Supplement of**:**

**Same soil - different climate: crop model inter-comparison on translocated lysimeters**

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SUPPLEMENT

Table S 1: Water balance components determined directly from lysimeter data; mean values of four hydrological years (November 1, 2014 - October 31, 2018) and standard deviation between the three replicate lysimeters at each location for precipitation (P), actual evapotranspiration (ETa), net drainage flux (NetQ: positive values directed in and negative values directed out/drainage), and grain yield (GY) at the locations Dedelow (Dd), Bad Lauchstädt (BL), and Selhausen (Se) for the crops winter wheat, winter barely, winter rye, and oats. Note that in 2015/2016 winter wheat was planted at Dd and winter barley at Se and BL. The soil water storage change was obtained as ΔS = P – ETa + NetQ.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | P | | | ETa | | | NetQ | | | ΔS | | |
|  |  | Dd | BL | Se | Dd | BL | Se | Dd | BL | Se | Dd | BL | Se |
| Year | Crop | -------------------------- mm y-1 ------------------- | | | | | | | | | | | |
| 2014-2015 | Winter wheat | 532  18 | 562  2 | 717  4 | 587  31 | 599  11 | 681  28 | -46  38 | 12  11 | -102  14 | -101   | -25   | -67   |
| 2015-2016 | Winter wheat  /Winter barley | 531  7 | 558  6 | 756  13 | 554  20 | 597  16 | 477  29 | 33  19 | 40  17 | -176  41 | 10   | -6  18 | 103   |
| 2016-2017 | Winter rye | 858  10 | 576  5 | 575  5 | 691  16 | 606  13 | 577  24 | -53  24 | 39  13 | -86  19 | 114   | 2  17 | -88   |
| 2017-2018 | Oat | 443  9 | 359  6 | 549  2 | 473  33 | 448  5 | 520  25 | -118  40 | 5  12 | -51  42 | -148   | -80   | -22   |
|  | *Mean* | *591*  ** | *514*  ** | *649*  *3* | *576*  *14* | *563*  ** | *564*  *24* | *-46*  ** | *22*  *17* | *-104*  *18* | -31  3 | -27   | -18   |

Table S 2: Mean grain yield for different crops over four growing seasons (2014- 2018). Mean grain yield was obtained from lysimeter observations and standard deviation was calculated between the three replicate lysimeters at each location Dedelow (Dd), Bad Lauchstädt (BL), and Selhausen (Se). The crop rotation over the observation period was winter wheat, winter barely, winter rye, and oat. Note that in 2015/2016 winter wheat was planted in Dd and winter barley in Se and BL. The large variability of grain yield for winter barley in Se, is related to one specific lysimeter which showed with 0.87 t ha-1 very low values for grain yield. Grain equivalent units were calculated according to Mönking, Klapp, et al. (2010) based on conversion factor for winter wheat (1.04), winter barley (1), winter rye (1), and oat (0.84).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Grain yield | | | Grain equivalent unit | | |
|  |  | Dd | BL | Se | Dd | BL | Se |
| Year | Crop | ---- t ha-1 ---- | | | ---- t ha-1 GE---- | | |
| 2014-2015 | Winter wheat | 9.4 0.4 | 5.9 0.3 | 4.7 0.8 | 9.8  | 6.1  | 4.9  |
| 2015-2016 | Winter wheat  /winter barley | 7.9 0.3 | 9.4 0.8 | 3.5 2.3 | 8.3  | 9.4  | 3.5  |
| 2016-2017 | Winter rye | 9.2 0.6 | 7.7 1.0 | 4.8 0.4 | 9.2  | 7.7  | 4.8  |
| 2017-2018 | Oat | 3.5 0.5 | 3.5 0.4 | 2.6 0.3 | 2.9  | 3.0  | 2.2  |
|  | *Mean* |  |  |  |  |  |  |

Table S 3: Overview of crop management at the sites Dedelow (Dd), Bad Lauchstädt (BL), and Selhausen (Se).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 2014/2015 | | | 2015/2016 | | | 2016/2017 | | | 2018 | | |
| Dd | BL | Se | Dd | BL | Se | Dd | BL | Se | Dd# | BL§ | Se |
| Crop type | Winter wheat | Winter wheat | Winter wheat | Winter wheat | Winter barely | Winter barely | Winter rye | Winter rye | Winter rye | Oat | Oat | Oat |
| Variety | Julius | Glaucus | Glaucus | Pionier | Antonella | Antonella | SU Cossani | SU Santini | SU Santini | Ivory | Ivory | Ivory |
| Previous crop | Persian clover | Oat | Oat | Winter wheat | Winter wheat | Winter wheat | Winter wheat | Winter barely | Winter barely | Winter rye | Winter rye | Winter rye |
| Sowing data | 17.09.14 | 13.10.14 | 15.10.14 | 02.10.15 | 22.09.15 | 07.10.15 | 06.10.16 | 05.10.16 | 11.10.16 | 11.04.18 | 06.04.18 | 15.03.18 |
| Harvest date | 23.07.15 | 28.07.15 | 21.07.15 | 27.07.16 | 30.06.16 | 08.07.16 | 02.08.17 | 17.07.17 | 21.7.17 | 27.07.18 | 18.07.18 | 24.07.18 |
| Sowing density m² | 260 | 350 | 350 | 280 | 200 | 280 | 200 | 200 | 210 | 350 | 393 | 330 |
| Seed emergence | 25.09.14  (-) | 22.10.14  (-) | - | 13.10.15  (272) | 01.10.15  (-) | -  (195) | 21.10.16  (-) | 18.10.16 | - | 19.04.18  (-) | - | - |
| 1st tillage | 17.09.14 (10 cm) | 30.09.14  (5 cm) | 13.06.14 (10 cm) | 28.08.15  (8-12 cm) | 05.08.15 (2 cm) | 23.09.15 | 05.10.16 (8-12 cm) | 08.07.16  (5 cm) | 11.10.16  (10 cm) | 11.04.18 (8-12 cm) | 20.07.17 (5 cm) | 19.09.17 |
| 2nd tillage | 17.09.14\* | 13.10.14  (5 cm)\* | 14.10.14\* | 02.10.15\* | 01.09.15 (2 cm)\* | 07.10.15 (10 cm)\* | 06.10.16\* | 05.10.2016 (5 cm)\* | 11.10.16\* | 11.04.18\* | 06.04.18\* | 02.02.18 (10 cm) |
| 3rd tillage | - | - | - | - | - | - | - | - | - | - | - | 15.03.18\* |
| Crop residuals remained until | (-) | 05.08.15 | 21.07.15 | 27.07.16 | 08.07.16 | 08.07.16 | 02.08.17 | 20.07.17 | 21.07.17 | (-) | 07.08.18 | 24.07.18 |

# Dd-2017: WR, sowing date (20.10.2017), sowing density (280 plants/m²), seed emergence (27.10.17), tillage (17.10.2017; 8-12 cm), early harvest of WR (11.04.2018).

§ BL-2018/2019: WW, RGT Reform, sowing date (02.10.2018), sowing density (350 plants/m²), seed emergence (17.10.18).

\* Tillage for seedbed preparation & furrow spade

Table S 4: Overview of fertilizer management at the sites Dedelow (Dd), Bad Lauchstädt (BL), and Selhausen (Se).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | Fertilizer | Dedelow | | | Bad Lauchstädt | | | Selhausen | | |
|  |  | Type | Date | Amount | Type | Date | Amount | Type | Date | Amount |
| 2014  /2015 | 1st | KAS  Kieserit | 23.03.15 | 80 kg N ha-1  100 kg ha-1 | KAS | 03.03.15 | 60 kg N ha-1 | KAS | 04.03.15 | 60 kg N ha-1 |
| 2nd | Urea | 22.04.15 | 80 kg N ha-1 | KAS  Kornkali  P | 13.04.15 | 40 kg N ha-1  100 kg K ha-1  20 kg P ha-1 | KAS | 30.04.15 | 30 kg N ha-1 |
| 2015  /2016 | 1st | Liquid mangan | 29.10.15 | 1 l ha-1 | KAS | 10.03.16 | 60 kg N ha-1 | KAS | 10.03.16 | 80 kg N ha-1 |
| 2nd | Urea  Kieserit | 08.03.16 | 60 kg N ha-1  100 kg ha-1 | KAS | 24.03.16 | 40 kg N ha-1 | - | - | - |
| 3rd | KAS | 13.04.14 | 80 kg N ha-1 | - | - | - | - | - | - |
| 4th | KAS | 06.06.16 | 60 kg N ha-1 | - | - | - | - | - | - |
| 2016  /2017 | 1st | KAS  Kieserit | 07.03.17 | 60 kg N ha-1  100 kg ha-1 | Kornkali  P | 18.08.16 | 150 kg K ha-1  50 kg P ha-1 | KAS | 28.03.17 | 78 kg N ha-1 |
| 2nd | KAS | 10.05.17 | 40 kg N ha-1 | KAS | 13.03.17 | 60 kg N ha-1 | - | - | - |
| 3rd | - | - | - | KAS | 06.04.17 | 40 kg N ha-1 | - | - | - |
| 2018 | 1st | KAS  Kieserit  P40 | 20.04.18 | 100 kg N ha-1  100 kg ha-1  22 kg ha-1 | KAS | 20.04.18 | 60 kg N ha-1 | KAS | 15.03.18 | 50 kg N ha-1 |
| 2nd | - | - | - | KAS | 09.05.18 | 40 kg N ha-1 | - | - | - |

