## *New Phytologist* Supporting Information

Article title: Tree height and leaf drought tolerance traits shape growth responses across droughts in a temperate broadleaf forest

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**Fig. S1** Time series of Palmer Drought Severity Index (PDSI) for each focal drought year.

**Fig. S2** Map of ForestGEO plot showing topographic wetness index and location of cored trees.

**Fig. S3** Distribution of reconstructed tree heights across drought years.

**Fig. S4** Distribution of independent variables by species.

**Fig. S5** Comparison of *Rt* and *RtARIMA* results, with residuals, for each drought scenario.

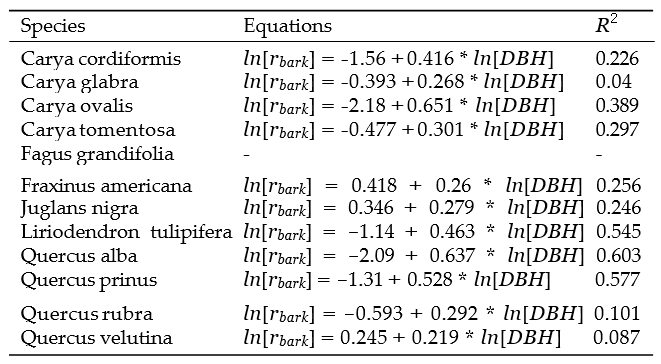
**Fig. S6** Density plot of drought recovery (*Rc*) values for each focal drought year.

**Fig. S7** Drought recovery (*Rc*) across species for the three focal droughts.

**Table S1** Monthly Palmer Drought Severity Index (PDSI), and its rank among all years between 1950 and 2009 (driest=1), for focal droughts.

|  |  |  |  |
| --- | --- | --- | --- |
| year | month | PDSI | rank |
| 1966 | May | -2.98 | 2 |
|  | June | -3.40 | 2 |
|  | July | -4.08 | 2 |
|  | August | -4.82 | 1 |
| 1977 | May | -2.96 | 3 |
|  | June | -3.28 | 3 |
|  | July | -3.61 | 3 |
|  | August | -3.68 | 3 |
| 1999 | May | -3.63 | 1 |
|  | June | -4.21 | 1 |
|  | July | -4.53 | 1 |
|  | August | -4.64 | 2 |

**Table S2** Species-specific regression equations for bark thickness (mm) as a function of diameter at breast height without bark (mm).



We used linear regression on log-transformed data to relate *rbark* to the diameter inside bark from 2008 data. These were then used to determine *rbark* in the *DBHY* reconstruction (DBH in year Y). No bark correction was applied for *Fagus grandifolia*, which has thin bark.

**Table S3** Species-specific regression equations for height (m) as a function of DBH (cm).

|  |  |  |
| --- | --- | --- |
| Species | Equations | *R2* |
| Carya cordiformis | ln[H] = 0.332+0.808\*ln[DBH] | 0.874 |
| Carya glabra | ln[H] = 0.685+0.691\*ln[DBH] | 0.841 |
| Carya ovalis | ln[H] = 0.533+0.741\*ln[DBH] | 0.924 |
| Carya tomentosa | ln[H] = 0.726+0.713\*ln[DBH] | 0.897 |
| Fagus grandifolia | ln[H] = 0.708+0.662\*ln[DBH] | 0.857 |
| Liriodendron tulipifera | ln[H] = 1.33+0.52\*ln[DBH] | 0.771 |
| Quercus alba | ln[H] = 0.74+0.645\*ln[DBH] | 0.719 |
| Quercus prinus | ln[H] = 0.41+0.757\*ln[DBH] | 0.886 |
| Quercus rubra | ln[H] = 1.00+0.574\*ln[DBH] | 0.755 |
| all | ln[H] = 0.839+0.642\*ln[DBH] | 0.857 |

**Table S4** Individual tests of species traits as drivers of drought resistance, where *Rt* is used as the response variable.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | all droughts | |  |  | 1966 |  |  | 1977 |  |  | 1999 |
| variable category | ∆AICc coefficients | |  | ∆AICc | coefficients |  | ∆AICc | coefficients |  | ∆AICc | coefficients |
| xylem porosity R | -0.8 0.0630 | |  | 2.29\*\* | 0.190 |  | 1.92 | -0.152 |  | 3.36\*\* | 0.1500 |
| D/SR | 0.0000 | |  |  | 0.000 |  |  | 0.000 |  |  | 0.0000 |
| *PLA* | 6.7\*\* | -0.0140 | 9.13\*\* | | -0.025 | -0.32 | | -0.010 | -0.95 | | -0.0070 |
| *LMA* | -2.01 | 0.0002 | -1.9 | | 0.001 | -1.68 | | -0.002 | -2.03 | | 0.0003 |
| *πtlp* | 1.33 | -0.1740 | -1.65 | | -0.107 | 1.23 | | -0.245 | -0.1 | | -0.1690 |
| *WD* | -1.97 | -0.0310 | -1.26 | | -0.206 | -1.44 | | -0.154 | 0.66 | | 0.2720 |

Variable abbreviations are as in Table 2. ∆AICc is the AICc of a model excluding the trait minus that of the model including it.

