**Supplementary Tables 1-14**

**Supplementary Table 1. Environmental variables in the sub soil under different treatments.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Category | Environmental variables | C | IP | DP | W | WIP | WDP |
| Plants | ANPP (gm-2) | 393.95±22.1ab | 469.11±18.87ab | 368.40±25.83b | 431.80±36.84ab | 496.00±26.38a | 381.06±29.54ab |
| GrassANPP (g m-2) | 175.64±57.78ab | 221.96±25.41ab | 188±41.47ab | 226.07±16.61ab | 322.35±111.56b | 152.73±20.29a |
| SedgeANPP (g m-2) | 76.7±23.94a | 82.9±37.45a | 66.15±30.37a | 49.11±21.57a | 95.81±42.42a | 45.55±25.45a |
| ForbANPP (g m-2) | 107.16±29.13a | 72.34±36.89a | 32.82±20a | 60.02±34.96a | 71.64±41.01a | 25.72±14.58a |
| BNPP (gm-2) | 720.91±89.28a | 822.51±77.35a | 787.03±66.35a | 852.67±83.69a | 951±71.89a | 903.31±171.18a |
| Plant richness | 34.67±0.84a | 32.67±0.95a | 33.50±1.20a | 30.67±1.48a | 31.67±0.84a | 25.33±1.36b |
| Carbon fluxes | Soil CO2 flux (mg C m-2 h-1) | 446.74±14.57bc | 386.63±21.98c | 424.28±27.27bc | 497.49±5.34ab | 530.32±14.04a | 452.98±3.29abc |
| Soil N2O flux (g m-2 h-1) | 4.62±1.67b | 13.36±4.17ab | 11.92±2.38ab | 3.57±3.03b | 19.75±3.96a | 15.34±2.54ab |
| Soil CH4 flux (μg C m-2 h-1) | -0.16±0.01a | -0.18±0.01ab | -0.24±0.01b | -0.31±0.02c | -0.2±0.01ab | -0.32±0.02c |
| NEE (g C m-2 yr-1) | -84.91±45.69ab | -178.68±10.77b | -82.05±33.55ab | -77.3±42.58ab | -190.33±14.23b | -4.24±44.63a |
| ER (g C m-2 yr-1) | 988.19±71.25b | 1041.73±39.21ab | 978.23±40.93b | 1180.18±16.32a | 1213.48±7.9a | 1048.41±23.16ab |
| GEP (g C m-2 yr-1) | -1073.1±39.5ab | -1220.41±29.54bc | -1060.28±8.57a | -1257.48±45.24cd | -1403.82±20.84d | -1052.65±37.56a |
|  | Soil temperature (oC) | 5.12±0.18bc | 4.99±0.17c | 4.92±0.22c | 6.41±0.54ab | 6.08±0.13abc | 6.67±0.27a |
|  | Soil pH | 8.13±0.07a | 8.00±0.13a | 8.10±0.05a | 7.97±0.12a | 8.00±0.10a | 8.13±0.02a |
| Topsoil | Soil water content (v/v) | 0.22±0.01a | 0.23±0.01a | 0.18±0.01bc | 0.17±0.01c | 0.22±0.01ab | 0.15±0.01c |
| TC (gkg-1) | 78.17±1.89a | 75.77±7.89a | 81.35±14.90a | 75.05±15.18a | 79.50±4.95a | 79.90±9.64a |
| TN (gkg-1) | 8.40±0.24a | 7.35±0.90a | 7.18±0.24a | 8.36±0.59a | 7.93±0.61a | 7.54±0.26a |
| NH4+ (gkg-1) | 17.36±3.66a | 15.68±2.55a | 15.61±3.18a | 16.58±3.09a | 21.76±4.94a | 13.00±1.62a |
| NO3- (gkg-1) | 11.35±1.90a | 9.68±2.28a | 13.69±1.77a | 9.30±1.84a | 8.39±2.29a | 13.53±1.68a |
| SOC (gkg-1) | 63.10±2.07a | 62.76±7.72a | 67.08±9.13a | 65.38±6.74a | 65.01±3.58a | 64.42±7.79a |
| DOC (mgkg-1) | 243.54±27.04ab | 210.20±22.93b | 327.34±11.52ab | 353.27±32.52a | 282.48±33.69ab | 300.38±26.78ab |
| DON (mgkg-1) | 35.91±3.51a | 34.83±2.73a | 45.05±3.53a | 43.67±3.74a | 34.12±0.21a | 41.78±1.63a |
| MBC (mgkg-1) | 607.36±48.67ab | 675.42±14.56a | 521.47±7.10bc | 556.03±23.72bc | 635.04±7.57ab | 483.74±25.28c |
| MBN (mgkg-1) | 58.85±3.33abc | 68.75±2.89a | 53.28±3.81bc | 58.08±2.66abc | 62.33±1.78ab | 46.75±1.57c |
| SOC/TN | 11.07±0.68a | 11.32±0.35a | 10.85±0.55a | 12.42±1.51a | 11.11±0.19a | 10.99±0.30a |
| DOC/DON | 8.76±0.93a | 8.79±1.26a | 7.65±0.57a | 8.69±0.44a | 8.13±1.01a | 8.84±1.27a |
|  | pH | 8.50±0.02a | 8.43±0.02a | 8.48±0.03a | 8.43±0.01a | 8.48±0.03a | 8.50±0.04a |
| Subsoil | Soil water content (v/v) | 0.21±0.00a | 0.21±0.00a | 0.2±0.00a | 0.21±0.01a | 0.22±0.01a | 0.19±0.01a |
| TC (gkg-1) | 36.16±0.72a | 35.37±0.90a | 38.58±1.29a | 36.01±0.90a | 36.82±0.50a | 35.69±0.72a |
| TN (gkg-1) | 1.75±0.11b | 1.92±0.31b | 2.76±0.15a | 2.06±0.14ab | 2.27±0.17ab | 1.85±0.10b |
| NH4+ (gkg-1) | 7.42±0.91a | 5.61±1.01a | 7.41±1.68a | 4.85±0.85a | 6.07±0.89a | 5.40±0.91a |
| NO3- (gkg-1) | 5.55±0.53a | 5.17±0.33a | 5.19±0.57a | 5.37±0.62a | 4.88±0.15a | 4.53±0.37a |
| SOC (gkg-1) | 17.95±1.70a | 16.20±3.10a | 18.97±1.99a | 18.97±1.42a | 19.12±0.38a | 13.62±3.08a |
| DOC (mgkg-1) | 120.26±18.01a | 90.75±27.02a | 104.6±9.53a | 125.37±20.18a | 77.51±10.23a | 107.79±16.28a |
| DON (mgkg-1) | 10.5±0.90a | 12.38±3.21a | 11.61±1.17a | 11.48±1.50a | 8.32±0.66a | 8.47±1.70a |
| MBC (mgkg-1) | 236.75±27.22a | 294.14±41.82a | 294.99±5.34a | 220.24±22.13a | 315.35±24.13a | 270.94±27.76a |
| MBN (mgkg-1) | 25.63±2.97a | 30.74±2.08a | 26.92±1.09a | 22.85±1.51a | 29.96±3.90a | 26.77±4.56a |
| SOC/TN | 10.45±1.37a | 8.32±0.40ab | 6.99±0.98b | 9.26±0.98ab | 8.54±0.50ab | 7.23±1.51ab |
| DOC/DON | 11.33±0.98a | 7.75±1.37a | 9.07±0.38a | 10.78±0.66a | 9.39±1.31a | 13.45±2.33a |

