

Response of water balance components to climate change in permanent grassland soil ecosystems

Veronika Forster et al.

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Table S 1: Site-specific cutting dates during 1st January 2015 until 31th December 2018.

| Year | Cutting regimes | Gumpenstein | Rollesbroich | Selhausen |
|------|-----------------|-------------|--------------|-----------|
| 2015 | 1 st | 05-27 | 05-26 | 05-26 |
| | 2 nd | 07-28 | 06-29 | 06-30 |
| | 3 rd | 10-13 | 08-21 | 08-21 |
| | 4 th | - | 10-14 | 10-13 |
| 2016 | 1 st | 05-31 | 06-07 | 06-07 |
| | 2 nd | 07-26 | 07-12 | 07-12 |
| | 3 rd | 10-04 | 08-30 | 08-30 |
| | 4 th | - | 10-18 | 10-18 |
| 2017 | 1 st | 05-30 | 05-15 | 05-16 |
| | 2 nd | 07-25 | 06-21 | 06-21 |
| | 3 rd | 10-03 | 08-29 | 08-29 |
| 2018 | 1 st | 05-29 | 05-07 | 05-08 |
| | 2 nd | 07-24 | 06-26 | 06-26 |
| | 3 rd | 10-02 | 09-11 | 09-11 |

- 10 **Table S 2:** Start of the growing and non-growing season as well as the duration of the growing season during 1 January 2015 until 31 December 2018 at the corresponding site Gumpenstein (GS), Rollesbroich (RO), and Selhausen (SE).

| Year | Start growing season | | | Start non-growing season | | | Duration growing season (days) | | |
|-------------|----------------------|-------|-------|--------------------------|-------|-------|--------------------------------|-----|-----|
| | GS | RO | SE | GS | RO | SE | GS | RO | SE |
| 2015 | 04-14 | 04-12 | 03-13 | 10-23 | 11-09 | 11-18 | 192 | 211 | 250 |
| 2016 | 04-02 | 04-05 | 03-05 | 10-15 | 10-23 | 11-02 | 196 | 201 | 242 |
| 2017 | 03-29 | 03-20 | 03-08 | 10-14 | 10-23 | 11-05 | 199 | 217 | 242 |
| 2018 | 04-11 | 04-07 | 03-14 | 10-27 | 10-25 | 11-08 | 199 | 201 | 239 |

Table S 3: Average amounts of precipitation during growing and non-growing seasons from 1 January 2015 until 31 December 2018. The values were averaged across replicated lysimeter measurements at each test sites Gumpenstein (GS) four treatments C2T0 (CO₂: +300 ppm, two lysimeter), C0T2 (temperature: +3°C, two lysimeter), C0T0 (ambient, one lysimeter), C2T2 (CO₂: +300 ppm, and temperature: +3°C, one lysimeter), Rollesbroich (RO) with C0CL0 (original, six lysimeter) and Selhausen (SE) with C0CL2 (translocated, three lysimeter).

| Year | Season | Precipitation | | | | | |
|---------|-------------|---------------|--------|--------|--------|--------------|-----------|
| | | Gumpenstein | | | | Rollesbroich | Selhausen |
| | | C2T0 | C0T2 | C0T0 | C2T2 | C0CL0 | C0CL2 |
| mm | | | | | | | |
| 2015 | non-growing | 331.0 | 310.6 | 308.3 | 305.4 | 580.9 | 225.3 |
| | growing | 700.3 | 670.4 | 711.0 | 648.8 | 510.9 | 475.1 |
| | annual | 1031.3 | 981.1 | 1019.3 | 954.2 | 1091.8 | 700.4 |
| 2016 | non-growing | 431.4 | 406.2 | 413.7 | 387.7 | 492.2 | 224.1 |
| | growing | 776.0 | 724.2 | 747.0 | 726.9 | 546.7 | 445.3 |
| | annual | 1207.3 | 1130.4 | 1160.7 | 1114.5 | 1038.9 | 669.4 |
| 2017 | non-growing | 458.0 | 459.2 | 463.9 | 464.6 | 506.9 | 199.6 |
| | growing | 844.5 | 829.7 | 842.2 | 826.9 | 569.4 | 402.5 |
| | annual | 1302.5 | 1288.8 | 1306.1 | 1291.4 | 1076.4 | 602.2 |
| 2018 | non-growing | 410.0 | 427.2 | 437.2 | 427.1 | 484.0 | 201.5 |
| | growing | 573.9 | 556.8 | 575.4 | 563.1 | 388.3 | 283.8 |
| | annual | 983.9 | 984.1 | 1012.6 | 990.3 | 872.3 | 485.3 |
| Average | non-growing | 407.6 | 400.8 | 405.8 | 396.2 | 516.0 | 212.6 |
| | growing | 723.7 | 695.3 | 718.9 | 691.4 | 503.8 | 401.7 |
| | annual | 1131.3 | 1096.1 | 1124.7 | 1087.6 | 1019.8 | 614.3 |