\*\*∆AICc > 2: variable considered significant as an individual predictor

**Table S5** Individual tests of species traits as drivers of drought resistance, where *RtARIMA* is used as the response variable.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | all droughts | |  |  | 1966 |  |  | 1977 |  |  | 1999 |
| variable category | ∆AICc coefficients | |  | ∆AICc | coefficients |  | ∆AICc | coefficients |  | ∆AICc | coefficients |
| xylem porosity R | -1.47 0.0420 | |  | 0.95 | 0.1520 |  | 2.84\*\* | -0.171 |  | 2.27\*\* | 0.155 |
| D/SR | 0.0000 | |  |  | 0.0000 |  |  | 0.000 |  |  | 0.000 |
| *PLA* | 4.48\*\* | -0.0120 | 10.15\*\* | | -0.0240 | -0.9 | | -0.008 | -1.67 | | -0.005 |
| *LMA* | -1.99 | -0.0003 | -2.02 | | 0.0005 | -0.42 | | -0.003 | -1.9 | | 0.001 |
| *πtlp* | 0.42 | -0.1510 | -1.94 | | -0.0530 | -0.53 | | -0.179 | 0.04 | | -0.200 |
| *WD* | -1.94 | -0.0390 | -0.08 | | -0.3040 | -1.57 | | -0.142 | 0.83 | | 0.316 |

Variable abbreviations are as in Table 2. ∆AICc is the AICc of a model excluding the trait minus that of the model including it.

\*\*∆AICc > 2: variable considered significant as an individual predictor

**Table S6** Individual test of species traits as drivers of drought recovery (*Rc*).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | all droughts | |  |  | 1966 |  |  | 1977 |  |  | 1999 |
| variable category | ∆AICc coefficients | |  | ∆AICc | coefficients |  | ∆AICc | coefficients |  | ∆AICc | coefficients |
| xylem porosity R | 15.25\*\* -0.280 | |  | 9.9\*\* | -0.474 |  | -1.67 | -0.0370 |  | 17.06\*\* | -0.3380 |
| D/SR | 0.000 | |  |  | 0.000 |  |  | 0.0000 |  |  | 0.0000 |
| *PLA* | -1.98 | 0.002 | -1.33 | | 0.014 | 1.10 | | -0.0090 | -2.03 | | 0.0010 |
| *LMA* | -1.35 | -0.002 | 0.32 | | -0.008 | -2.04 | | -0.0001 | -2.03 | | -0.0005 |
| *πtlp* | -1.13 | -0.149 | -1.94 | | -0.101 | 1.08 | | -0.1630 | -1.14 | | -0.2020 |
| *WD* | -1.86 | -0.088 | -1.6 | | 0.278 | -1.68 | | -0.0980 | -1.03 | | -0.2950 |

Variable abbreviations are as in Table 2. ∆AICc is the AICc of a model excluding the trait minus that of the model including it.

\*\*∆AICc > 2: variable considered significant as an individual predictor

**Table S7** Individual test of species traits as drivers of drought resilience (*Rs*).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | all droughts | |  |  | 1966 |  |  | 1977 |  |  | 1999 |
| variable category | ∆AICc coefficients | |  | ∆AICc | coefficients |  | ∆AICc | coefficients |  | ∆AICc | coefficients |
| xylem porosity R | 0.24 -0.147 | |  | -1.29 | -0.110 |  | 1.42 | -0.263 |  | -1.11 | -0.0840 |
| D/SR | 0.000 | |  |  | 0.000 |  |  | 0.000 |  |  | 0.0000 |
| *PLA* | 1.09 | -0.016 | 1.09 | | -0.020 | -0.51 | | -0.017 | 0.67 | | -0.0130 |
| *LMA* | -1.9 | -0.001 | -1.00 | | -0.004 | -1.95 | | -0.001 | -2.02 | | -0.0004 |
| *πtlp* | 2.5\*\* | -0.347 | -1.11 | | -0.212 | 1.57 | | -0.468 | 6.11\*\* | | -0.3730 |
| *WD* | -1.83 | -0.109 | -2.05 | | -0.020 | -1.37 | | -0.298 | -2.02 | | 0.0360 |

Variable abbreviations are as in Table 2. ∆AICc is the AICc of a model excluding the trait minus that of the model including it.

