.08 |
| OZ                                | -0.25 | -0.37 | 0.01 | 0.05 | -0.31 | -0.84 | -0.05 | -0.11 | -0.24 | 0.19 | -0.31 | 0.20 | -0.25 |
| NP                                | -0.04 | -0.14 | -0.06 | -0.24 | -0.08 | -0.17 | 0.12 | 0.05 | -0.05 | 0.09 | -0.26 | 0.10 | 0.11 |
| CP                                | -0.06 | -0.11 | -0.02 | -0.01 | -0.19 | -0.13 | -0.09 | -0.11 | -0.12 | 0.02 | -0.16 | 0.06 | -0.09 |
| SP                                | -0.12 | -0.18 | 0.13 | 0.13 | -0.36 | -0.27 | -0.05 | -0.13 | -0.17 | 0.00 | -0.13 | 0.08 | -0.14 |
| NR                                | 0.05 | -0.03 | 0.07 | -0.18 | 0.12 | 0.04 | 0.20 | 0.28 | -0.22 | 0.24 | -0.20 | 0.02 | 0.14 |
| SR                                | -0.10 | -0.10 | 0.04 | 0.12 | -0.30 | -0.13 | -0.18 | -0.11 | -0.26 | -0.13 | -0.05 | -0.01 | 0.02 |
| DS                                | -0.05 | -0.09 | -0.01 | 0.09 | -0.23 | -0.04 | -0.17 | -0.12 | 0.01 | 0.03 | -0.06 | -0.04 | -0.07 |
| GB                                | -0.08 | -0.20 | -0.03 | -0.16 | -0.15 | -0.12 | -0.20 | 0.00 | -0.30 | 0.32 | -0.24 | -0.15 | 0.05 |
| PN                                | 0.13 | 0.16 | 0.03 | -0.03 | 0.26 | 0.20 | -0.03 | 0.32 | 0.21 | 0.33 | 0.07 | -0.01 | 0.14 |
| PS                                | -0.07 | -0.16 | -0.02 | -0.08 | -0.06 | -0.04 | -0.17 | 0.01 | -0.16 | 0.07 | -0.16 | 0.20 | 0.06 |
| TU                                | 0.10 | 0.20 | 0.16 | 0.20 | 0.23 | 0.27 | 0.09 | 0.27 | 0.17 | 0.38 | 0.05 | -0.05 | -0.04 |
| TA                                | 0.03 | 0.14 | 0.12 | 0.03 | 0.15 | 0.20 | 0.03 | 0.13 | 0.05 | 0.20 | 0.00 | -0.20 | -0.29 |
Table S4. **Matrix of Precipitation response to forest loss for all Domains.** Change in June-July-August average Precipitation in each Domain (rows) due to tree removal in a Domain (columns) in units of mm/yr. Bold italicized values pass a statistical significance test at 95% confidence. For a key of Domain abbreviations see Table S1, and for a map of Domain locations see Fig. 5.

| Domain in which trees were removed | NE   | MA   | SE   | GL   | AP   | OZ   | NR   | SR   | DS   | GB   | PN   | PS   | TA   |
|-----------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| NE                                | -9.90| -8.97| -12.59| -10.08| 10.18| -10.02| -21.90| -16.22| -12.60| 8.41  | -22.45| 1.21 | -6.84|
| MA                                | -18.37| -30.67| -5.22| -22.81| -56.89| -51.99| -46.69| -67.93| -10.23| -7.47 | -27.98| -28.78| -11.03|
| SE                                | 31.21| -0.72| -105.61| -41.74| -4.20| 0.13  | 9.72  | -21.36| 29.92 | -24.98| 21.93 | -11.75| -9.40|
| GL                                | -16.38| -3.18| -16.69| -13.36| -24.37| -0.97 | -22.91| -23.36| -9.26  | -2.63 | -4.11 | -21.18| -19.98|
| PP                                | 3.33 | 46.59| 4.37 | 40.85| 31.56| 33.99| -9.64| -6.41| 25.25 | 12.25 | 36.22 | -14.79| 17.08|
| AP                                | 8.19 | 79.01| 51.40| 37.26| 24.78| 20.54| -18.96| -14.13| 44.18 | 12.81 | 44.76 | 11.06| 39.75|
| OZ                                | 34.13| 81.22| -5.17| 7.73 | 40.52| 5.10  | -0.62| 23.23 | 68.61 | -18.63| 47.83 | -8.55 | 49.98|
| NP                                | -1.00| 5.35 | -15.10| 3.72 | 0.01 | 34.31| -14.23| -22.97| 16.27 | 4.07  | -5.53 | -5.47 | -22.96|
| CP                                | 11.10| 42.55| 27.02| 20.85| 72.18| 45.58| 18.16| 62.47| 23.92 | 10.40 | 34.00 | -23.32| 53.14|
| SP                                | 32.10| 24.81| -38.27| -14.79| 45.69| 35.82| 1.21 | 36.51| 34.30 | -29.29| 33.40 | 7.03  | 32.03|
| NR                                | 42.43| 17.93| -0.57| -11.44| 24.54| 38.58| -5.79| -12.97| 51.15| -5.98 | 2.92  | 8.38  | -5.19|