Values are shown as the mean ± SE derived from replicate plots. Superscript letters are used to distinguish sample groups that were significantly different (adjusted *P* < 0.05). ANPP, aboveground primary production; BNPP, belowground primary production; GrassANPP, the ANPP of grass; SedgeANPP, the ANPP of sedge; ForbANPP, the ANPP of forb; NEE, net ecosystem CO2 exchange; ER, ecosystem respiration; GEP, gross ecosystem production; TC total carbon; TN, total nitrogen; NH4+, ammonia; NO3-, nitrate; SOC, soil organic carbon; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; MBC, microbial biomass carbon; MBN, microbial biomass nitrogen.

**Supplementary Table 2. The significance tests of depth effects on the environmental variables by linear mixed-effects models (LMMs).**

|  |  |  |
| --- | --- | --- |
| Soil variables | β | *P* |
| pH | 0.06 | < 0.001 \*\*\* |
| SWC | -0.06 | < 0.001 \*\*\* |
| TC | -0.06 | < 0.001 \*\*\* |
| TN | -0.06 | < 0.001 \*\*\* |
| NH4+ | -0.06 | < 0.001 \*\*\* |
| NO3- | -0.06 | < 0.001 \*\*\* |
| SOC | -0.06 | < 0.001 \*\*\* |
| DOC | -0.06 | < 0.001 \*\*\* |
| DON | -0.06 | < 0.001 \*\*\* |
| MBC | -0.05 | < 0.001 \*\*\* |
| MBN | -0.05 | < 0.001 \*\*\* |