\*\*∆AICc > 2: variable considered significant as an individual predictor

**Table S8** Summary of top full models for each drought instance, where *Rt* is used as the response variable.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| drought | ∆AICc | *MarginalR2* | *ConditionalR*2 | Intercept | *ln*[*H*] | *ln*[*TWI*] | *ln*[*H*] ∗ *ln*[*TWI]* | *PLA* | *πtlp* |
| **all** | **0.000** | **0.08** | **0.12** | **1.131** | **-0.057** | **-0.086** | **-** | **-0.012** | **-0.113** |
|  | 0.583 | 0.06 | 0.11 | 1.423 | -0.055 | -0.086 | - | -0.013 | - |
|  | 0.726 | 0.08 | 0.12 | 1.537 | -0.202 | -0.326 | 0.082 | -0.012 | -0.114 |
|  | 1.352 | 0.06 | 0.11 | 1.826 | -0.198 | -0.324 | 0.081 | -0.013 | - |
| **1966** | **0.000** | **0.16** | **0.25** | **1.622** | **-0.135** | **-** | **-** | **-0.025** | **-** |
| **1977** | **0.000** | **0.06** | **0.22** | **0.503** | **-** | **-0.144** | **-** | **-** | **-0.24** |
|  | 0.908 | 0.01 | 0.21 | 1.069 | - | -0.144 | - | - | - |
|  | 0.988 | 0.06 | 0.22 | 0.568 | -0.03 | -0.139 | - | - | -0.246 |
|  | 1.144 | 0.08 | 0.24 | 0.684 | - | -0.142 | - | -0.007 | -0.204 |
|  | 1.267 | 0.04 | 0.22 | 1.211 | - | -0.141 | - | - 0.01 | - |
| **1999** | **0.000** | **0.01** | **0.18** | **1.061** | **-** | **-0.102** | **-** | **-** | **-** |
|  | 0.023 | 0.04 | 0.19 | 0.659 | - | -0.101 | - | - | -0.169 |
|  | 0.954 | 0.02 | 0.19 | 1.157 | - | -0.1 | - | -0.007 | - |
|  | 1.513 | 0.05 | 0.21 | 0.783 | - | -0.1 | - | -0.005 | -0.145 |
|  | 1.803 | 0.01 | 0.18 | 1.024 | 0.013 | -0.103 | - | - | - |
|  | 1.901 | 0.04 | 0.19 | 0.635 | 0.011 | -0.102 | - | - | -0.166 |

Models are ranked by AICc. Shown are all models whose AICc value falls within 2.0 (∆AICc<1) of the best model (bold). *R*2 refers to conditional *R*2. Year was included in the model for all drought years, but its effect was not included in any top models, and coefficients were small (1966: 0, 1977: -0.019, 1999: -0.005; same values in all top models).

**Table S9** Summary of top full models for each drought instance, where *RtARIMA* is used as the response variable.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| drought | ∆AICc | *MarginalR*2 | *ConditionalR*2 | Intercept | *ln*[*H*] | *ln*[*TWI*] | *ln*[*H*] ∗ *ln*[*TWI]* | *PLA* | *πtlp* |
| **all** | **0.000** | **0.05** | **0.09** | **2.113** | **-0.307** | **-0.506** | **0.14** | **-0.012** | **-** |
|  | 0.419 | 0.06 | 0.10 | 1.872 | -0.31 | -0.508 | 0.141 | -0.011 | -0.096 |
|  | 1.217 | 0.05 | 0.09 | 1.395 | -0.06 | -0.1 | - | -0.012 | - |
|  | 1.698 | 0.06 | 0.10 | 1.153 | -0.062 | -0.1 | - | -0.011 | -0.095 |
| **1966** | **0.000** | **0.17** | **0.23** | **1.660** | **-0.154** | **-** | **-** | **-0.024** | **-** |
|  | 1.393 | 0.17 | 0.23 | 1.735 | -0.152 | -0.047 | - | -0.024 | - |
|  | 1.457 | 0.16 | 0.23 | 1.859 | -0.152 | - | - | -0.025 | 0.078 |
| **1977** | **0.000** | **0.01** | **0.16** | **1.130** | **-** | **-0.18** | **-** | **-** | **-** |
|  | 0.424 | 0.02 | 0.16 | 2.453 | -0.461 | -0.896 | 0.25 | - | - |
|  | 0.688 | 0.03 | 0.17 | 0.720 | - | -0.179 | - | - | -0.173 |
|  | 0.922 | 0.04 | 0.17 | 2.040 | -0.466 | -0.898 | 0.251 | - | -0.18 |
|  | 0.927 | 0.03 | 0.17 | 1.248 | - | -0.177 | - | -0.008 | - |
|  | 1.322 | 0.03 | 0.17 | 2.569 | -0.461 | -0.893 | 0.25 | -0.008 | - |
|  | 1.709 | 0.01 | 0.15 | 1.183 | -0.02 | -0.177 | - | - | - |
| **1999** | **0.000** | **0.04** | **0.20** | **0.563** | **-** | **-0.076** | **-** | **-** | **-0.2** |
|  | 0.064 | 0.03 | 0.19 | 0.421 | - | - | - | - | -0.202 |
|  | 0.127 | 0.00 | 0.18 | 1.036 | - | -0.077 | - | - | - |
|  | 0.256 | 0.00 | 0.18 | 0.899 | - | - | - | - | - |
|  | 1.777 | 0.04 | 0.20 | 0.529 | 0.016 | -0.078 | - | - | -0.195 |
|  | 1.797 | 0.01 | 0.20 | 1.101 | - | -0.076 | - | -0.004 | - |
|  | 1.815 | 0.00 | 0.18 | 0.986 | 0.018 | -0.079 | - | - | - |
|  | 1.838 | 0.01 | 0.20 | 0.972 | - | - | - | -0.005 | - |
|  | 1.933 | 0.03 | 0.19 | 0.391 | 0.012 | - | - | - | -0.199 |
|  | 1.979 | 0.04 | 0.21 | 0.612 | - | -0.075 | - | -0.002 | -0.19 |
|  | 1.999 | 0.04 | 0.21 | 0.482 | - | - | - | -0.002 | -0.19 |

