Supplementary material

The supplementary material for this manuscript consists of three figures and three tables. The figure captions including methodology are given below.

**Fig. S1.** Variation of Moran’s I along distance bands for observed (grey dot) and residuals in general linear models (black open), for inter-specific (left column, a, d, g), intra-specific (central column, b, e, h), and total (right column c, f, i) variations in the leaf nitrogen (upper row, a-c), phosphorus (middle row, d-f) concentrations and leaf N:P (lower row, g-i).

**Fig. S2.** Histograms showing the distributions of leaf nitrogen (mg g−1) (a), phosphorus (mg g−1) (b), and N:P (c) for all observations.

**Fig. S3.** Decomposition of total variation in leaf N (a, d), P (b, e) and N:P (c, f) of shrubs in temperate shrbland (a-c) and desert shrubland (d-f).

**Fig. S4.** Different leaf N (black) and P (grey) concentrations among life forms (a) and different leaf N concentration among functional groups (b) in China. In (a), data for “tree” and “shrub” were from Han *et al.* (2005); data for “herb” were from Han *et al.* (2005) and He *et al.* (2006); data for “shrub\*” were from this study. Letters above the error bars show the results of multiple comparisons tests. Life forms and functional groups with same letters are not significantly different, while different letters are significantly different.



Fig. S1



Fig. S2



Fig. S3



Fig. S4

Table S1. Pearson correlations (R) of soil total nitrogen (STN) and phosphorus (STP) concentrations between different soil layers.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| STP STN | 0-10 cm | 10-20 cm | 20-30 cm | 30-50 cm | 50-70 cm | 70-100 cm |
| 0-10 cm |  | 0.88\*\*\* | 0.79\*\*\* | 0.62\*\*\* | 0.41\*\*\* | 0.39\*\*\* |
| 10-20 cm | 0.90\*\*\* |  | 0.92\*\*\* | 0.82\*\*\* | 0.53\*\*\* | 0.54\*\*\* |
| 20-30 cm | 0.82\*\*\* | 0.92\*\*\* |  | 0.79\*\*\* | 0.57\*\*\* | 0.62\*\*\* |
| 30-50 cm | 0.67\*\*\* | 0.75\*\*\* | 0.84\*\*\* |  | 0.80\*\*\* | 0.67\*\*\* |
| 50-70 cm | 0.61\*\*\* | 0.70\*\*\* | 0.77\*\*\* | 0.90\*\*\* |  | 0.89\*\*\* |
| 70-100 cm | 0.53\*\*\* | 0.58\*\*\* | 0.65\*\*\* | 0.81\*\*\* | 0.88\*\*\* |  |