Table S 5: Overview of plant growth management at the sites Dedelow (Dd), Bad Lauchstädt (BL), and Selhausen (Se).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | Plant growth regulator | Dedelow | | | Bad Lauchstädt | | | Selhausen | | |
|  |  | Type | Date | Amount | Type | Date | Amount | Type | Date | Amount |
| 2014  /2015 | 1st | CCC  Moddus | 15.04.15 | 1.2 l ha-1  0.1 l ha-1 | Stabilan 720 | 20.03.15 | 1 l ha-1 | Chlormequat Chlorid  Moddus | 24.04.15 | 0.5 l ha-1  0.2 l ha-1 |
| 2nd | - | - | - | Medax Top  Turbo | 11.05.15 | 0.5 l ha-1  0.5 kg ha-1 | - | - | - |
| 2015  /2016 | 1st | CCC  Moddus | 02.05.16 | 0.5 l ha-1  0.15 l ha-1 | Medax Top  Turbo | 20.04.16 | 0.75 l ha-1  0.75 kg ha-1 | Moddus | 14.04.16 | 0.6 l ha-1 |
| 2nd | - | - | - | Medax Top  Turbo | 04.05.16 | 0.75 l ha-1  0.75 kg ha-1 | Cerone660 | 04.05.16 | 0.4 l ha-1 |
| 2016  /2017 | 1st | Medax Top  Turbo | 10.04.17 | 0.8 l ha-1  0.8 kg ha-1 | Medax Top  Turbo | 30.03.17 | 0.5 l ha-1  0.5 kg ha-1 | - | - | - |
| 2nd | - | - | - | Medax Top  Turbo | 03.05.17 | 1 l ha-1  1 kg ha-1 | - | - | - |
| 2018 | 1st | - | - | - | Prodax | 14.05.18 | 0.75 kg ha-1 | - | - | - |

Table S 6: Overview of pesticide management (herbi-, fungi, and insecticides) at the sites Dedelow (Dd), Bad Lauchstädt (BL), and Selhausen (Se).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | Pesticide application | Dedelow | | | Bad Lauchstädt | | | Selhausen | | |
|  |  | Type | Date | Amount | Type | Date | Amount | Type | Date | Amount |
| 2014  /2015 | 1st | Bacara forte  Karate Zeon | 29.10.14 | 0.8 l ha-1  0.075 l ha-1 | Basagran DP | 25.03.15 | 3 l ha-1 | Arelon TOP | 09.04.15 | 2.5 l ha-1 |
| 2nd | Capalo | 15.04.15 | 1.5 l ha-1 | Adexar | 16.04.15 | 4 l ha-1 | Ceralo | 24.04.15 | 1 l ha-1 |
| 3rd | - | - | - | Adexar | 08.05.15 | 2 l ha-1 | Adexar  Diamant | 03.06.15 | 1.5 l ha-1  0.5 l ha-1 |
| 2015  /2016 | 1st | Round up | 16.09.15 | 2.5 l ha-1 | Duanti | 04.04.16 | 4 l ha-1 | Isoproturon  Fenikan  Cytrin | 05.11.15 | 1.5 l ha-1  2 l ha-1  0.1 l ha-1 |
| 2nd | Herold  Pointer SX  Karate Zeon | 29.10.15 | 0.4 l ha-1  20 g ha-1  0.075 l ha-1 | Capalo | 20.04.16 | 1.2 l ha-1 | Lodin | 19.04.16 | 0.7 l Ha -1 |
| 3rd | Capalo | 02.05.15 | 1.6 l ha-1 | Adexar  Diamant | 12.05.16 | 1.1 l ha-1  1.1 l ha-1 | Cirkon | 14.04.16 | 1 l ha-1 |
| 4th | Seguris | 23.05.15 | 1 l ha-1 | - | - | - | Bontima  Credo | 04.05.16 | 1.4 l ha-1  1 l ha-1 |
| 5th | Skyway Xpro  Tepetti | 06.06.16 | 1 l ha-1  140 g ha-1 | - | - | - | - | - | - |
| 2016  /2017 | 1st | Sumimay  Ciral | 03.11.16 | 15 g ha-1  15 g ha-1 | Duanti | 30.03.17 | 3 l ha-1 | Glyphosat | 13.08.16 | 3.5 l ha-1 |
| 2nd | Skyway Xpro | 02.06.17 | 1.25 l ha-1 | Capalo | 03.05.17 | 1.6 l ha-1 | Axial | 13.02.17 | 1 l ha-1 |
| 3rd | Round up | 13.09.17 | - | Adexar | 29.05.17 | 2 l ha-1 | - | - | - |
| 2018 | 1st | Round-up  SSA | 23.03.18 | 3 l ha-1  2 kg ha-1 | Basagran DP  Capalo | 14.05.18 | 3 l ha-1  1.6 l ha-1 | Lodin | 09.05.18 | 0.7 l ha-1 |
| 2nd | Biathlon  Dash | 04.05.18 | 70 g ha-1  1 l ha-1 | - | - | - | - | - | - |