Models are ranked by AICc. Shown are all models whose AICc value falls within 2.0 (∆AICc<1) of the best model (bold). *R*2 refers to conditional *R*2. Year was included in the model for all drought years and appeared in all its top models, but coefficients were small (1966: 0, 1977: -0.03, 1999: 0.008; same values in all top models).

**Table S10** Summary of top full models for each drought instance, where *Rc* is used as the response variable.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| drought | ∆AICc | *MarginalR*2 | *ConditionalR*2 | Intercept | *ln*[*H*] | *ln*[*TWI*] | *ln*[*H*] ∗ *ln*[*TWI*] *PLA* | | *πtlp* |
| **all** | **0.000** | **0.05** | **0.17** | **0.434** | **0.345** | **0.844** | **-0.269** | **-** | **-** |
|  | 0.995 | 0.05 | 0.17 | 1.913 | -0.126 | - | - | - | - |
|  | 1.135 | 0.06 | 0.17 | 0.077 | 0.344 | 0.845 | -0.269 | - | -0.152 |
|  | 1.991 | 0.05 | 0.18 | 0.410 | 0.346 | 0.843 | -0.269 | 0.002 | - |
| **1966** | **0.000** | **0.01** | **0.28** | **-0.797** | **0.89** | **1.263** | **-0.475** | **-** | **-** |
|  | 1.040 | 0.00 | 0.25 | 1.577 | - | - | - | - | - |
|  | 1.367 | 0.02 | 0.30 | -0.984 | 0.888 | 1.257 | -0.474 | 0.013 | - |
|  | 1.785 | 0.00 | 0.26 | 1.781 | - | -0.114 | - | - | - |
|  | 1.956 | 0.01 | 0.30 | -1.025 | 0.89 | 1.261 | -0.475 | - | -0.097 |
| **1977** | **0.000** | **0.17** | **0.17** | **2.485** | **-0.482** | **-** | **-** | **-** | **-0.157** |
|  | 0.299 | 0.17 | 0.17 | 2.943 | -0.47 | - | - | -0.008 | - |
|  | 0.716 | 0.17 | 0.18 | 2.657 | -0.477 | - | - | -0.006 | -0.114 |
|  | 0.807 | 0.17 | 0.18 | 1.152 | 0.071 | 1.026 | -0.308 | -0.009 | - |
|  | 0.875 | 0.17 | 0.18 | 2.729 | -0.47 | 0.124 | - | -0.009 | - |
|  | 0.891 | 0.17 | 0.18 | 2.271 | -0.479 | 0.115 | - | - | -0.158 |
|  | 0.910 | 0.17 | 0.18 | 0.712 | 0.054 | 1.004 | -0.304 | - | -0.159 |
|  | 1.315 | 0.17 | 0.18 | 0.871 | 0.065 | 1.023 | -0.308 | -0.006 | -0.112 |
|  | 1.331 | 0.16 | 0.17 | 2.805 | -0.464 | - | - | - | - |
|  | 1.372 | 0.17 | 0.18 | 2.445 | -0.475 | 0.122 | - | -0.006 | -0.112 |
|  | 1.974 | 0.16 | 0.17 | 2.597 | -0.466 | 0.118 | - | - | - |
| **1999** | **0.000** | **0.00** | **0.16** | **1.281** | **-** | **-** | **-** | **-** | **-** |
|  | 0.532 | 0.00 | 0.17 | 1.093 | - | 0.105 | - | - | - |
|  | 1.091 | 0.02 | 0.19 | 0.779 | - | - | - | - | -0.212 |
|  | 1.609 | 0.02 | 0.19 | 0.578 | - | 0.106 | - | - | -0.217 |
|  | 1.755 | 0.00 | 0.17 | 1.200 | 0.027 | - | - | - | - |
|  | 1.996 | 0.00 | 0.18 | 1.251 | - | - | - | 0.002 | - |