**Supplementary Table 3. The significance tests of treatment effects on the environmental variables by linear mixed-effects models (LMMs).**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Warming | | Precipitation | | Warming\*Precipitation | |
|  |  | β | *P* | β | *P* | β | *P* |
| Plants | ANPP | 0.33 | 0.177 | 1.29 | 0.004 | 0.18 | 0.757 |
| BNPP | 0.53 | 0.111 | 0.15 | 0.79 | 0.05 | 0.948 |
| GrassANPP | 0.92 | 0.044 | 0.23 | 0.447 | 0.52 | 0.147 |
| SedgeANPP | -0.36 | 0.419 | 0.26 | 0.505 | 0.52 | 0.349 |
| ForbANPP | -0.48 | 0.293 | 0.51 | 0.195 | 0.08 | 0.878 |
| Plant richness | -1.1 | < 0.001\*\*\* | -0.21 | 0.592 | 1.79 | 0.003 |
| Carbon fluxes | Soil CO2 flux | 1.38 | <0.001\*\*\* | -0.7 | 0.16 | 2.13 | 0.006\*\* |
| Soil N2O flux | -0.11 | 0.48 | -0.55 | 0.215 | 0.43 | 0.1476 |
| Soil CH4 flux | -1.28 | < 0.001\*\*\* | 0.9 | 0.039 | 0.93 | 0.114 |
| NEE | 0.3 | 0.315 | -1.16 | 0.035 | -1.08 | 0.146 |
| ER | 1.33 | < 0.001\*\*\* | 0.58 | 0.183 | 0.93 | 0.136 |
| GEP | -0.85 | < 0.001\*\*\* | -1.13 | 0.003 | -1.35 | 0.009 |
|  | Soil Temperature | 1.64 | < 0.001\*\*\* | 0.08 | 0.772 | -0.79 | 0.074 |
|  | Soil pH | -0.06 | 0.856 | -0.17 | 0.591 | -0.56 | 0.225 |
| Topsoil | Soil water content | -0.98 | < 0.001\*\*\* | 1.4 | 0.005 | 0.59 | 0.345 |
| TC | -0.03 | 0.941 | -0.59 | 0.41 | 0.55 | 0.587 |
| TN | 0.33 | 0.530 | 0.18 | 0.839 | 0.24 | 0.852 |
| NH4+ | 0.14 | 0.576 | 0.01 | 0.981 | 1.34 | 0.037 |
| NO3- | -0.29 | 0.285 | -0.99 | 0.042 | -0.28 | 0.669 |
| SOC | 0.28 | 0.505 | 1.46 | 0.059 | -0.57 | 0.572 |
| DOC | 0.76 | 0.036 | -1.71 | 0.008 | 1.45 | 0.093 |
| DON | 0.19 | 0.611 | -1.51 | 0.026 | 0.38 | 0.673 |
| MBC | -0.69 | 0.014 | 1.38 | 0.005 | 0.65 | 0.315 |
| MBN | -0.62 | 0.012 | 1.54 | < 0.001 | 0.44 | 0.423 |
| SOC/TN | 0.42 | 0.463 | 0.47 | 0.634 | -0.35 | 0.804 |
| DOC/DON | 0.08 | 0.828 | 0.64 | 0.351 | -1.04 | 0.288 |
| Subsoil | Soil pH | -0.08 | 1.000 | 0.50 | 0.165 | 0.39 | 0.433 |
| Soil water content | -0.29 | 0.283 | 0.86 | 0.072 | 0.83 | 0.225 |
| TC | -0.35 | 0.291 | -1.67 | 0.007\*\* | 2.04 | 0.021\* |
| TN | -0.21 | 0.567 | -1.79 | 0.009\*\* | 2.57 | 0.010\* |
| NH4+ | -0.59 | 0.055 | -0.84 | 0.101 | 1.28 | 0.090 |
| NO3- | -0.39 | 0.297 | -0.02 | 0.974 | 0.48 | 0.608 |
| SOC | -0.10 | 0.775 | -0.31 | 0.338 | 0.95 | 0.053 |
| DOC | -0.03 | 0.941 | -0.38 | 0.609 | -0.41 | 0.704 |
| DON | -0.6 | 0.163 | 0.22 | 0.759 | -0.3 | 0.773 |
| MBC | -0.17 | 0.708 | -0.01 | 0.985 | 0.59 | 0.598 |
| MBN | -0.42 | 0.337 | 0.69 | 0.348 | -0.71 | 0.512 |
| SOC/TN | 0.42 | 0.463 | 0.47 | 0.634 | -0.35 | 0.804 |
| DOC/DON | 0.6 | 0.118 | -0.44 | 0.502 | -0.91 | 0.328 |

