

WRF-SPA: supplementary material

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WRF-SPA uses parameters which represent the dominant UK ecosystems (evergreen forest, deciduous forest, mixed
5 forest, managed grassland, grassland, arable cropland and urban). In this supplementary material these parameters are
detailed along with further information as to their origin. The parameters used are broadly consistent with previous SPA
studies, derived from a combination of site specific and data assimilation studies.

Table 1 and Table 2 provide ecosystem specific variables for the parameters that are broadly common to all ecosystems,
while Table 3 details arable crop specific parameters. Table 4 and Table 5 provide descriptions of each parameters used
10 by WRF-SPA.

Table 1: Vegetation parameters required by WRF-SPA for evergreen forest, deciduous forest, mixed forest and managed grassland. All parameters are consistent with those found in previous SPA papers. Evergreen parameters are derived from Williams et al. [2001], O'Neill et al. [2002], Medlyn et al. [2005], Fox et al. [2009] and deciduous forest parameters are derived from Williams et al. [1996], Waring et al. [1998], Fox et al. [2009]. Mixed forest parameters are a modified version of the evergreen parameter set. Managed grassland parameters are derived from Williams et al. [2000], Fox et al. [2009] and modified with information from a managed grassland at Easter Bush and Wullschleger [1993]. '-' indicate that a parameter is not used in the representation of a given land cover type. Two values are given for characteristic leaf dimension for ecosystem covers which include needle leaf vegetation. The first values is needle width and the second is cone diameter.

| Parameter | Unit | Evergreen forest | Deciduous forest | Mixed forest | Managed grassland |
|---|--|----------------------|----------------------|----------------------|----------------------|
| Canopy height | m | 12 | 15 | 12 | 0.3 |
| Average foliar N conc. | gN m ⁻² | 2.25 | 2.1 | 2.25 | 1.0 |
| Minimum leaf water potential | MPa | -1.7 | -2.5 | -2.0 | -1.9 |
| Characteristic leaf dimension | m | 0.002, 0.045 | 0.08 | 0.002, 0.045 | 0.01 |
| Water use efficiency | - | 1.0007 | 1.007 | 1.0007 | 1.007 |
| Leaf capacitance | mmol m ⁻² leaf area MPa ⁻¹ | 4000 | 8000 | 4000 | 2000 |
| Stem Conductivity | mmol m ⁻¹ s ⁻¹ MPa ⁻¹ | 20 | 30 | 20 | 5 |
| Root resistivity | MPa s g mmol ⁻¹ | 20 | 20 | 20 | 10 |
| Ratio of Vcmax to foliar N | μmolC gN ⁻¹ s ⁻¹ | 21.3 | 14 | 17.5 | 43 |
| Ratio of Jmax to foliar N | μmolC gN ⁻¹ s ⁻¹ | 44.4 | 36 | 47 | 85 |
| Leaf carbon per area | gC m ⁻² | 120 | 55 | 114 | 30 |
| Max root depth | m | 1.4 | 1.5 | 1.4 | 0.6 |
| Root depth coefficient | gC m ⁻² | 100 | 100 | 100 | 50 |
| Root radius | m | 0.0005 | 0.0001 | 0.0005 | 0.0001 |
| Emissivity | | 0.96 | 0.96 | 0.96 | 0.96 |
| Foliar PAR reflectance | fraction | 0.11 | 0.11 | 0.11 | 0.16 |
| Foliar PAR transmittance | fraction | 0.16 | 0.16 | 0.16 | 0.16 |
| Foliar NIR reflectance | fraction | 0.16 | 0.43 | 0.16 | 0.43 |
| Foliar NIR transmittance | fraction | 0.26 | 0.26 | 0.26 | 0.26 |
| Soil PAR reflectance | fraction | 0.033 | 0.033 | 0.033 | 0.033 |
| Soil NIR reflectance | fraction | 0.023 | 0.023 | 0.023 | 0.023 |
| Litter decomposition rate | hour ⁻¹ | 4.0x10 ⁻⁶ | 1.5x10 ⁻⁷ | 4.0x10 ⁻⁶ | 4.0x10 ⁻⁶ |
| Soil heterotrophic temperature response coefficient | - | 0.0693 | 0.0693 | 0.0693 | 0.0693 |
| GPP allocation to autotrophic respiration | fraction | 0.47 | 0.32 | 0.47 | 0.47 |
| NPP allocation to foliage | fraction | 0.30 | 0.70 | 0.32 | 0.50 |
| NPP root | fraction | 0.43 | 0.457 | 0.43 | 0.75 |
| Foliage turn over | hour ⁻¹ | 6.4x10 ⁻⁵ | 2.3x10 ⁻³ | 1.0x10 ⁻⁴ | 3.3x10 ⁻⁴ |
| Structural turn over | hour ⁻¹ | 2.5x10 ⁻⁶ | 2.5x10 ⁻⁶ | 2.5x10 ⁻⁶ | 2.5x10 ⁻⁴ |
| Root turn over | hour ⁻¹ | 1.0x10 ⁻⁴ | 2.8x10 ⁻⁴ | 1.4x10 ⁻⁴ | 2.6x10 ⁻⁴ |
| Leaf loss to litter | fraction | - | 0.45 | - | - |
| Litter mineralisation | hour ⁻¹ | 0.001 | 0.001 | 0.001 | 0.001 |
| SOM mineralisation | hour ⁻¹ | 1.0x10 ⁻⁶ | 1.0x10 ⁻⁶ | 1.0x10 ⁻⁶ | 1.0x10 ⁻⁶ |
| Labile turn over | hour ⁻¹ | - | 5.0x10 ⁻³ | - | - |
| Labile cost | hour ⁻¹ | - | 0.129 | - | - |
| Autotrophic turnover | hour ⁻¹ | 0.07 | 0.07 | 0.07 | 0.07 |
| Growing degree days | °C day ⁻¹ | - | 250 | - | - |
| Minimum temperature | °C | - | 5 | - | - |
| Max foliar carbon | gC m ⁻² | - | 270 | - | - |