Table S 7: Physical and chemical soil characteristics of soil from Dedelow (Dd) at Dedelow, Bad Lauchstädt, and Selhausen including soil horizon, horizon thickness, bulk density, gravel, sand, silt, clay, calcium carbonate (CaCO3), soil organic carbon (SOC); total nitrogen (Nt), ratio between carbon and nitrogen ration (C/N), and pH in CaCl2. Cursive data are taken from samples of a different soil profile, but same diagnostic horizon.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Soil location |  | Horizon | Upper depth | Lower depth | Bulk density | Gravel | Sand | Silt | Clay | CaCO3 | SOC | Nt | C/N | pHCaCl2 |
| Transfer |  |  | m | m | g/cm³ | wt.-% | % | % | % | % | % | % |  |  |
| Dedelow | Dd\_1 | Ap | 0.00 | 0.30 | 1.43 | 2 | 54 | 31 | 15 | 0 | 0.73 | 0.091 | 8 | 7.0 |
|  |  | Al+Bt | 0.30 | 0.42 | 1.55 | 2 | 51 | 34 | 15 | 0 | 0.42 | 0.063 | 7 | 6.5 |
|  |  | Bt | 0.42 | 0.80 | 1.59 | 4 | 52 | 23 | 25 | 0 | 0.31 | 0.050 | 6 | 7.0 |
|  |  | elCcv | 0.80 | 1.50 | 1.60 | 6 | 59 | 29 | 12 | 12 | 0.06 | 0.012 | 5 | 7.8 |
| Dedelow | Dd\_3 | Ap | 0.00 | 0.35 | 1.60 | 3 | 47 | 38 | 15 | 0 | 0.75 | 0.092 | 8 | 6.4 |
|  |  | Bt | 0.35 | 0.75 | 1.56 | 2 | 50 | 24 | 26 | 0 | 0.47 | 0.06 | 7 | 7.1 |
|  |  | elCcv1 | 0.75 | 1.15 | 1.40 | 5 | 66 | 24 | 11 | 13 | 0.06 | 0.02 | 4 | 7.8 |
|  |  | elCcv2 | 1.15 | 1.5 | 1.62 | 3 | 61 | 27 | 12 | 13 | 0.00 | 0.01 | 0 | 7.8 |
| Dedelow | Dd\_5 | Ap | 0.00 | 0.30 | 1.50 | 3 | 47 | 37 | 16 | 0 | 0.75 | 0.088 | 9 | 6.6 |
|  |  | Bt | 0.30 | 0.65 | 1.52 | 3 | 50 | 24 | 26 | 0 | 0.47 | 0.06 | 7 | 7.1 |
|  |  | elCcv1 | 0.65 | 1.15 | 1.69 | 4 | 66 | 24 | 11 | 13 | 0.06 | 0.02 | 4 | 7.8 |
|  |  | elCcv2 | 1.15 | 1.50 | 1.79 | 3 | 61 | 27 | 12 | 13 | 0.05 | 0.01 | 4 | 7.8 |
| Bad Lauchstädt | BL2\_1 | Ap1 | 0.00 | 0.20 | 1.67 | 2 | 55 | 30 | 15 | <0.1 | 0.83 | 0.100 | 8 | 6.4 |
|  |  | Ap2 | 0.20 | 0.34 | 1.66 | 2 | 54 | 31 | 15 | <0.1 | 0.72 | 0.090 | 8 | 6.4 |
|  |  | Al+Bt | 0.34 | 0.46 | 1.62 | 1 | 44 | 37 | 19 | <0.1 | *0.44* | *0.063* | *7* | *6.5* |
|  |  | Bt | 0.46 | 0.95 | 1.63 | 0 | 53 | 23 | 24 | <0.1 | *0.35* | *0.050* | *7* | *7.0* |
|  |  | elCv1 | 0.95 | 1.30 | 1.75 | 1 | 63 | 22 | 15 | *11.5* | *0.00* | *0.012* | *0* | *7.8* |
|  |  | elCv2 | 1.30 | 1.50 | 1.76 | 6 | 63 | 22 | 15 | *11.5* | *0.00* | *0.012* | *0* | *7.8* |
| Bad Lauchstädt | BL2\_3 | Ap | 0.00 | 0.34 | 1.45 | 3 | 57 | 28 | 15 | <0.1 | 0.83 | 0.100 | 8 | 6.6 |
|  |  | Bt | 0.34 | 0.7 | 1.47 | 2 | *50* | *24* | *26* | *<0.1* | *0.466* | *0.062* | *7* | *7.1* |
|  |  | elCcv | 0.7 | 1.50 | 1.75 | 4 | *66* | *24* | *10* | *13* | *0.059* | *0.015* | *3.9* | *7.8* |
| Bad Lauchstädt | BL2\_5 | Ap | 0.00 | 0.28 | 1.54 | 4 | 51 | 38 | 11 | <0.1 | 0.74 | 0.093 | 8 | 6.4 |
|  |  | Bt1 | 0.28 | 0.60 | 1.57 | 4 | *50* | *37* | *13* | *<0.1* | *0.21* | *0.037* | *6* | *6.5* |
|  |  | Bt2 | 0.60 | 0.90 | 1.63 | 1 | *45* | *32* | *23* | *<0.1* | *0.18* | *0.036* | *5* | *7.1* |
|  |  | elCcv1 | 0.90 | 1.10 | 1.64 | 4 | *48* | *37* | *15* | *10* | *0.12* | *0.021* | *6* | *7.8* |
|  |  | elCcv2 | 1.10 | 1.50 | 1.65 | 4 | *48* | *37* | *15* | *10* | *0.12* | *0.021* | *6* | *7.8* |
| Selhausen | Se4\_1 | Ap | 0.00 | 0.30 | 1.53 | 3 | 56 | 29 | 15 | <0.1 | 0.76 | 0.096 | 8 | 6.7 |
|  |  | Bt | 0.30 | 0.55 | 1.58 | 2 | 50 | 24 | 26 | <0.1 | 0.43 | 0.059 | 7 | 7.2 |
|  |  | elCcv | 0.55 | 1.00 | 1.49 | 5 | 65 | 24 | 11 | 12.8 | 0.12 | 0.015 | 8 | 7.8 |
|  |  | elCv | 1.00 | 1.50 | 1.68 | 3 | 61 | 27 | 12 | 13.0 | 0.06 | 0.014 | 4 | 7.8 |
| Selhausen | Se4\_5 | Ap | 0.00 | 0.37 | 1.61 | 2 | 61 | 27 | 13 | <0.1 | 0.75 | 0.092 | 8 | 6.6 |
|  |  | Bt | 0.37 | 0.75 | 1.44 | 3 | *50* | *24* | *26* | <0.1 | *0.43* | *0.059* | *7* | *7.0* |
|  |  | elCcv | 0.75 | 1.50 | 1.72 | 4 | *61* | *27* | *12* | *11.5* | *0.09* | *0.015* | *6* | *7.8* |
| Selhausen | Se4\_6 | Ap | 0.00 | 0.35 | 1.64 | 3 | 51 | 34 | 15 | <0.1 | 0.68 | 0.081 | 8 | 6.2 |
|  |  | Bt | 0.35 | 0.75 | 1.49 | 2 | *50* | *24* | *26* | <0.1 | *0.43* | *0.059* | *7* | *7.0* |
|  |  | Bvt | 0.75 | 0.84 | 1.58 | 2 | *50* | *24* | *26* | <0.1 | *0.43* | *0.059* | *7* | *7.2* |
|  |  | elCcv | 0.84 | 1.05 | 1.65 | 5 | *65* | *24* | *11* | *12.8* | *0.12* | *0.015* | *8* | *7.8* |
|  |  | elCv | 1.05 | 1.50 | 1.71 | 5 | *61* | *27* | *12* | *13* | *0.06* | *0.014* | *4* | *7.8* |