The significance effects were indicated as \*\*\**P* < 0.001, \*\**P* < 0.010, \**P* < 0.050. β is the regression coefficients of linear mixed model. ANPP, aboveground primary production; BNPP, belowground primary production; GrassANPP, the ANPP of grass; SedgeANPP, the ANPP of sedge; ForbANPP, the ANPP of forb; NEE, net ecosystem CO2 exchange; ER, ecosystem respiration; GEP, gross ecosystem production; TC total carbon; TN, total nitrogen; NH4+, ammonia; NO3-, nitrate; SOC, soil organic carbon; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; MBC, microbial biomass carbon; MBN, microbial biomass nitrogen.

**Supplementary Table 4. Significance tests of treatment effects on microbial diversity index by linear mixed-effects models (LMMs).**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | W | P | D | W\*P | W\*D | P\*D | W\*P\*D |
| Metaxa | Richness | Estimate | -63.11 | 40.83 | -98.44 | -90.33 | 98.78 | -63 | 121.67 |
| *P* | 0.104 | 0.223 | < 0.001\*\*\* | 0.339 | 0.073 | 0.184 | 0.363 |
| Shannon | Estimate | -0.07 | 0.01 | -0.16 | -0.02 | 0.11 | -0.03 | 0.03 |
| *P* | 0.008\*\* | 0.486 | < 0.001\*\*\* | 0.774 | 0.002\*\* | 0.383 | 0.716 |
| Simpson | Estimate | -0.02 | 0 | -0.05 | -0.01 | 0.03 | -0.01 | 0.00 |
| *P* | 0.013\* | 0.87 | < 0.001\*\*\* | 0.594 | 0.011\* | 0.478 | 0.885 |
| 16S rRNA | Richness | Estimate | -127.73 | 195.5 | 5.31 | -837.87 | 281.33 | -166.1 | 954.73 |
| *P* | 0.583 | 0.325 | 0.964 | 0.148 | 0.394 | 0.563 | 0.241 |
| Shannon | Estimate | 0.00 | 0.07 | -0.13 | -0.32 | 0.12 | -0.06 | 0.33 |
| *P* | 0.996 | 0.488 | 0.038\* | 0.283 | 0.485 | 0.693 | 0.43 |
| Simpson | Estimate | 149.08 | -57.92 | -194.94 | -0.63 | -71.68 | 33.49 | -110.05 |
| *P* | 0.045\* | 0.355 | < 0.001\*\*\* | 0.997 | 0.49 | 0.711 | 0.667 |
| ITS | Richness | Estimate | 140.12 | 68.17 | -23.66 | -315.65 | -77.25 | 14 | 122.32 |
| *P* | 0.177 | 0.439 | 0.646 | 0.217 | 0.596 | 0.91 | 0.731 |
| Shannon | Estimate | 1.03 | 0.23 | -0.16 | -1.32 | -0.31 | -0.10 | 1.41 |
| *P* | 0.053 | 0.601 | 0.544 | 0.307 | 0.676 | 0.877 | 0.435 |
| Simpson | Estimate | 44.08 | 9.70 | -5.61 | -61.35 | -28.89 | -16.35 | 87.37 |
| *P* | 0.002\*\* | 0.397 | 0.403 | 0.067 | 0.13 | 0.313 | 0.062 |

Metaxa, Metaxa dataset; 16S rRNA, ampllicon sequencing of bacteria; ITS, amplicon sequencing of ITS2 region. Shannon, Shannon diversity; Simpson, simpson diversity. W, the treatment effects of warming; P, the treatment effects of precipitation alteration; D, the treatment effects of depth; W\*P, the interactive effects of warming and precipitation alteration; W\*D, the interactive effects of warming and soil depth; P\*D, the interactive effects of precipitation alteration and soil depth; W\*P\*D, the interactive effects of warming, precipitation alteration and soil depth.

\*, 0.010 < *P* <0.050; \*\*, 0.001 < *P* < 0.010; \*\*\*, *P* < 0.001.

**Supplementary Tables 5-14 are shown in the Excel file.**