Table S 4: Average amounts of non-rainfall water during growing and non-growing seasons from 1 January 2015 until 31 December 2018. The values were averaged across replicated lysimeter measurements at each test sites Gumpenstein (GS) four treatments C2T0 (CO₂: +300 ppm, two lysimeter), C0T2 (temperature: +3°C, two lysimeter), C0T0 (ambient, one lysimeter), C2T2 (CO₂: +300ppm, and temperature: +3°C, one lysimeter), Rollesbroich (RO) with C0CL0 (original, six lysimeter) and Selhausen (SE) with C0CL2 (translocated, three lysimeter).

| Year | Season | Non-rainfall water | | | | | | |
|---------|-------------|--------------------|------|------|------|--------------|--------------------|----|
| | | Gumpenstein | | | | Rollesbroich | Selhausen | |
| | | C2T0 | C0T2 | C0T0 | C2T2 | C0CL0 | C0CL2 | |
| | | mm | | | | | | 25 |
| 2015 | non-growing | 50.8 | 30.8 | 30.4 | 27.7 | 30.1 | 18.3 | |
| | growing | 25.5 | 18.3 | 20.9 | 17.4 | 26.8 | 30.4 | |
| | annual | 76.3 | 49.1 | 51.3 | 45.1 | 56.9 | 48.7 | |
| 2016 | non-growing | 56.8 | 32.8 | 44.0 | 26.0 | 36.9 | 21.5 | |
| | growing | 36.0 | 23.9 | 30.3 | 22.8 | 27.0 | 22.8 | |
| | annual | 92.8 | 56.6 | 74.3 | 48.8 | 63.8 | 44.2 | |
| 2017 | non-growing | 45.5 | 42.4 | 43.9 | 40.6 | 30.5 | 25.3 ³⁰ | |
| | growing | 32.3 | 22.5 | 29.2 | 21.4 | 26.2 | 21.4 | |
| | annual | 77.8 | 65.0 | 73.1 | 62.0 | 56.7 | 46.7 | |
| 2018 | non-growing | 39.1 | 40.7 | 41.4 | 39.6 | 26.2 | 21.5 | |
| | growing | 19.0 | 13.2 | 18.5 | 13.7 | 19.1 | 16.6 | |
| | annual | 58.1 | 53.9 | 59.9 | 53.3 | 45.4 | 38.1 | |
| Average | non-growing | 48.1 | 36.7 | 39.9 | 33.5 | 30.9 | 21.6 | |
| | growing | 28.2 | 19.5 | 24.7 | 18.8 | 24.8 | 22.8 | |
| | annual | 76.3 | 56.1 | 64.6 | 52.3 | 55.7 | 44.4 ³⁵ | |

Table S 5: Non-rainfall water as percentage of precipitation amounts during growing and non-growing seasons from 1 January 2015 until 31 December 2018. The values were averaged across replicated lysimeter measurements at each test sites Gumpenstein (GS) four treatments C2T0 (CO₂: +300 ppm, two lysimeter), C0T2 (temperature: +3°C, two lysimeter), C0T0 (ambient, one lysimeter), C2T2 (CO₂: +300ppm, and temperature: +3°C, one lysimeter), Rollesbroich (RO) with C0CL0 (original, six lysimeter) and Selhausen (SE) with C0CL2 (translocated, three lysimeter).