Table S 8: Parameter for the soil water retention characteristic and unsaturated hydraulic conductivity function of the Mualem-van Genuchten model. Model parameters were obtained with the evaporation method using HYPROP technique. Values for the saturated hydraulic conductivity (Ks) were measured with a permeameter or from fitted HYPROP data (cursive data).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Soil location |  | Horizon | Upper depth | Lower depth | θs | θr | α | n | Ks | nFK | FK | PWP |
| Transfer |  |  | m | m | cm3 cm-3 | cm3 cm-3 | cm-1 | - | cm d-1 | Vol. % | Vol. % | Vol. % |
| Dedelow | Dd\_1 | Ap | 0.00 | 0.30 | 0.419 | 0.019 | 0.0361 | 1.312 | 442.9 | 21.3 | 32.1 | 10.7 |
|  |  | Al+Bt | 0.30 | 0.42 | 0.364 | 0.028 | 0.0255 | 1.311 | 179.7 | 18.7 | 29.6 | 10.9 |
|  |  | Bt | 0.42 | 0.80 | 0.376 | 0.045 | 0.0717 | 1.280 | 278.1 | 15.7 | 27.3 | 11.6 |
|  |  | elCcv | 0.80 | 1.50 | 0.337 | 0.004 | 0.0276 | 1.329 | 112.2 | 18.6 | 26.3 | 7.8 |
| Dedelow | Dd\_3 | Ap | 0.00 | 0.35 | 0.435 | 0.000 | 0.064 | 1.250 | 243.0 | 21.9 | 29.6 | 7.7 |
|  |  | Bt | 0.35 | 0.75 | 0.432 | 0.010 | 0.051 | 1.235 | 71.0 | 22.0 | 31.7 | 9.7 |
|  |  | elCcv1 | 0.75 | 1.15 | *0.377* | *0.000* | *0.017* | *1.252* | 94.3 | *23.3* | *32.4* | *9.2* |
|  |  | elCcv2 | 1.15 | 1.5 | 0.330 | 0.000 | 0.030 | 1.249 | 31.7 | 19.0 | 26.1 | 7.1 |
| Dedelow | Dd\_5 | Ap | 0.00 | 0.30 | 0.381 | 0.000 | 0.0529 | 1.241 | *413.2* | 19.8 | 27.3 | 7.5 |
|  |  | Bt | 0.30 | 0.65 | 0.384 | 0.000 | 0.0546 | 1.225 | *92.9* | 19.6 | 27.9 | 8.4 |
|  |  | elCcv1 | 0.65 | 1.15 | 0.335 | 0.000 | 0.0136 | 1.257 | *7.3* | 21.2 | 29.6 | 8.4 |
|  |  | elCcv2 | 1.15 | 1.50 | 0.294 | 0.000 | 0.0204 | 1.264 | *124.7* | 18.1 | 24.4 | 6.4 |
| Bad Lauchstädt | BL2\_1 | Ap1 | 0.00 | 0.20 | 0.370 | 0.050 | 0.0275 | 1.248 | *65.7* | 18.6 | 30.7 | 12.0 |
|  |  | Ap2 | 0.20 | 0.34 | 0.374 | 0.003 | 0.0608 | 1.200 | *177.0* | 18.1 | 27.7 | 9.7 |
|  |  | Al+Bt | 0.34 | 0.46 | 0.363 | 0.000 | 0.0457 | 1.200 | *144.0* | 18.4 | 28.1 | 9.7 |
|  |  | Bt | 0.46 | 0.95 | 0.399 | 0.068 | 0.0300 | 1.200 | *7.0* | 17.7 | 34.1 | 16.4 |
|  |  | elCv1 | 0.95 | 1.30 | 0.328 | 0.000 | 0.0222 | 1.214 | *21.7* | 18.5 | 27.8 | 9.3 |
|  |  | elCv2 | 1.30 | 1.50 | 0.414 | 0.035 | 0.0090 | 1.200 | *5.0* | 21.3 | 38.8 | 17.5 |
| Bad Lauchstädt | BL2\_3 | Ap | 0.00 | 0.34 | 0.375 | 0.000 | 0.0441 | 1.206 | *101.0* | 19.3 | 29.0 | 9.7 |
|  |  | Bt | 0.34 | 0.7 | 0.374 | 0.000 | 0.0547 | 1.221 | *72.2* | 19.0 | 27.3 | 8.4 |
|  |  | elCcv | 0.7 | 1.50 | 0.355 | 0.000 | 0.0250 | 1.313 | *86.2* | 22.2 | 27.7 | 5.4 |
| Bad Lauchstädt | BL2\_5 | Ap | 0.00 | 0.28 | 0.386 | 0.002 | 0.030 | 1.266 | *46.4* | 22.5 | 30.1 | 7.6 |
|  |  | Bt1 | 0.28 | 0.60 | 0.360 | 0.033 | 0.052 | 1.239 | *29.4* | 17.0 | 26.9 | 9.9 |
|  |  | Bt2 | 0.60 | 0.90 | 0.370 | 0.000 | 0.016 | 1.200 | *7.1* | 20.7 | 32.9 | 12.2 |
|  |  | elCcv1 | 0.90 | 1.10 | 0.350 | 0.000 | 0.009 | 1.273 | *16.8* | 23.1 | 32.0 | 8.9 |
|  |  | elCcv2 | 1.10 | 1.50 | 0.369 | 0.000 | 0.010 | 1.327 | *28.5* | 26.2 | 33.3 | 7.1 |
| Selhausen | Se4\_1 | Ap | 0.00 | 0.30 | 0.426 | 0.009 | 0.0451 | 1.311 | *115.0* | 23.1 | 29.3 | 6.2 |
|  |  | Bt | 0.30 | 0.55 | 0.427 | 0.027 | 0.0409 | 1.253 | *51.8* | 22.0 | 32.4 | 10.4 |
|  |  | elCcv | 0.55 | 1.00 | 0.352 | 0.000 | 0.0219 | 1.348 | *272.0* | 23.0 | *27.5* | *4.6* |
|  |  | elCv | 1.00 | 1.50 | 0.351 | 0.000 | 0.0125 | 1.298 | *64.3* | 23.6 | *30.9* | *7.2* |
| Selhausen | Se4\_5 | Ap | 0.00 | 0.37 | 0.396 | 0.002 | 0.0457 | 1.200 | *85.9* | 20.0 | 30.7 | 10.7 |
|  |  | Bt | 0.37 | 0.75 | 0.374 | 0.011 | 0.0592 | 1.239 | *135.0* | 18.5 | 26.6 | 8.1 |
|  |  | elCcv | 0.75 | 1.50 | 0.345 | 0.000 | 0.0241 | 1.303 | *160.0* | 21.5 | 27.2 | 5.7 |
| Selhausen | Se4\_6 | Ap | 0.00 | 0.35 | 0.351 | 0.000 | 0.0145 | 1.267 | *10.2* | 22.4 | 30.6 | 8.2 |
|  |  | Bt | 0.35 | 0.75 | 0.401 | 0.010 | 0.0618 | 1.230 | *115.0* | 19.8 | 28.1 | 8.3 |
|  |  | Bvt | 0.75 | 0.84 | 0.366 | 0.038 | 0.0213 | 1.357 | *7.3* | 21.6 | 29.5 | 7.9 |
|  |  | elCcv | 0.84 | 1.05 | 0.361 | 0.000 | 0.0310 | 1.275 | *252.0* | 21.2 | 27.7 | 6.5 |
|  |  | elCv | 1.05 | 1.50 | 0.338 | 0.000 | 0.0148 | 1.302 | *71.5* | 22.5 | 29.0 | 6.5 |

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Automatisch generierte Beschreibung

Figure S 1: Comparison of simulated versus measured above ground biomass (AgBio) for lysimeters at the reference site Dedelow (Dd, green symbols; i.e., model calibration) with those transferred to the locations Bad Lauchstädt (BL, red symbols) and Selhausen (Se, blue symbols) (i.e., validation) for winter wheat (squares), winter rye (circles), and oat (triangles). Model abbreviations: AgroC (AC), DailyDayCent (DC), Daisy (DY), Expert-N SPASS (SP), Expert-N SUCROS (SU), Expert-N CERES (CE), Expert-N GECROS (GE), Hermes (HE), MONICA (MO), Theseus (TH), Theseus- Hydrogeosphere (HG; no data), and the Multi-Model-Mean (MM). MnRMSE denotes the average nRMSE over three lysimeters at each site.

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Automatisch generierte Beschreibung

Figure S 2: Comparison of simulated versus measured actual cumulative evaporation (i.e., periods without vegetation) Comparison of simulated with measured values of the cumulative bare soil evaporation (i.e., Ea) for lysimeters at the reference site Dedelow (Dd; green symbols) and lysimeters transferred to Bad Lauchstädt (BL; red symbols) and Selhausen (Se; blue symbols) and for the periods before and after winter wheat (squares), winter rye (circles), and before and after oat (triangles) cropping. Model abbreviations: AgroC (AC), DailyDayCent (DC), Daisy (DY), Expert-N SPASS (SP), Expert-N SUCROS (SU), Expert-N CERES (CE), Expert-N GECROS (GE), Hermes (HE), MONICA (MO), Theseus (TH), Theseus- Hydrogeosphere (HG), and the Multi-Model-Mean (MM). MnRMSE denotes the average nRMSE over three lysimeters at each site, calculated based on daily values.

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Automatisch generierte Beschreibung

Figure S 3: Comparison of simulated versus measured seasonal cumulative net water flux across the 1.5 m depth (NetQ) for lysimeters at the reference site Dedelow (Dd; green symbols) and lysimeters transferred to Bad Lauchstädt (BL; red symbols) and Selhausen (Se; blue symbols) and for the hydrological years, including periods before and after winter wheat (squares), winter rye (circles), and oat (triangles) cropping; negative values of NetQ indicate outflow out of the lysimeter and positive values denote inflow. Model abbreviations: AgroC (AC), DailyDayCent (DC), Daisy (DY), Expert-N SPASS (SP), Expert-N SUCROS (SU), Expert-N CERES (CE), Expert-N GECROS (GE), Hermes (HE), MONICA (MO), Theseus (TH), Theseus- Hydrogeosphere (HG), and the Multi-Model-Mean (MM). MnRMSE denotes the average nRMSE over three lysimeters at each site, calculated based on daily values.