| SR                                | 5.17 | -4.29| 4.64 | -28.43| 14.62| -2.03| 1.16 | 22.68| -2.23| 21.30 | -16.70| -10.80| 2.51|
| DS                                | 8.62 | 6.67 | 6.23 | -14.46| 21.37| 0.63 | 16.58| 29.20| 0.82  | 17.68 | 2.14  | 1.21  | 17.56|
| GB                                | 27.12| 24.40| 3.34 | -0.28| 21.34| 24.15| 12.52| -1.11| 33.12| -9.95 | -3.21 | 0.47  | -0.94|
| PN                                | -1.73| -0.33| 0.76 | 3.59 | 1.93 | 3.72 | -2.32| 5.72 | 1.14  | -3.42 | -4.30 | -3.72 | -8.15|
| PS                                | 0.97 | 3.36 | 0.50 | -0.81| 1.21 | 3.19 | -0.22| 1.65 | 2.62  | 0.41  | 0.92  | 0.79  | 0.26|
| TU                                | -16.63| -11.97| 9.89 | -1.64| -28.41| -7.22| -23.64| -16.65| -12.36| -6.79 | -34.73| 6.30  | -12.79|
| TA                                | 39.02| 31.14| 20.40| 15.93| 0.74 | 32.34| 15.98| 24.05| 28.28| 22.19 | 6.87  | 42.30 | 19.88|
Table S5. Matrix of low Cloud fraction response to forest loss for all Domains. Change in June-July-August average low Cloud fraction in each Domain (rows) due to tree removal in a Domain (columns). Bold italicized values pass a statistical significance test at 95% confidence. For a key of Domain abbreviations see Table S1, and for a map of Domain locations see Fig. 5.

| Domain in which trees were removed | NE  | MA  | SE  | GL  | AP  | OZ  | NR  | SR  | DS  | GB  | PN  | PS  | TA  |
|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NE                               | 0.0075 | 0.0021 | -0.0047 | -0.0044 | -0.0011 | 0.0018 | -0.0031 | -0.0058 | -0.0050 | -0.0068 | -0.0047 | -0.0079 | -0.0091 |
| MA                               | 0.0071 | 0.0120 | -0.0058 | -0.0067 | -0.0002 | 0.0000 | -0.0047 | -0.0083 | 0.0029 | -0.0070 | 0.0014 | -0.0082 | -0.0046 |
| SE                               | 0.0058 | 0.0135 | 0.0011 | -0.0044 | 0.0032 | 0.0036 | 0.0021 | -0.0003 | 0.0095 | -0.0084 | 0.0052 | -0.0064 | -0.0022 |
| GL                               | -0.0031 | 0.0057 | -0.0026 | 0.0027 | -0.0015 | 0.0059 | -0.0073 | -0.0057 | -0.0011 | -0.0095 | -0.0031 | -0.0152 | -0.0066 |
| PP                               | 0.0043 | 0.0182 | -0.0019 | 0.0138 | 0.0117 | 0.0208 | -0.0034 | -0.0014 | 0.0115 | -0.0097 | 0.0120 | -0.0126 | 0.0069 |
| AP                               | 0.0122 | 0.0250 | 0.0027 | 0.0020 | 0.0159 | 0.0181 | 0.0034 | 0.0005 | 0.0163 | -0.0057 | 0.0152 | -0.0029 | 0.0103 |
| OZ                               | 0.0093 | 0.0203 | -0.0050 | -0.0017 | 0.0133 | 0.0220 | 0.0055 | 0.0069 | 0.0154 | -0.0064 | 0.0114 | -0.0065 | 0.0090 |
| NP                               | -0.0051 | -0.0013 | -0.0061 | 0.0035 | -0.0083 | 0.0065 | -0.0110 | -0.0098 | 0.0001 | -0.0158 | 0.0044 | -0.0175 | -0.0160 |
| CP                               | 0.0049 | 0.0092 | 0.0005 | 0.0070 | 0.0114 | 0.0123 | -0.0011 | 0.0078 | 0.0057 | 0.0121 | -0.0068 | 0.0080 |
| SP                               | 0.0056 | 0.0058 | -0.0092 | -0.0053 | 0.0110 | 0.0097 | 0.0045 | 0.0075 | 0.0068 | -0.0043 | 0.0036 | 0.0003 | 0.0039 |
| NR                               | 0.0040 | 0.0015 | -0.0037 | -0.0024 | 0.0004 | 0.0017 | -0.0026 | -0.0051 | 0.0068 | -0.0082 | 0.0007 | -0.0009 | 0.0089 |
| SR                               | 0.0006 | 0.0005 | 0.0004 | -0.0024 | 0.0020 | 0.0007 | 0.0000 | 0.0019 | 0.0011 | 0.0015 | 0.0002 | -0.0006 | 0.0002 |
| DS                               | 0.0021 | 0.0006 | 0.0012 | -0.0023 | 0.0029 | 0.0007 | 0.0018 | 0.0028 | -0.0010 | 0.0009 | 0.0013 | 0.0013 | 0.0021 |
| GB                               | 0.0026 | 0.0038 | -0.0011 | -0.0011 | 0.0021 | 0.0017 | 0.0001 | -0.0023 | 0.0059 | -0.0051 | 0.0009 | 0.0005 | -0.0043 |