| Year | Season | Non-rainfall water % of precipitation | | | | | |
|---------|-------------|---------------------------------------|------|------|------|--------------|-----------|
| | | Gumpenstein | | | | Rollesbroich | Selhausen |
| | | C2T0 | C0T2 | C0T0 | C2T2 | C0CL0 | C0CL2 |
| % of P | | | | | | | |
| 2015 | non-growing | 15.3 | 9.9 | 9.9 | 9.1 | 5.2 | 8.1 |
| | growing | 3.6 | 2.7 | 2.9 | 2.7 | 5.2 | 6.4 |
| | annual | 7.4 | 5.0 | 5.0 | 4.7 | 5.2 | 6.9 |
| 2016 | non-growing | 13.2 | 8.1 | 10.6 | 6.7 | 7.5 | 9.6 |
| | growing | 4.6 | 3.3 | 4.1 | 3.1 | 4.9 | 5.1 |
| | annual | 7.7 | 5.0 | 6.4 | 4.4 | 6.1 | 6.6 |
| 2017 | non-growing | 9.9 | 9.2 | 9.5 | 8.7 | 6.0 | 12.7 |
| | growing | 3.8 | 2.7 | 3.5 | 2.6 | 4.6 | 5.3 |
| | annual | 6.0 | 5.0 | 5.6 | 4.8 | 5.3 | 7.8 |
| 2018 | non-growing | 9.5 | 9.5 | 9.5 | 9.3 | 5.4 | 10.7 |
| | growing | 3.3 | 2.4 | 3.2 | 2.4 | 4.9 | 5.8 |
| | annual | 5.9 | 5.5 | 5.9 | 5.4 | 5.2 | 7.9 |
| Average | non-growing | 11.8 | 9.2 | 9.8 | 8.5 | 6.0 | 10.2 |
| | growing | 3.9 | 2.8 | 3.4 | 2.7 | 4.9 | 5.7 |
| | annual | 6.7 | 5.1 | 5.7 | 4.8 | 5.5 | 7.2 |

Table S 6: Average amounts of evapotranspiration during growing and non-growing seasons from 1 January 2015 until 31 December 2018. The values were averaged across replicated lysimeter measurements at each test sites Gumpenstein (GS) four treatments C2T0 (CO₂: +300 ppm, two lysimeter), C0T2 (temperature: +3°C, two lysimeter), C0T0 (ambient, one lysimeter), C2T2 (CO₂: +300ppm, and temperature: +3°C, one lysimeter), Rollesbroich (RO) with C0CL0 (original, six lysimeter) and Selhausen (SE) with C0CL2 (translocated, three lysimeter).

| Year | Season | Evapotranspiration | | | | | |
|---------|-------------|--------------------|-------|-------|-------|--------------|-----------|
| | | Gumpenstein | | | | Rollesbroich | Selhausen |
| | | C2T0 | C0T2 | C0T0 | C2T2 | C0CL0 | C0CL2 |
| mm | | | | | | | |
| 2015 | non-growing | 128.9 | 125.3 | 108.4 | 114.0 | 108.5 | 115.4 |
| | growing | 488.3 | 684.4 | 620.4 | 649.0 | 550.5 | 690.6 |
| | annual | 617.2 | 809.7 | 728.8 | 763.0 | 659.0 | 806.0 |
| 2016 | non-growing | 128.0 | 155.6 | 114.6 | 143.3 | 79.0 | 80.8 |
| | growing | 510.2 | 699.6 | 568.3 | 656.4 | 531.5 | 582.6 |
| | annual | 638.2 | 855.2 | 682.9 | 799.7 | 610.6 | 663.4 |
| 2017 | non-growing | 106.5 | 129.7 | 111.5 | 117.2 | 66.3 | 71.7 |
| | growing | 594.9 | 741.3 | 673.2 | 689.9 | 577.1 | 610.8 |
| | annual | 701.4 | 871.1 | 784.7 | 807.0 | 643.4 | 682.5 |
| 2018 | non-growing | 96.2 | 124.3 | 103.9 | 125.4 | 95.3 | 86.9 |
| | growing | 573.2 | 662.0 | 619.0 | 584.9 | 548.8 | 500.1 |
| | annual | 669.4 | 786.3 | 722.9 | 710.3 | 644.1 | 587.0 |
| Average | non-growing | 114.9 | 133.7 | 109.6 | 125.0 | 87.3 | 88.7 |
| | growing | 541.6 | 696.8 | 620.2 | 645.0 | 552.0 | 596.1 |
| | annual | 656.5 | 830.5 | 729.8 | 770.0 | 639.3 | 684.7 |