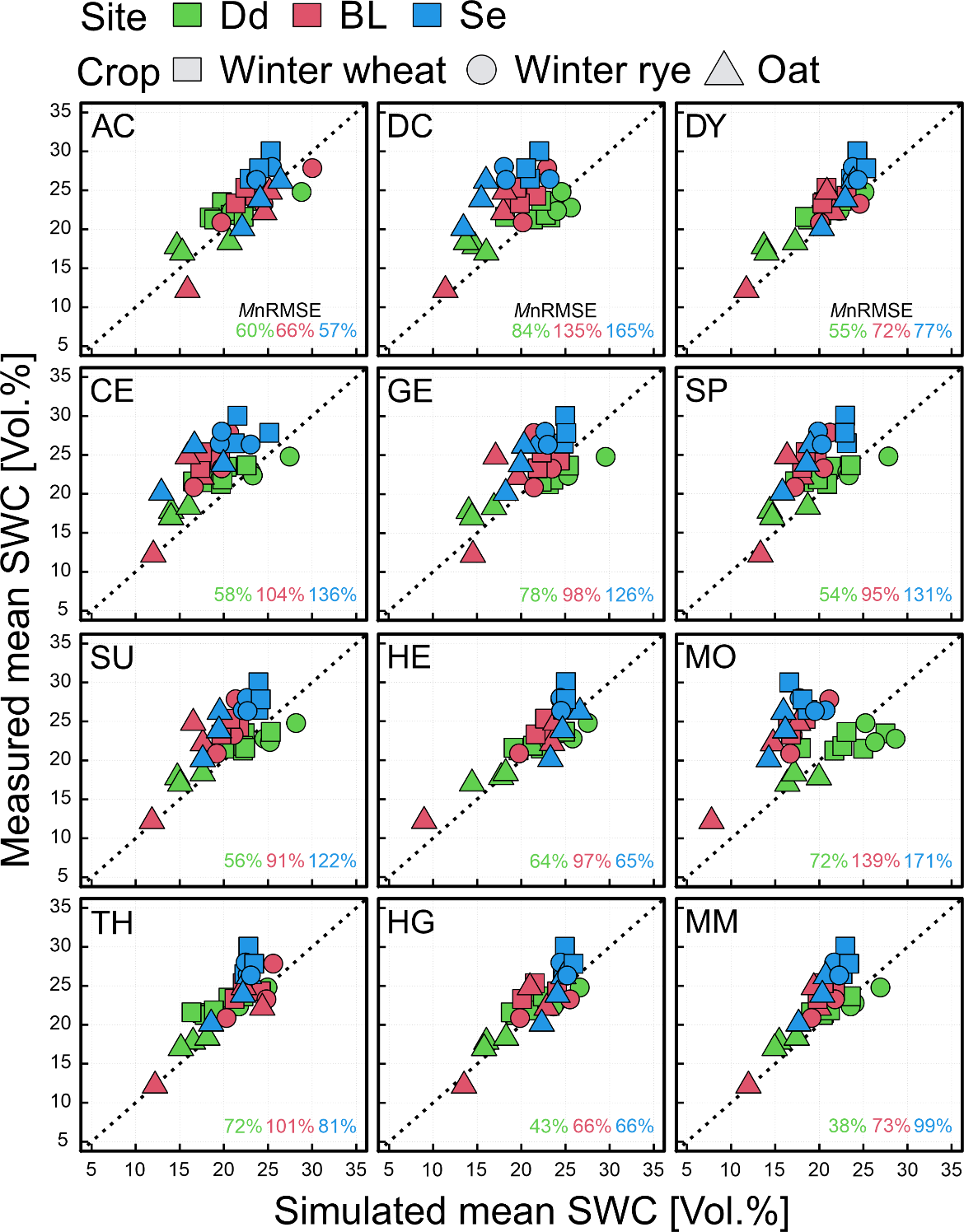


Figure S 4: Comparison of simulated versus measured soil water content (SWC) in 0-60 cm soil depth for lysimeters at the reference site Dedelow (green symbols) and lysimeters transferred to Bad Lauchstädt (red symbols) and Selhausen (blue symbols) and for the cropping seasons of winter wheat (squares), winter rye (circles), and oat (triangles). Model abbreviations: AgroC (AC), DailyDayCent (DC), Daisy (DY), Expert-N SPASS (SP), Expert-N SUCROS (SU), Expert-N CERES (CE), Expert-N GECROS (GE), Hermes (HE), MONICA (MO), Theseus (TH), Theseus- Hydrogeosphere (HG), and the Multi-Model-Mean (MM). MnRMSE denotes the average nRMSE over three lysimeters at each site, calculated based on daily values.

Table S 9: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model AgroC

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat - AgroC** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| AMX | kg CO2/  ha leaf/h | AgBio, directly  GY, directly | potential CO2-  assimilation rate of  a unit leaf area for  light saturation | Triggers AgBio  and GY  production | 25 | 10 | 115 | 81.7 | Global optimizer  (SCE-UA algorithm, Duan, Sorooshian, et al., 1992) |
| SLA | ha leaf/  kg DM | AgBio, directly  GY, directly | specific leaf area  of new leaves | Triggers LAI,  AgBio, GY but  indirectly also  water fluxes  by transpiration  loss | 0.0022 | 0.0002 | 0.005 | 0.00059 |
| p2h | mm | Transpiration, indirectly  SWC´s, directly  AgBio, directly  NetQ, directly | Parameter for  water stress  function | Triggers AgBio  but also water  fluxes and water  contents | -80000 | -100000 | -10000 | -72594 |
| Table 11 multiplyer | day | Transpiration, indirectly  SWC´s, directly  AgBio, directly  NetQ, directly | DS or time against  a kc (actual crop coefficient) | Triggers  transpiration but  also water  contents and  fluxes | 1 | 0.6 | 1.8 | 1.096 |
| Table 6  multiplyer | °C | AgBio, directly  GY, directly  LAI, directly | Temperature sum  against fraction of  dry matter  allocated to the  leaves | Triggers portion-  ing between plant  organs such as  leaves, steam  and seeds | 1 | 0.2 | 1.8 | 0.3408 |
| Table 7  multiplyer | °C | AgBio, directly  GY, directly  LAI, directly | Temperature sum  against fraction of  dry matter  allocated to the  stem | Triggers portion-  ing between plant  organs such as  leaves, steam  and seeds | 1 | 0.6 | 1.8 | 0.8644 |
|  | **Parameter winter rye - AgroC** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short  parameter  description | choice of the  parameter (why) | Default  Value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| AMX | kg CO2/  ha leaf/h | AgBio, directly  GY, directly | potential CO2-  assimilation rate  of a unit leaf  area for light  saturation | Triggers total  biomass  production | 30 | 20 | 115 | 68.2 | Global optimizer  (SCE-UA algorithm, Duan, Sorooshian, et al., 1992) |
| SLA | ha leaf/  kg DM | AgBio, directly  GY, directly | specific leaf area  of new leaves | Triggers LAI,  biomass but  indirectly also  water fluxes  by transpiration  loss | 0.0024 | 0.001 | 0.005 | 0.0016 |
| p2h | mm | Transpiration, indirectly  SWC´s, directly  AgBio, directly  NetQ, directly | Parameter for  water stress  function | Triggers biomass  but also water  fluxes and water contents | -80000 | -100000 | -10000 | -36366 |
| Table 11 multiplyer | day | Transpiration, indirectly  SWC´s, directly  AgBio, directly  NetQ, directly | DS or time against  a kc (actual crop coefficient) | Triggers  transpiration but  also water  contents and  fluxes | 1 | 0.6 | 1.8 | 1.5346 |
| Table 6  multiplyer | °C | AgBio, directly  GY, directly  LAI, directly | Temperature sum  against fraction  of dry matter  allocated to the  leaves | Triggers portion-  ing between plant  organs such as  leaves, steam  and seeds | 1 | 0.4 | 1.8 | 0.056997 |
| Table 7  multiplyer | °C | AgBio, directly  GY, directly  LAI, directly | Temperature sum  against fraction of  dry matter  allocated to the  stem | Triggers portion-  ing between plant  organs such as  leaves, steam  and seeds | 1 | 0.6 | 1.8 | 0.7676 |
|  | **Parameter winter wheat - AgroC** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short  parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| AMX | kg CO2/  ha leaf/h | AgBio, directly  GY, directly | potential CO2-  assimilation rate  of a unit leaf  area for light  saturation | Triggers total  biomass  production | 47 | 30 | 115 | 98.3 | Global optimizer  (SCE-UA algorithm, Duan, Sorooshian, et al., 1992) |
| SLA | ha leaf/  kg DM | AgBio, directly  GY, directly | specific leaf area  of new leaves | Triggers LAI, bio-  mass but indirectly also  water fluxes  by transpiration  loss | 0.0024 | 0.001 | 0.005 | 0.0014 |
| p2h | mm | Transpiration, indirectly  SWC´s, directly  AgBio, directly  NetQ, directly | Parameter for  water stress  function | Triggers biomass  but also water  fluxes and water contents | -80000 | -100000 | -10000 | -91827 |
| Table 11 multiplyer | day | Transpiration, indirectly  SWC´s, directly  AgBio, directly  NetQ, directly | DS or time  against a kc  (actual crop  coefficient) | Triggers  transpiration but  also water  contents and  fluxes | 1 | 0.6 | 1.8 | 1.4831 |
| Table 6  multiplyer | °C | AgBio, directly  GY, directly  LAI, directly | Temperature sum  against fraction of  dry matter  allocated to the  leaves | Triggers portion-  ing between plant  organs such as  leaves, steam  and seeds | 1 | 0.6 | 1.8 | 0.8986 |
| Table 7  multiplyer | °C | AgBio, directly  GY, directly  LAI, directly | Temperature sum  Against fraction of  dry matter  allocated to the  stem | Triggers portion-  ing between plant  organs such as  leaves, steam  and seeds | 1 | 0.6 | 1.8 | 0.8910 |