Table S2. Summary of general linear models for leaf N (a), P (b) concentrations and N:P (c) of shrubs in Northern China with interaction terms.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Interspecific variation | |  | Intraspecific variation | |  | Total variation | | |
|  |  | F | SS |  | F | SS |  | F | SS | SS% |
| (a) | MAT | 0.012 | 0.2NS |  | 0.08 | 1.1NS |  | 0.01 | 0.3NS | 0.00 |
|  | AP | 50.72 | 932.1\*\*\* |  | 0.86 | 12NS |  | 22.17 | 742.9\*\*\* | 5.73 |
|  | STN | 18.75 | 344.6\*\*\* |  | 0.89 | 12.4NS |  | 6.75 | 226.2\*\* | 1.74 |
|  | STP | 0.01 | 0.2NS |  | 2.07 | 29.1NS |  | 0.75 | 25.3NS | 0.20 |
|  | MAT:AP | 0.4 | 7.4NS |  | 0.68 | 9.6NS |  | 0.93 | 31.2NS | 0.24 |
|  | AP:STN | 11.19 | 205.8\*\*\* |  | 0.15 | 2.1NS |  | 6.94 | 232.6\*\* | 1.79 |
|  | MAT:STN | 11.37 | 208.9\*\*\* |  | 3.99 | 56\* |  | 1.55 | 51.9NS | 0.40 |
|  | AP:STP | 3.42 | 62.9NS |  | 0.01 | 0NS |  | 2.05 | 68.5NS | 0.53 |
|  | Residuals |  | 6359.1 |  |  | 4671.9 |  |  | 11594.6 |  |
|  | Total |  | 8121.2 |  |  | 4794.2 |  |  | 12973.5 | 10.63 |
|  | AIC | 2051.8 | |  | 1884.7 | |  | 2265.0 | | |
|  | AIC (main-effect) | 2069.9 | |  | 1881.6 | |  | 2268.6 | | |
| (b) | MAT | 18.72 | 1.821\*\*\* |  | 11.14 | 1.272\*\*\* |  | 29.25 | 6.026\*\*\* | 5.69 |
|  | AP | 37.25 | 3.625\*\*\* |  | 1.58 | 0.18NS |  | 26.09 | 5.375\*\*\* | 5.07 |
|  | STN | 2.9 | 0.282NS |  | 13.57 | 1.549\*\*\* |  | 2.55 | 0.526NS | 0.50 |
|  | STP | 0.29 | 0.028NS |  | 39.9 | 4.554\*\*\* |  | 18.61 | 3.834\*\*\* | 3.62 |
|  | MAT:AP | 19.39 | 1.887\*\*\* |  | 0.27 | 0.031NS |  | 7.1 | 1.463\*\* | 1.38 |
|  | MAT:STN | 20.85 | 2.029\*\*\* |  | 0.81 | 0.092NS |  | 14.53 | 2.993\*\*\* | 2.82 |
|  | AP:STN | 5.22 | 0.508\* |  | 0.54 | 0.061NS |  | 1.24 | 0.255NS | 0.24 |
|  | MAT:STP | 8.01 | 0.78\*\* |  | 3.34 | 0.381NS |  | 11.02 | 2.271\*\*\* | 2.14 |
|  | AP:STP | 8.65 | 0.842\*\* |  | 9.99 | 1.14\*\* |  | 18.93 | 3.9\*\*\* | 3.68 |