Table S 7: Average amounts of water flux across the lysimeter bottom (NetQ) during the growing and non-growing seasons from 1 January 2015 until 31 December 2018. The values were averaged across replicated lysimeter measurements at each test sites Gumpenstein (GS) four treatments C2T0 (CO₂: +300 ppm, two lysimeter), C0T2 (temperature: +3°C, two lysimeter), C0T0 (ambient, one lysimeter), C2T2 (CO₂: +300ppm, and temperature: +3°C, one lysimeter), Rollesbroich (RO) with C0CL0 (original, six lysimeter) and Selhausen (SE) with C0CL2 (translocated, three lysimeter). Positive NetQ values are denoted as seepage and negative NetQ values as upward directed water from deeper soil layers or groundwater table.

| Year | Season | NetQ | | | | | |
|---------|-------------|-------------|-------|-------|-------|--------------|-----------|
| | | Gumpenstein | | | | Rollesbroich | Selhausen |
| | | C2T0 | C0T2 | C0T0 | C2T2 | C0CL0 | C0CL2 |
| | | mm | | | | | |
| 2015 | non-growing | 294.7 | 220.3 | 259.2 | 201.2 | 526.5 | 16.2 |
| | growing | 237.9 | 11.1 | 98.0 | 12.9 | -5.6 | -45.1 |
| | annual | 532.6 | 231.4 | 357.2 | 214.0 | 521.0 | -29.0 |
| 2016 | non-growing | 312.8 | 198.9 | 285.6 | 208.7 | 382.5 | 32.8 |
| | growing | 287.2 | 65.9 | 194.6 | 93.3 | 106.3 | -21.4 |
| | annual | 600.0 | 264.9 | 480.2 | 302.0 | 488.7 | 11.4 |
| 2017 | non-growing | 422.4 | 355.7 | 381.1 | 378.2 | 455.0 | 25.1 |
| | growing | 274.6 | 137.6 | 190.1 | 139.6 | 40.2 | -100.3 |
| | annual | 697.0 | 493.3 | 571.1 | 517.9 | 495.2 | -75.2 |
| 2018 | non-growing | 375.9 | 314.2 | 378.0 | 353.2 | 353.7 | 45.9 |
| | growing | 5.9 | 3.6 | 5.6 | 1.8 | -27.7 | -66.0 |
| | annual | 381.8 | 317.8 | 383.6 | 355.0 | 325.9 | -20.1 |
| Average | non-growing | 351.5 | 272.3 | 326.0 | 285.3 | 429.4 | 30.00 |
| | growing | 201.4 | 54.5 | 122.1 | 61.9 | 28.3 | -58.22 |
| | annual | 552.9 | 326.8 | 448.0 | 347.2 | 457.7 | -28.2 |

Table S 8: Average changes of the soil water storage (ΔS) during the growing and non-growing seasons from 1 January 2015 until 31 December 2018. The values were averaged across replicated lysimeter measurements at each test sites Gumpenstein (GS) four treatments C2T0 (CO₂: +300 ppm, two lysimeter), C0T2 (temperature: +3°C, two lysimeter), C0T0 (ambient, one lysimeter), C2T2 (CO₂: +300ppm, and temperature: +3°C, one lysimeter), Rollesbroich (RO) with C0CL0 (original, six lysimeter) and Selhausen (SE) with C0CL2 (translocated, three lysimeter). Positive values are denoted as a decreasing and positive as an increasing ΔS .