Table S 10: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model DAYCENT.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat - DAYCENT** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| PRDX(1) | - | GY, directly | Radiation use  efficiency of oat | Controls GY, very  sensitive | 1 | 0 | no max | 0.56 | Stepwise optimisation (manual) |
| FRTC(2) | - | AgBio, directly | Affects allocation  factor | Affects AgBio | 0.1 | 0 | 1 | 0.1 |
| FRTC(4) | - | AgBio, directly | Affects allocation  factor, maximum  increase in the  fraction of C  going to the roots  due to water stress | Affects AgBio  under water  stress | 0.2 | 0 | 1 | 0.15 |
| FRTC(5) | - | AgBio, directly | Affects allocation  Factor: maximum  increase in the  fraction of C  going to the roots  due to nutrient  stress | Affects AgBio  under nutrients  stress | 0.3 | 0 | 1 | 0.3 |
| FWLOSS  (4) | - | ETa, directly | Scaling factor for  potential  evapotranspiration | Affects ETa | 0.8 | 0 | 1 | 0.95 |
|  | **Parameter winter rye - DAYCENT** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| PRDX(1) | - | GY, directly | Radiation use  efficiency of winter rye | Controls GY,  very sensitive | 0.5 | 0 | no max | 0.55 |  |
| FRTC(2) | - | AgBio, directly | Affects allocation  factor | Affects AgBio | 0.1 | 0 | 1 | 0.07 | Stepwise optimisation (manual) |
| FRTC(4) | - | AgBio, directly | Affects allocation  factor, maximum  increase in the  fraction of C  going to the roots  due to water stress | Affects AgBio  under water  stress | 0.1 | 0 | 1 | 0.25 |
| FRTC(5) | - | AgBio, directly | Affects allocation  factor: maximum  increase in the  fraction of C  going to the roots  due to nutrient  stress | Affects AgBio  under nutrients  stress | 0.3 | 0 | 1 | 0.1 |
| FWLOSS  (4) | - | ETa, directly | Scaling factor for  potential  evapotranspiration | Affects ETa | 0.8 | 0 | 1 | 0.95 |
|  | **Parameter winter wheat - DAYCENT** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| PRDX(1) | - | GY, directly | Radiation use efficiency  of winter wheat | Controls GY,  very sensitive | 0.85 | 0 | no max | 0.63 | Stepwise optimisation (manual) |
| FRTC(2) | - | AgBio, directly | Affects allocation  factor | Affects AgBio | 0.1 | 0 | 1 | 0.1 |
| FRTC(4) | - | AgBio, directly | Affects allocation  factor, maximum  increase in the  fraction of C  going to the roots  due to water stress | Affects AgBio  under water  stress | 0.1 | 0 | 1 | 0.15 |
| FRTC(5) | - | AgBio, directly | Affects allocation  factor: maximum  increase in the  fraction of C  going to the roots  due to nutrient  stress | Affects AgBio  Under nutrients  stress | 0.3 | 0 | 1 | 0.1 |
| FWLOSS  (4) | - | ETa, directly | Scaling factor for  potential  evapotranspiration | Affects ETa | 0.8 | 0 | 1 | 0.95 |  |

Table S 11: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model DAISY

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat - DAISY** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| DSrate1 | DS day-1 | BBCH, indirectly# | Development  stage (DS) rate  in the vegetative  phase | Decrease plant development rate | 0.4 | - | - | 0.038 | Manual calibration |
| DSrate2 | DS day-1 | BBCH, indirectly# | Development  stage (DS) rate  in the reproductive  stage | Decrease plant  development rate | 0.025 | - | - | 0.023 |
| LfDR at  DS2 | day-1 | LAI, directly | Death rate of leaf’s  depending on DS  state | Increase LAI by decreasing leaf  death | * 1. at DS 2 | - | - | * 1. at DS 2 |
|  | **Parameter winter rye - DAISY** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| DSrate2 | DS day-1 | BBCH, indirectly# | Development stage (DS)  in the reproductive  stage | Decrease plant  development rate | 0.027 | - | - | 0.05 | Manual calibration |
| LfDR at  DS2 | day-1 | LAI, directly | Death rate of leafs  depending on DS  state | Increase LAI by decreasing leaf  death | 0.01 at DS 0.25  0.1 at DS 2 | - | - | 0.008 at DS 0.25  0.04 at DS 2 |
|  | **Parameter winter wheat – DAISY** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| TempEff | - | AgBio, directly  ETa, directly  LAI, directly | Temperature factor  for assimilate  production | Decreasing crop  growth at low  temperatures | 4˚C: 0.25  8˚C: 0.55  12˚C: 0.95  16˚C: 1.30 | - | - | 4˚C: 0.1  8˚C: 0.38  12˚C: 0.76  16˚C: 1.18 | Manual calibration |
| Dsrate1 | DS day-1 | BBCH, indirectly# | Development stage  (DS) in the  vegetative phase | Decrease plant development rate | 0.032 | - | - | 0.03 |
| DSrate2 | DS day-1 | BBCH, indirectly# | Development stage  (DS) in the  reproductive stage | Decrease plant  development rate | 0.048 | - | - | 0.04 |
| LfDR at  DS2 | day-1 | LAI, directly | Death rate of leaf’s  depending on DS  state | Increase LAI by decreasing leaf  death | DS: LfDR  0.5: 0.015  0.9: 0.025  1.3: 0.05 | - | - | DS: LfDR  0.5: 0.01  0.9: 0.02  1.3: 0.04 |

# The development stage (DS) calculated by Daisy was converted to BBCH stage based on look up table according to Wang and Engel (1998)

\* As the optimization was done manual (trial and error) no min and max range are given.

Table S 12: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model Expert-N CERES

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat - Expert-N CERES** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| G1 | 1/g | LAI, directly  AgBio, directly  GY, directly | Grain number  per g stem weight | Triggers GY | 35 | 30 | 50 | 30.0 | Local optimizer  UCODE  Poeter E. P., Hill M. C.,  et al. 2005 |
| G2 | mg/d | LAI, directly  AgBio, directly  GY, directly | maximal storage  growth rate per  grain | Triggers GY | 2.0 | 2 | 10 | 6.6 |
| SPLW | kg/ha | leaf area growth | Specific leaf  weight | Triggers leaf  area growth | 425 | 200 | 500 | 200 |
| MER | cm/d | root length growth | Maximal extension  growth rate of root | Determines root  length growth | 1.8 | 1 | 3.5 | 1.8 |
|  | **Parameter winter rye – Expert-N CERES** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| G1 | 1/g | LAI, directly  AgBio, directly  GY, directly | Grain number  per g stem weight | TriggersGY | 42.5 | 30 | 50 | 50.0 | Local optimizer  UCODE  Poeter E. P., Hill M. C.,  et al. 2005 |
| G2 | mg/d | LAI, directly  AgBio, directly  GY, directly | maximal storage  growth rate  per grain | Triggers GY | 2.5 | 2 | 10 | 7.1 |
| SPLW | kg/ha | leaf area growth | Specific leaf  weight | Triggers leaf  area growth | 425 | 200 | 500 | 250 |
| MER | cm/d | root length growth | Maximal extension  growth rate of root | Determines root  length growth | 1.8 | 1 | 3.5 | 1.8 |  |
|  | **Parameter winter wheat - Expert-N CERES** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| G1 | 1/g | LAI, directly  AgBio, directly  GY, directly | Grain number  per g stem weight | Triggers GY | 35 | 30 | 50 | 41,4 | Local optimizer  UCODE  Poeter E. P., Hill M. C.,  et al. 2005 |
| G2 | mg/d | LAI, directly  AgBio, directly  GY, directly | maximal storage  growth rate  per grain | Triggers GY | 2.5 | 2 | 10 | 7.1 |
| SPLW | kg/ha | leaf area growth | Specific leaf weight | Triggers leaf  area growth | 425 | 200 | 500 | 255.2 |
| MER | cm/d | root length growth | Maximal extension  growth rate of root | Determines root  length growth | 1.8 | 1 | 3.5 | 1.8 |

Table S 13: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model Expert-N GECROS