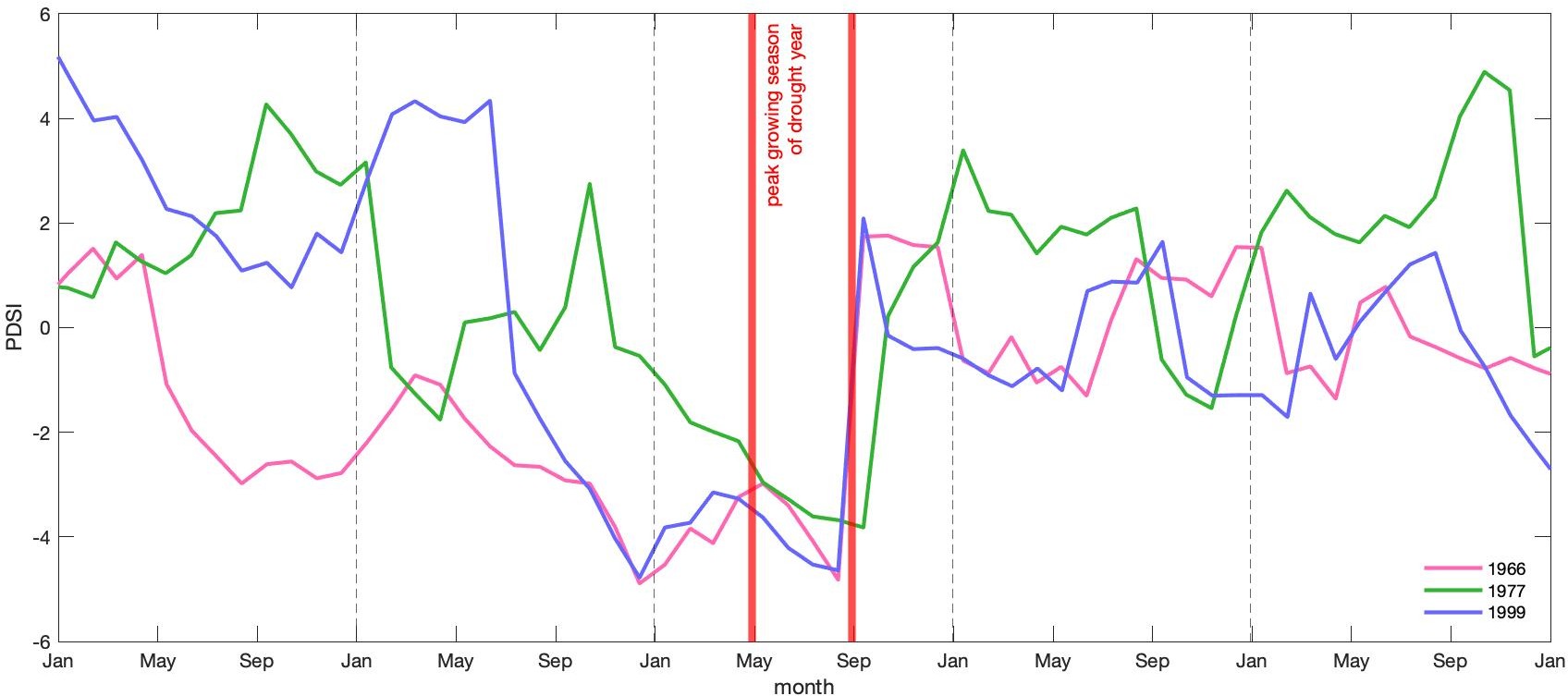
Models are ranked by AICc. Shown are all models whose AICc value falls within 2.0 (∆AICc<1) of the best model (bold). *R*2 refers to conditional *R*2. Year was included in the model for all drought years and appeared in all its top models (1966: 0, 1977: -0.14, 1999: -0.217; same values in all top models).