|  | STN:STP | 8.09 | 0.787\*\* |  | 8.08 | 0.922\*\* |  | 16.86 | 3.475\*\*\* | 3.28 |
|  | MAT:AP:STN | 0.54 | 0.052NS |  | 0.24 | 0.027NS |  | 0.17 | 0.034NS | 0.03 |
|  | MAT:AP:STP | 0.01 | 0.001NS |  | 6.77 | 0.772\*\* |  | 3.38 | 0.697NS | 0.66 |
|  | MAT:STN:STP | 4.59 | 0.446\* |  | 14.33 | 1.636\*\*\* |  | 18.55 | 3.822\*\*\* | 3.61 |
|  | AP:STN:STP | 0.14 | 0.013NS |  | 9.18 | 1.048\*\* |  | 5.95 | 1.227\* | 1.16 |
|  | Residuals |  | 33.08 |  |  | 37.32 |  |  | 70.06 |  |
|  | Total |  | 46.19 |  |  | 50.99 |  |  | 105.95 | 33.88 |
|  | AIC | 197.0 | |  | 245.0 | |  | 463.3 | | |
|  | AIC (main-effect) | 248.2 | |  | 276.8 | |  | 533.0 | | |
| (c) | MAT | 7.49 | 103.2\*\* |  | 3.54 | 58.4NS |  | 10.99 | 312\*\* | 1.96 |
|  | AP | 253.01 | 3487.2\*\*\* |  | 0.82 | 13.5NS |  | 138.26 | 3926.6\*\*\* | 24.64 |
|  | STN | 6.03 | 83.1\* |  | 0.02 | 0.3NS |  | 2.73 | 77.6NS | 0.49 |
|  | STP | 0.81 | 11.2NS |  | 12.32 | 203.1\*\*\* |  | 4.11 | 116.6\* | 0.73 |
|  | MAT:AP | 28.52 | 393\*\*\* |  | 0.3 | 4.9NS |  | 17.1 | 485.5\*\*\* | 3.05 |
|  | MAT:STN | 4.92 | 67.8\* |  | 3.28 | 54.1NS |  | 7.96 | 226.2\*\* | 1.42 |
|  | AP:STN | 20.01 | 275.8\*\*\* |  | 0.7 | 11.5NS |  | 12.36 | 351.2\*\*\* | 2.20 |
|  | MAT:STP | 0.75 | 10.4NS |  | 0.01 | 0.1NS |  | 0.43 | 12.1NS | 0.08 |
|  | AP:STP | 4.33 | 59.6\* |  | 0.53 | 8.7NS |  | 3.85 | 109.4NS | 0.69 |
|  | STN:STP | 0.42 | 5.7NS |  | 1.32 | 21.7NS |  | 1.87 | 53.2NS | 0.33 |
|  | MAT:AP:STN | 9.4 | 129.6\*\* |  | 0 | 0NS |  | 6.54 | 185.8\* | 1.17 |
|  | MAT:AP:STP | 1.76 | 24.2NS |  | 1.65 | 27.2NS |  | 0 | 0.1NS | 0.00 |
|  | MAT:STN:STP | 7.88 | 108.5\*\* |  | 5.24 | 86.4\* |  | 13.98 | 397.1\*\*\* | 2.49 |
|  | AP:STN:STP | 2.05 | 28.3NS |  | 0.01 | 0.1NS |  | 0.95 | 27NS | 0.17 |
|  | Residuals |  | 4686.2 |  |  | 5390.7 |  |  | 9656.2 |  |
|  | Total |  | 9473.8 |  |  | 5880.7 |  |  | 15936.6 | 39.41 |
|  | AIC | 1955.4 | |  | 1945.6 | |  | 2212.1 | | |
|  | AIC (main-effect) | 2010.5 | |  | 1939.0 | |  | 2254.2 | | |