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat - Expert-N GECROS** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| MTDV | d | BBCH, indirectly | Minimal thermal  days for vegetative  growth phase | Sensitive  parameter of phenological development | 50 | - | - | 55 | Manual calibration |
| MTDR | d | BBCH | Minimal thermal  days for reproductive growth phase | Sensitive parameter  of phenological development | 40 |  |  | 25 |
|  | **Parameter winter rye - Expert-N GECROS** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short  parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| MTDV | d | BBCH, indirectly | Minimal thermal days for vegetative  growth phase | Sensitive  Parameter of phenological development | 50 | - | - | 85 | Manual calibration |
| MTDR | d | BBCH, indirectly | Minimal thermal  days for  reproductive  growth phase | Sensitive  parameter of phenological development | 40 | - | - | 35 |
|  | **Parameter winter wheat - Expert-N GECROS** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short  parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| MTDV | d | BBCH, indirectly | Minimal thermal  days for vegetative  growth phase | Sensitive  parameter of  phenological development | 50 |  |  | 55 | Manual calibration |
| MTDR | d | BBCH, indirectly | Minimal thermal  days for  reproductive  growth phase | Sensitive  Parameter of  phenological development | 40 |  |  | 57 |

Table S 14: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model Expert-N SPASS and Expert-N SUCROS

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat – Expert-N SPASS and Expert-N SUCROS** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| PDD1 | 1/g | LAI, directly  AgBio, directly  GY, directly | Grain number  per g stem weight | Triggers GY | 35 | 30 | 50 | 30.0 | Local optimizer  UCODE  Poeter E. P., Hill M. C.,  et al. (2005) |
| PDD2 | mg/d | LAI, directly  AgBio, directly  GY, directly | maximal storage  growth rate per  grain | Triggers GY | 2.0 | 2 | 10 | 6.6 |
| SPLW | kg/ha | leaf area growth | Specific leaf weight | Triggers leaf  area growth | 425 | 200 | 500 | 200 |
| MER | cm/d | root length growth | Maximal extension  growth rate of root | Determines root  length growth | 1.8 | 1 | 3.5 | 1.8 |
|  | **Parameter winter rye – Expert-N SPASS and Expert-N SUCROS** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| PDD1 | d | BBCH, indirectly | pre-anthesis  physiological  development days | Triggers  Phenological  development | 38 | 20 | 50 | 42.4 | Local optimizer  UCODE  Poeter E. P., Hill M. C.,  et al. (2005) |
| PDD2 | d | BBCH, indirectly | post-anthesis  physiological  development days | Triggers  Phenological  development | 25 | 20 | 50 | 28.9 |
| SPLW | kg/ha | leaf area growth | specific leaf weight | Triggers leaf  area growth | 425 | 200 | 500 | 255.2 |
| MER | cm/d | root length growth | Maximal extension  growth rate of root | Determines root  Length growth | 1.8 | 1 | 3.5 | 2.5 |
|  | **Parameter winter wheat – Expert-N SPASS and Expert-N SUCROS** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min\* | Range-  max\* | Optimal  value | What software/ method  was used to find the optimal  parameter |
| PDD1 | d | BBCH, indirectly | pre-anthesis  physiological  development days | Triggers  phenological development | 38 | 20 | 50 | 25.4 | Local optimizer  UCODE  Poeter E. P., Hill M. C.,  et al. (2005) |
| PDD2 | d | BBCH, indirectly | post-anthesis  physiological  development days | Triggers  phenological  development | 25 | 20 | 50 | 42.9 |
| SPLW | kg/ha | leaf area growth | specific leaf weight | Triggers  leaf area growth | 425 | 200 | 500 | 255.2 |
| MER | cm/d | root length growth | Maximal extension  growth rate of root | Determines root  length growth | 1.8 | 1 | 3.5 | 2.5 |

Table S 15: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model HERMES

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat - HERMES** | | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter description | choice of the  parameter (why) | Default  value | Range-  min | | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| Tsum2 | °C d | BBCH, indirectly from  heading | Temperature  sum emergence  to double ridge | Adjustment  phenology | 214 | 200 | | 400 | 250 |  |
| Tsum3 | °C d | BBCH, directly from  heading | Temperature  sum double  ridge to ear  emergence | Adjustment  phenology | 250 | 220 | | 400 | 280 |
| Tsum4 | °C d | BBCH, directly from  flowering | Temperature  sum ear  emergence to  flowering | Adjustment  phenology | 100 | 80 | | 200 | 180 | Manual calibration |
| Tsum5 | °C d | BBCH, maturity estimated  indirectly from harvest | Temperature  sum grain  filling | Adjustment  phenology | 350 | 300 | | 550 | 480 |
| SLA1,2 | LAI kg-1 TM | AgBio, indirectly | specific LAI per mass,  phase 1 and 2 | match LAI,  biomass | 0.002 | 0.0012 | | 0.0025 | 0.0015 |
| SLA3 | LAI kg-1 TM | LAI, directly | specific LAI per  mass, phase 3 | match LAI,  biomass | 0.002 | 0.0012 | | 0.0025 | 0.0013 |
| SLAI4 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific LAI per  mass, phase 4 | match LAI,  biomass | 0.002 | 0.0012 | | 0.0025 | 0.0012 |
|  | **Parameter winter rye - HERMES** | | | | | | | | | |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter description | choice of the  parameter (why) | Default  value | | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| Amax | kg CO2 ha-1 h-1 | AgBio, directly | Max. assimilation  rate at light  saturation. | match final AgBio | 45 | | 41 | 52 | 50 | Manual calibration r |
| specific  LAI1 | LAI kg-1 TM | AgBio, indirectly | specific LAI as  area per mass,  phase 1 | match LAI,  AgBio | 0.002 | | 0.0012 | 0.0025 | 0.0015 |
| specific  LAI2 | LAI kg-1 TM | LAI, directly | specific leaf area  per mass, phase 2 | match LAI,  AgBio | 0.002 | | 0.0012 | 0.0025 | 0.0015 |
| specific  LAI3 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 3 | match LAI,  AgBio | 0.002 | | 0.0012 | 0.0025 | 0.0012 |
| specific  LAI6 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 6 | match LAI,  AgBio | 0.002 | | 0.0012 | 0.0025 | 0.0012 |
| Part3 | - | LAI, indirectly  AgBio, indirectly | partitioning of  assimilates at the  end of phase3 | match LAI,  AgBio | 0.3 leaves  0.57 stem | | 0 | 1 | 0.25 leaves,  0.62 stem |
| Part4 | - | LAI, indirectly  AgBio, indirectly | partitioning of  assimilates at the  end of phase4 | match LAI,  AgBio | 1.0 ear | | 0 | 1 | 0.04 stem  0.96 ear |  |
| death  rate5 | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase 5 | match LAI,  AgBio | 0.05 | | ≥0 | ≥0 | 0.05 leaves |  |
| death  rate6 | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase 6 | match LAI,  AgBio | 0.05 | | ≥0 | ≥0 | 0.05 leaves |  |
| kc4 | - | AgBio; indirectly  GY, indirectly | kc-factor at the end  of phase 4 | match crop  variables | 1.15 | | 0.25 | 1.25 | 1.1 |  |
| kc5 | - | AgBio; indirectly  GY, indirectly | kc-factor at the end  of phase 5 | match crop  variables | 0.9 | | 0.25 | 1.25 | 0.8 |  |
| kc6 | - | GY, indirectly | kc-factor at the end  of phase 6 | match crop  variables | 0.4 | | 0.25 | 1.25 | 0.25 |  |
|  | **Parameter winter wheat - HERMES** | | | | | | | | | |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter description | choice of the  parameter (why) | Default  value | | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| Part3 | - | LAI, indirectly  AgBio, indirectly | partitioning  assimilates at end  of phase 3 | match LAI,  a.gr. biomass | 0.33 leaves  0.54 stem | | 0 | 1 | 0.25 leaves  0.62 stem | Manual calibration |