**Table S11** Summary of top full models for each drought instance, where *Rs* is used as the response variable.

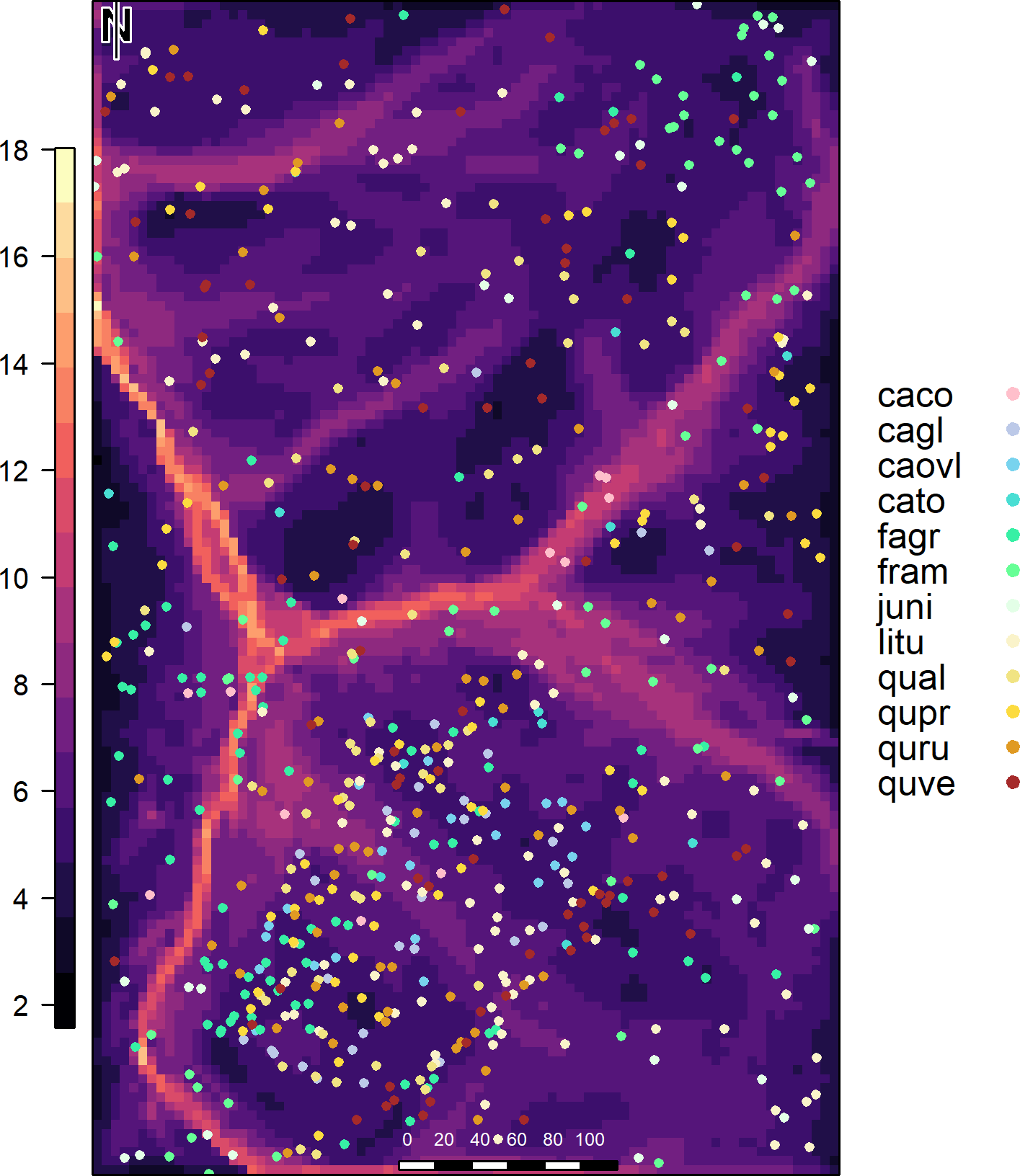
|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| drought | ∆AICc | *MarginalR*2 | *ConditionalR*2 | Intercept | *ln*[*H*] | *ln*[*TWI*] | *ln*[*H*] ∗ *ln*[*TWI*] *PLA* | | *πtlp* |
| **all** | **0.000** | **0.10** | **0.17** | **-0.265** | **0.348** | **0.864** | **-0.291** | **-0.012** | **-0.287** |
|  | 0.176 | 0.08 | 0.16 | -0.572 | 0.347 | 0.859 | -0.291 | - | -0.347 |
|  | 1.518 | 0.07 | 0.16 | 0.458 | 0.354 | 0.866 | -0.292 | -0.016 | - |
|  | 1.552 | 0.09 | 0.17 | 1.253 | -0.166 | - | - | -0.011 | -0.288 |
|  | 1.698 | 0.08 | 0.16 | 0.940 | -0.166 | - | - | - | -0.348 |
| **1966** | **0.000** | **0.04** | **0.15** | **1.834** | **-0.085** | **-** | **-** | **-0.02** | **-** |
|  | 0.402 | 0.03 | 0.16 | 1.589 | - | - | - | -0.02 | - |
|  | 1.189 | 0.00 | 0.14 | 1.534 | -0.082 | - | - | - | - |
|  | 1.313 | 0.00 | 0.15 | 1.293 | - | - | - | - | - |
|  | 1.692 | 0.04 | 0.16 | 1.534 | -0.085 | - | - | -0.018 | -0.116 |
| **1977** | **0.000** | **0.14** | **0.28** | **-0.932** | **0.294** | **1.207** | **-0.384** | **-** | **-0.467** |
|  | 0.497 | 0.13 | 0.28 | 1.194 | -0.383 | - | - | - | -0.469 |
|  | 1.304 | 0.15 | 0.30 | -0.648 | 0.294 | 1.208 | -0.383 | -0.011 | -0.411 |
|  | 1.542 | 0.13 | 0.28 | 1.026 | -0.387 | 0.095 | - | - | -0.472 |
|  | 1.555 | 0.09 | 0.28 | 0.138 | 0.304 | 1.211 | -0.385 | - | - |
|  | 1.852 | 0.14 | 0.29 | 1.467 | -0.381 | - | - | -0.01 | -0.416 |
| **1999** | **0.000** | **0.07** | **0.13** | **0.237** | **-** | **-** | **-** | **-** | **-0.366** |
|  | 0.313 | 0.08 | 0.14 | 0.472 | - | - | - | -0.008 | -0.317 |
|  | 0.503 | 0.07 | 0.13 | 0.358 | -0.048 | - | - | - | -0.376 |
|  | 0.532 | 0.07 | 0.13 | 0.394 | - | -0.086 | - | - | -0.364 |
|  | 0.726 | 0.09 | 0.14 | 0.588 | -0.047 | - | - | -0.008 | -0.328 |
|  | 1.079 | 0.09 | 0.15 | 0.602 | - | -0.081 | - | -0.008 | -0.319 |
|  | 1.249 | 0.07 | 0.13 | 0.495 | -0.044 | -0.08 | - | - | -0.374 |
|  | 1.706 | 0.09 | 0.14 | 0.699 | -0.044 | -0.075 | - | -0.007 | -0.329 |