| PN                               | -0.0045 | -0.0041 | -0.0021 | -0.0039 | -0.0153 | -0.0036 | -0.0080 | -0.0216 | -0.0024 | -0.0166 | -0.0032 | -0.0066 | -0.0149 |
| PS                               | 0.0046 | 0.0036 | -0.0015 | -0.0015 | 0.0010 | 0.0023 | 0.0003 | -0.0011 | 0.0017 | -0.0004 | 0.0001 | 0.0059 | 0.0008 |
| TU                               | -0.0028 | -0.0030 | -0.0059 | -0.0040 | -0.0094 | -0.0069 | -0.0094 | -0.0044 | -0.0072 | -0.0054 | -0.0099 | 0.0016 | -0.0008 |
| TA                               | 0.0028 | -0.0017 | -0.0010 | -0.0013 | -0.0043 | -0.0013 | -0.0076 | -0.0030 | -0.0008 | -0.0012 | -0.0025 | 0.0108 | 0.0086 |
Figure S1. Shared Modes of Variability. Spatial modes (maps) and weighting coefficients (bar plots) showing the shared modes of variability across all 13 experiments for (A) annual average GPP, (B) June-July-August average near surface air temperature ($T_{JJA}$), (C) June-July-August average near surface air temperature (Precip$_{JJA}$), (D) June-July-August average height of the 500mb surface, (E) June-July-August average low cloud fraction. Numbers in the lower left corner of the map show the total variance across all 13 experiments explained by that mode. The Domains are ordered from most negative overall impact on US average GPP on the left to most positive impact on the right as in Fig. 2.
**Figure S2.** Impacts of forest loss on summertime near surface air temperature across North America. The response of June-July-August averaged near surface air temperature in each simulated grid point due to forest loss in the domain highlighted in yellow, where red colors indicate higher temperatures and blue colors indicate lower temperatures. Each panel is labeled by the abbreviated name of the Domain where forest was lost. A map of Domain names is in Fig. 5D.
Figure S3. *Impacts of forest loss on summertime precipitation across North America.* The response of June-July-August averaged precipitation in each simulated grid point due to forest loss in the domain highlighted in yellow, where blue colors indicate higher precipitation and red colors indicate lower precipitation. Each panel is labeled by the abbreviated name of the Domain where forest was lost. A map of Domain names is in Fig. 5D.
Figure S4. Impacts of forest loss on summertime low cloud fraction across North America. The response of June-July-August averaged low cloud fraction in each simulated grid point due to forest loss in the domain highlighted in yellow, where blue colors indicate more clouds and red colors indicate fewer clouds. Each panel is labeled by the abbreviated name of the Domain where forest was lost. A map of Domain names is in Fig. 5D.
Figure S5. Impacts of forest loss on summertime pressure height across North America. The response of June-July-August averaged height of the 500mb pressure level in each simulated grid point due to forest loss in the domain highlighted in yellow, where red colors indicate more column heating and blue colors indicate less column heating. Each panel is labeled by the abbreviated name of the Domain where forest was lost. A map of Domain names is in Fig. 5D.
Figure S6. Response of low cloud cover to forest loss. The response of summertime low cloud cover is shown for each domain listed on the y-axis due to forest loss in each domain listed on the x-axis (as in Fig. 5). Domains are ordered from most overall negative impact on US GPP to most overall positive impact. Small white circles indicate that the change in a variable is considered significantly different from zero at 95% confidence.