The effects of MAT, AP, STN, STP and all of their possible interactions on leaf N (a), P (b) concentrations and N:P (c) were analyzed using general linear models (GLM). Akaike information criterion (AIC) was used to select competing models. For each trait, effects that were selected in the any of the three models (interspecific, intraspecific and total variation) were included in the final model.

Abbreviations: MAT, mean annual temperature; AP, annual precipitation; STN, soil total nitrogen; STP, soil total phosphorus. \*\*\* *p*<0.001, \*\* *p*< 0.01 and NS non-significance.

Table S3. Summary of main-effect general linear models for leaf N (a, d), P (b, d) concentrations and N:P (c, e) of shrubs in temperate shrbland (a-c) and desert shrubland (d-f).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Interspecific variation | |  | Intraspecific variation | |  | Total variation | | |
| F | SS |  | F | SS |  | F | SS | SS% |
| (a) | MAT | <0.1 | 0.6NS |  | <0.1 | 0.0NS |  | <0.1 | 0.8NS | <0.1 |
|  | AP | 4.0 | 58.8\* |  | 0.4 | 5.2NS |  | 3.3 | 98.4NS | 1.2 |
|  | STN | 13.9 | 206.4\*\*\* |  | 1.2 | 16.1NS |  | 3.6 | 107.5NS | 1.3 |
|  | STP | 0.5 | 7.5NS |  | 3.4 | 46.0NS |  | 3.1 | 91.0NS | 1.1 |
|  | Residual |  | 4125.9 |  |  | 3674.2 |  |  | 8259.9 |  |
|  | Total |  | 4399.2 |  |  | 3741.5 |  |  | 8557.6 | 3.5 |
| (b) | MAT | 38.2 | 2.1\*\*\* |  | 9.9 | 1.4\*\* |  | 36.0 | 6.8\*\*\* | 9.4 |
|  | AP | 58.1 | 3.2\*\*\* |  | 0.8 | 0.1NS |  | 23.8 | 4.5\*\*\* | 6.2 |
|  | STN | 0.1 | <0.1NS |  | 11.6 | 1.6\*\*\* |  | 7.8 | 1.5\*\* | 2 |
|  | STP | 2.6 | 0.1NS |  | 38.8 | 5.4\*\*\* |  | 39.0 | 7.4\*\*\* | 10.2 |
|  | Residual |  | 15.1 |  |  | 38.0 |  |  | 52.3 |  |
|  | Total |  | 20.5 |  |  | 46.5 |  |  | 72.3 | 27.7 |
| (c) | MAT | 17.9 | 117.6\*\*\* |  | 4.6 | 72.6\* |  | 18.5 | 370.2\*\*\* | <0.1 |
|  | AP | 105.6 | 691.6\*\*\* |  | 0.1 | 2.2NS |  | 38.9 | 776.2\*\*\* | 6.7 |
|  | STN | 9.6 | 62.7\*\* |  | 0.1 | 2.1NS |  | 2.2 | 43.6NS | 0.1 |
|  | STP | 0.2 | 1.0NS |  | 12.2 | 191.1\*\*\* |  | 10.9 | 218.1\*\* | 0.2 |
|  | Residual |  | 1821.1 |  |  | 4262.2 |  |  | 5551.4 |  |
|  | Total |  | 2694 |  |  | 4530.2 |  |  | 6959.5 | 7 |
| (d) | MAT | 0.8 | 27.9NS |  | 0.1 | 2.6NS |  | 0.9 | 44.1NS | 1.4 |
|  | AP | 0.4 | 13.3NS |  | 0.6 | 11.0NS |  | 1.0 | 45.8NS | 1.4 |
|  | STN | 1.0 | 32.7NS |  | <0.1 | 0.5NS |  | 0.6 | 29.7NS | 0.9 |
|  | STP | 1.1 | 37.1NS |  | 0.8 | 13.8NS |  | 1.9 | 88.9NS | 2.7 |
|  | Residual |  | 2125.5 |  |  | 1000.0 |  |  | 3038.5 |  |
|  | Total |  | 2236.5 |  |  | 1027.9 |  |  | 3247.0 | 6.4 |
| (e) | MAT | 0.1 | <0.1NS |  | 0.1 | <0.1NS |  | 0.2 | <0.1NS | 0.1 |
|  | AP | 59.4 | 11.3\*\*\* |  | 2.1 | 0.1NS |  | 53.3 | 14.0\*\*\* | 42.5 |
|  | STN | 5.5 | 1.0\* |  | <0.1 | <0.1NS |  | 4.1 | 1.1\* | 3.3 |
|  | STP | 3.2 | 0.6NS |  | 0.9 | 0.1NS |  | 3.9 | 1.0NS | 3.1 |
|  | Residual |  | 12.2 |  |  | 4.1 |  |  | 16.8 |  |
|  | Total |  | 25.2 |  |  | 4.3 |  |  | 32.9 | 49 |
| (f) | MAT | 6.9 | 275.8\* |  | 0.4 | 9.9NS |  | 6.0 | 382.6\* | 6.4 |
|  | AP | 30.7 | 1225.9\*\*\* |  | 0.3 | 6.5NS |  | 22.0 | 1404.4\*\*\* | 23.3 |
|  | STN | 1.2 | 47.6NS |  | 0.1 | 1.9NS |  | 0.5 | 34.5NS | 0.6 |
|  | STP | 4.6 | 182.9\* |  | 0.3 | 6.2NS |  | 1.8 | 117.8NS | 2 |
|  | Residual |  | 2553.7 |  |  | 1305.9 |  |  | 4084.6 |  |
|  | Total |  | 4285.9 |  |  | 1330.4 |  |  | 6023.9 | 32.2 |