Models are ranked by AICc. Shown are all models whose AICc value falls within 2.0 (∆AICc<1) of the best model (bold). *R*2 refers to conditional *R*2. Year was included in the model for all drought years and appeared in all its top models (1966: 0, 1977: -0.099, -0.099, -0.099, -0.097, -0.097; 1999: -0.174, -0.174, -0.174, -0.173, -0.172).

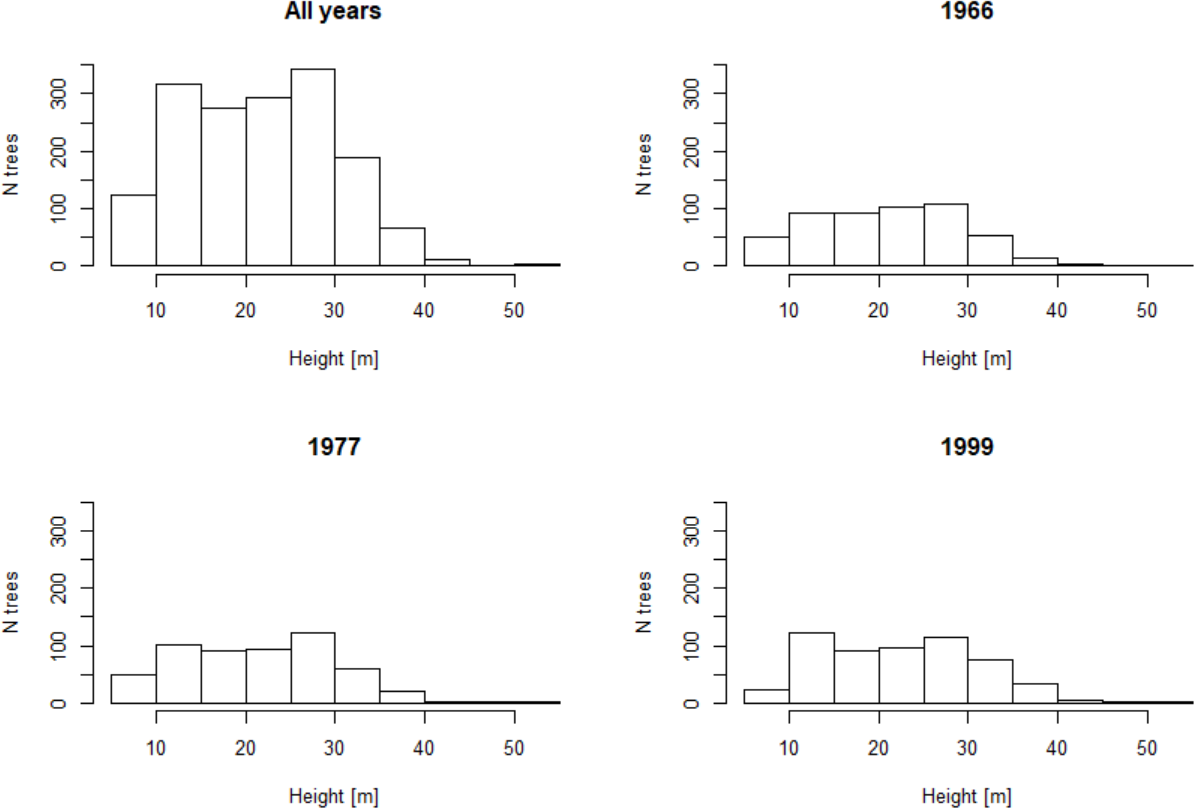
**Fig. S1** Time series of Palmer Drought Severity Index (PDSI) for each focal drought year.