Table S 16: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model MONICA

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter Oat - MONICA** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| Amax | kg CO2 ha-1 h-1 | AgBio | Max. assimilation  rate at light  saturation | match GY  and AgBio | 20 | 30 | 29.8 | 38 | Global optimizer  (SUFI2, Kamali, Stella, et al., 2022) |
| specific LAI2 | LAI kg-1 TM | AgBio, indirectly | specific LAI as area per mass, phase 1 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.00121 |
| specific LAI3 | LAI kg-1 TM | LAI, directly | specific leaf area  per mass, phase 2 | match LAIand AgBio | 0.002 | 0.0013 | 0.00121 | 0.00125 |
| specific LAI4 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 3 | match LAI  and AgBio | 0.002 | 0.0013 | 0.00125 | 0.00111 |
| specific LAI5 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 4 | match LAI,  and AgBio | 0.002 | 0.0013 | 0.00111 | 0.0011 |
| specific LAI6 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 6 | match LAI  and AgBiobiomass | 0.002 | 0.0013 | 0.0011 | 0.00134 |
|  | **Parameter winter rye - MONICA** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| Amax | kg CO2 ha-1 h-1 | AgBio | Max. assimilation  rate at light  saturation | match GY  and AgBio | 25 | 20 | 35 | 50 |  |
| specific LAI2 | LAI kg-1 TM | AgBio, indirectly | specific LAI as area per mass, phase 1 | match LAI  and AgBiobiomass | 0.002 | 0.0013 | 0.0018 | 0.0013 |
| specific LAI3 | LAI kg-1 TM | LAI, directly | specific leaf area  per mass, phase 2 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.00165 |
| specific LAI4 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 3 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.0015 |
| specific LAI5 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 4 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.0014 |
| specific LAI6 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 6 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.0013 | Global optimizer  (SUFI2, Kamali, Stella, et al., 2022) |
| Senescence  Rate6,roor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase6 root | match LAI  and AgBio | 0.01 | 0.01 | 0.035 | 0.05 |
| Senescence  rate6,shoor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase6 leaf | match LAI  and AgBio | 0.035 | 0.01 | 0.035 | 0.049 |
| Senescence  rate6, leaf | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase6 shoot | match LAI  and AgBio | 0.035 | 0.01 | 0.035 | 0.038 |
| Senescence  rate5,roor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase5 root | match LAI  and AgBio | 0.01 | 0.01 | 0.035 | 0.029 |
| Senescence  rate5,shoor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase5 leaf | match LAI  and AgBio | 0.035 | 0.01 | 0.035 | 0.028 |
| Senescence  rate5, leaf | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase5 shoot | match LAI  and AgBio | 0.035 | 0.01 | 0.035 | 0.031 |
| kc4 | - | AgBio, indirectly  GY, indirectly | kc-factor at the end of phase 4 | match crop  variables | 1.15 | 0.7 | 1.35 | 0.88 |
| kc5 | - | AgBio, indirectly  GY, indirectly | kc-factor at the end of phase 5 | match crop  variables | 0.9 | 0.7 | 1.35 | 0.78 |
| kc6 | - | AgBio, indirectly  GY, indirectly | kc-factor at the end of phase 6 | match crop  variables | 0.4 | 0.25 | 0.5 | 0.25 |
|  | **Parameter winter wheat - MONICA** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| Amax | kg CO2 ha-1 h-1 | AgBio | Max. assimilation  rate at light  saturation | match GY and AgBio | 20 | 30 | 29.8 | 38 | Global optimizer  (SUFI2, Kamali, Stella, et al., 2022) |
| specific LAI2 | LAI kg-1 TM | AgBio, indirectly | specific LAI as area per mass, phase 1 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.0017 |
| specific LAI3 | LAI kg-1 TM | LAI, directly | specific leaf area  per mass, phase 2 | match LAIand AgBio | 0.002 | 0.0013 | 0.0018 | 0.00135 |
| specific LAI4 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 3 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.0015 |
| specific LAI5 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 4 | match LAI  and AgBio | 0.002 | 0.0013 | 0.0018 | 0.00135 |
| specific LAI6 | LAI kg-1 TM | LAI, directly  AgBio, indirectly | specific leaf area  per mass, phase 6 | match LAI and AgBio | 0.002 | 0.0013 | 0.0018 | 0.00144 |
| Senescence  Rate6,roor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase6 root | match LAI and AgBio | 0.01 | 0.01 | 0.035 | 0.052 |
| Senescence  rate6,shoor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase6 leaf | match LAI and AgBio | 0.035 | 0.01 | 0.035 | 0.049 |
| Senescence  rate6, leaf | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase6 shoot | match LAI  and AgBio | 0.035 | 0.01 | 0.035 | 0.050 |
| Senescence  rate5,roor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase5 root | match LAI  and AgBio | 0.01 | 0.01 | 0.035 | 0.050 |
| Senescence  rate5,shoor | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase5 leaf | match LAIand AgBio | 0.035 | 0.01 | 0.035 | 0.048 |
| Senescence  rate5, leaf | - | LAI, indirectly  AgBio, indirectly | death rate at the  end of phase5 shoot | match LAIand AgBio | 0.035 | 0.01 | 0.035 | 0.048 |

Table S 17: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model HydroGeoSphere

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter** oat - **HydroGeoSphere** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short  parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| LAI | unitless | modelled | Leaf area  index | defined model  parameter |  |  |  |  | Theseus# |
| RD | m | modelled | Root depth | defined model  parameter |  |  |  |  |
|  | **Parameter winter rye** - **HydroGeoSphere** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short  parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| LAI | unitless | modelled | Leaf area  index | defined model  parameter |  |  |  |  | Theseus# |
| RD | m | modelled | Root depth | defined model  parameter |  |  |  |  |
|  | **Parameter winter wheat** **- HydroGeoSphere** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short  parameter description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| LAI | unitless | modelled | Leaf area  index | defined model  parameter |  |  |  |  | Theseus# |
| RD | m | modelled | Root depth | defined model  parameter |  |  |  |  |

# HydroGeoSphere does not include a growth model for plants, so quantities such as leaf area index, root depth and leaf storage are expected as input parameters. These parameters were calibrated separately with the Theseus model see Table S 18.

Table S 18: Documentation of the calibration process, including parameter choice, parameter value (default, range, and optimal), and software method to identify the optimal parameter for the model Theseus

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Parameter oat - Theseus** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| TSUM1 | oC | BBCH, indirectly | Temperature  sum from  emergence to  anthesis | Sensitive for DS  and crop growth  in terms of AgBio  and GY | § | \* | \* | 800 | Manual calibration |
| TSUM2 | oC | BBCH, indirectly | Temperature  sum from  anthesis to  maturity | Sensitive for DS  and crop growth  in terms of AgBio  and GY | § | \* | \* | 750 |
| SLATB | kg/ha | LAI, directly | specific leaf area  [0.1 ha kg-1] as  function of  crop development  stage DS (0-2) | Sensitive for LAI | § | \* | \* | DS: SLATB  0.00: 0.0030  0.30: 0.0010  0.90: 0.0005  1.45: 0.0005  2.00: 0.0005 |
|  | **Parameter winter rye - Theseus** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| TSUM1 | oC | BBCH, indirectly | Temperature sum  from emergence  to anthesis | Sensitive for DS  and crop growth  in terms of AgBio  and GY | 1700 | \* | \* | 1700 | Manual calibration |
| TSUM2 | oC | BBCH, indirectly | Temperature sum  from anthesis to  maturity | Sensitive for DS  and crop growth  in terms of AgBio  and GY | 600 | \* | \* | 700 |
| SLATB | kg/ha | LAI, directly | specific leaf area  [0.1 ha kg-1] as  function of  crop development  stage DS (0-2) | Sensitive for LAI | DS SLATB  0.0: 0.00212  2.0: 0.00212 | \* | \* | DS SLATB  0.00: 0.00142  2.00: 0.00142 |
|  | **Parameter winter wheat - Theseus** | | | | | | |  |  |
| abbr. | unit | Which target obs.  variable/s were used?  Was this done directly  or indirectly? | Short parameter  description | choice of the  parameter (why) | Default  value | Range-  min | Range-  max | Optimal  value | What software/ method  was used to find the optimal  parameter |
| TSUM1 | oC | BBCH, indirectly | Temperature sum  from emergence  to anthesis | Sensitive for DS  and crop growth  in terms of AgBio  and GY | 1700 | \* | \* | 1700 | Manual calibration |
| TSUM2 | oC | BBCH, indirectly | Temperature sum  from anthesis to  maturity | Sensitive for DS  and crop growth  in terms of AgBio  and GY | 600 | \* | \* | 900 |

# The development stage (DS) calculated by Daisy was converted to BBCH stage based on look up table according to Wang and Engel (1998)

\* As the optimization was done manual (trial and error) no min and max range are given.

§ For oats, there were no parameters available for the application of the growth model. Thus, these parameters were new estimated.

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