| Year | Season | ΔS | | | | | |
|---------|-------------|-------------|-------|-------|-------|--------------|-----------|
| | | Gumpenstein | | | | Rollesbroich | Selhausen |
| | | C2T0 | C0T2 | C0T0 | C2T2 | C0CL0 | C0CL2 |
| | | mm | | | | | |
| 2015 | non-growing | -41.8 | -4.2 | -28.9 | 17.9 | -24 | 112 |
| | growing | -0.4 | -6.8 | 13.5 | 4.3 | -7.2 | -140 |
| | annual | -42.2 | -10.9 | -15.4 | 22.3 | -31.3 | -27.9 |
| 2016 | non-growing | 47.4 | 84.5 | 57.5 | 61.7 | 67.6 | 132 |
| | growing | 14.6 | -17.4 | 14.4 | 0.0 | -64.1 | -93.1 |
| | annual | 61.9 | 66.9 | 71.9 | 61.6 | 3.4 | 38.8 |
| 2017 | non-growing | -25.4 | 16.2 | 15.2 | 9.8 | 16.1 | 128.1 |
| | growing | 7.3 | -26.7 | 8.1 | 18.8 | -21.7 | -86.6 |
| | annual | -18.1 | -10.6 | 23.4 | 28.5 | -5.5 | 41.6 |
| 2018 | non-growing | -23 | 29.4 | -3.3 | -11.9 | 61.2 | 90.2 |
| | growing | 13.8 | -95.6 | -30.7 | -9.9 | -113.7 | -133.7 |
| | annual | -9.2 | -66.1 | -34 | -21.7 | -52.3 | -43.5 |
| Average | non-growing | -10.7 | 31.5 | 10.1 | 19.4 | 30.2 | 115.5 |
| | growing | 8.9 | -36.5 | 1.3 | 3.3 | -51.7 | -113.38 |
| | annual | -1.8 | -5.1 | 11.5 | 22.7 | -21.5 | 2.2 |

Table S 9: Information on the average dry aboveground biomass (g m⁻²) from 1 January 2015 until 31 December 2018. The values were averaged across replicated lysimeter measurements at each test sites Gumpenstein (GS) four treatments C2T0 (CO₂: +300 ppm, two lysimeter), C0T2 (temperature: +3°C, two lysimeter), C0T0 (ambient, one lysimeter), C2T2 (CO₂: +300ppm, and temperature: +3°C, one lysimeter), Rollesbroich (RO) with C0CL0 (original, six lysimeter) and Selhausen (SE) with C0CL2 (translocated, three lysimeter).

| Year | Cutting regimes | Gumpenstein | | | | Rollesbroich | Selhausen |
|------|-----------------|-------------------|-------|-------|-------|--------------|-----------|
| | | C2T0 | C0T2 | C0T0 | C2T2 | C0CL0 | C0CL2 |
| | | g m ⁻² | | | | | |
| 2015 | 1 st | 287.9 | 345.7 | 406.5 | 299.2 | 316.3 | 555.7 |
| | 2 nd | 183.7 | 197.5 | 356.7 | 183.6 | 121.0 | 112.0 |
| | 3 rd | 115.8 | 123.1 | 188.3 | 150.9 | 260.0 | 111.7 |
| | 4 th | - | - | - | - | 195.2 | 249.0 |
| 2016 | 1 st | 284.1 | 385.2 | 369.2 | 224.3 | 503.5 | 528.7 |
| | 2 nd | 240.5 | 255.5 | 359.3 | 316.1 | 226.8 | 214.3 |
| | 3 rd | 164.2 | 219.2 | 415.5 | 147.6 | 193.0 | 69.7 |
| | 4 th | - | - | - | - | 65.3 | 21.0 |
| 2017 | 1 st | 351.3 | 364.4 | 385.7 | 280.1 | 56.5 | 225.7 |
| | 2 nd | 212.1 | 234.3 | 386.5 | 180.8 | 424.5 | 158.3 |
| | 3 rd | 201.1 | 167.4 | 346.4 | 174.5 | 222.5 | 217.0 |
| 2018 | 1 st | 404.7 | 310.1 | 655.2 | 232.0 | 190.7 | 240.0 |
| | 2 nd | 204.3 | 227.9 | 290.1 | 186.0 | 288.2 | 156.7 |
| | 3 rd | 152.1 | 142.9 | 210.4 | 165.2 | 113.8 | 24.0 |