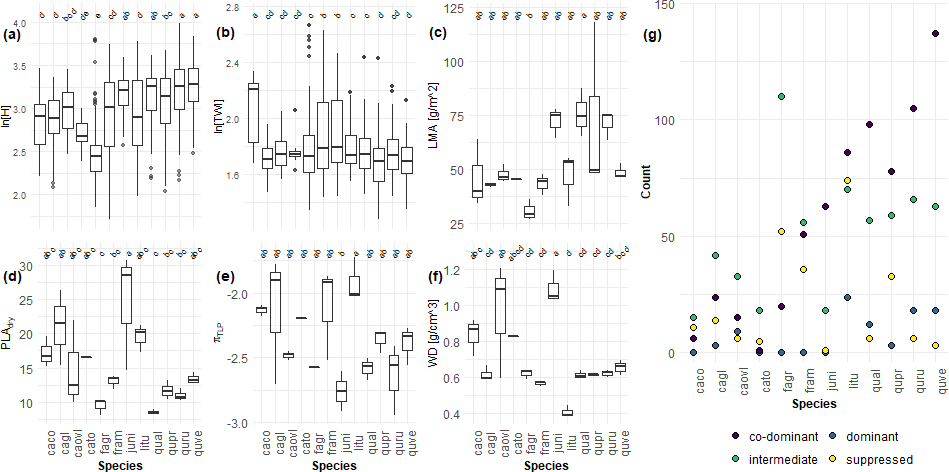
**Fig. S2** Map of ForestGEO plot showing topographic wetness index and location of cored trees. Scale units are in meters.



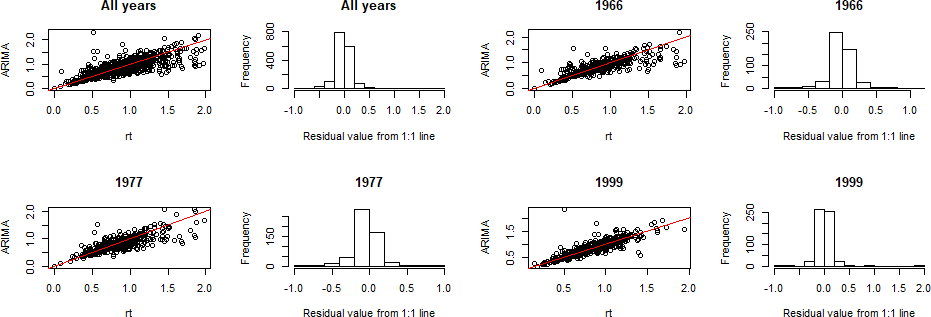
**Fig. S3** Distribution of reconstructed tree heights across drought years.



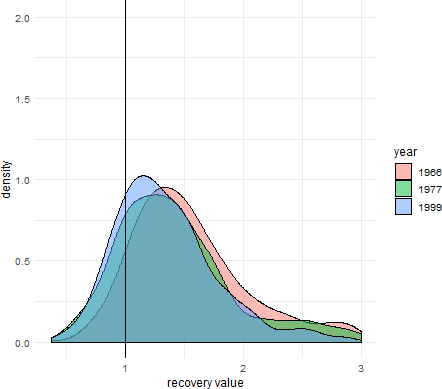
**Fig. S4** Distribution of independent variables by species. Species that are assigned the same letter are not significantly different from each other with regard to the tested variable. Letter groupings do not transfer between variables.



**Fig. S5** Comparisons of *Rt* and *RtARIMA* results, with residuals, for each drought scenario.



**Fig. S6** Density plot of drought recovery (*Rc*) for each focal drought year.



**Fig. S7** Drought recovery (*Rc*) across species for the three focal droughts. Species that are assigned the same letter are not significantly different from each other with regard to the tested variable.