Table 2: Vegetation parameters required by WRF-SPA for grassland, upland, arable crop and urban. All parameters are consistent with those found in previous SPA papers. Grassland is a modified version of the managed grassland parameterisation and adjusted reflectance similar to JULES [Best et al., 2011]. Upland parameters are derived from Williams et al. [2000], Fox et al. [2009]. Crop parameters for both winter wheat and winter barley are from Sus et al. [2010] with updated reflectance values from Nagler et al. [2003]. Vcmax and Jmax coefficients and leaf carbon per area are for winter wheat / winter barley. Urban cover is assumed to be a low density evergreen forest with a reduced emissivity. Emissivity was assumed to be the same as the value used by the default WRFv3.2 land surface scheme. ‘-’ indicate that a parameter is not used in the representation of a given land cover type.

| Parameter | Unit | Grassland | Upland | Crop | Urban |
|---|--|----------------------|----------------------|-----------------------|----------------------|
| Canopy height | m | 0.5 | 0.3 | 1.2 | 12 |
| Average foliar N conc. | gN m ⁻² | 1.0 | 2.0 | 1.0 | 1.0 |
| Minimum leaf water potential | MPa | -1.9 | -1.5 | -1.9 | -1.7 |
| Characteristic leaf dimension | m | 0.01 | 0.01 | 0.013 | 0.04 |
| Water use efficiency | - | 1.007 | 1.0007 | 1.007 | 1.0007 |
| Leaf capacitance | mmol m ⁻² leaf area MPa ⁻¹ | 2000 | 2000 | 2000 | 4000 |
| Stem Conductivity | mmol m ⁻¹ s ⁻¹ MPa ⁻¹ | 5 | 2 | 5 | 30 |
| Root resistivity | MPa s g mmol ⁻¹ | 10 | 200 | 10 | 20 |
| Ratio of Vcmax to foliar N | μmolC gN ⁻¹ s ⁻¹ | 43 | 20.8 | 64/79 | 17.5 |
| Ratio of Jmax to foliar N | μmolC gN ⁻¹ s ⁻¹ | 83 | 47.9 | 137/157 | 47 |
| Leaf carbon per area | gC m ⁻² | 30 | 120 | 19.5/15 | 45 |
| Max root depth | m | 0.6 | 0.4 | 1.5 | 1.6 |
| Root depth coefficient | gC m ⁻² | 50 | 100 | 50 | 100 |
| Root radius | m | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Emissivity | | 0.96 | 0.96 | 0.96 | 0.88 |
| Foliar PAR reflectance | fraction | 0.10 | 0.10 | 0.11 | 0.20 |
| Foliar PAR transmittance | fraction | 0.16 | 0.16 | 0.16 | 0.16 |
| Foliar NIR reflectance | fraction | 0.58 | 0.58 | 0.38 | 0.50 |
| Foliar NIR transmittance | fraction | 0.26 | 0.26 | 0.26 | 0.26 |
| Soil PAR reflectance | fraction | 0.033 | 0.033 | 0.033 | 0.033 |
| Soil NIR reflectance | fraction | 0.023 | 0.023 | 0.023 | 0.023 |
| Litter decomposition rate | hour ⁻¹ | 1.5x10 ⁻⁷ | 1.0x10 ⁻⁷ | 2.8x10 ⁻⁵ | 4.0x10 ⁻⁴ |
| Soil heterotrophic temperature response | | 0.0693 | 0.0693 | 0.0693 | 0.0693 |
| GPP allocation to autotrophic respiration | fraction | 0.46 | 0.50 | 0.44 | 0.47 |
| NPP allocation to foliage | fraction | 0.60 | 0.70 | varied by DS | 0.32 |
| NPP root | fraction | 0.60 | 0.70 | varied by DS | 0.43 |
| Foliage turn over | hour ⁻¹ | 2.3x10 ⁻³ | 2.0x10 ⁻⁴ | varied by DS | 1.5x10 ⁻⁴ |
| Structural turn over | hour ⁻¹ | 2.3x10 ⁻³ | 2.0x10 ⁻⁵ | varied by DS | 2.5x10 ⁻⁶ |
| Root turn over | hour ⁻¹ | 2.8x10 ⁻⁴ | 2.0x10 ⁻⁵ | varied by DS | 2.8x10 ⁻⁴ |
| Leaf loss to litter | fraction | - | - | - | - |
| Litter mineralisation | hour ⁻¹ | 0.001 | 0.0001 | 2.8x ⁻⁴ | 0.001 |
| SOM mineralisation | hour ⁻¹ | 1.0x10 ⁻⁶ | 1.0x10 ⁻⁶ | 2.28x10 ⁻⁶ | 1.0x10 ⁻⁶ |
| Labile turn over | hour ⁻¹ | - | - | 6.25x10 ⁻³ | - |
| Labile cost | hour ⁻¹ | - | - | 0.21 | - |
| Autotrophic turnover | hour ⁻¹ | 0.07 | 0.07 | 0.07 | 0.07 |
| Growing degree days | °C day ⁻¹ | - | - | 125 | - |
| Minimum temperature | °C | - | - | - | - |
| Max foliar carbon | gC m ⁻² | - | - | - | - |

Table 3: Winter arable crop specific parameters required by WRF-SPA, the parameters are common to both winter wheat and winter barley. All other parameters are consistent with those described in Sus et al. [2010], except litter reflectance values which are taken from Nagler et al. [2003].

| Parameter | Unit | Value |
|---------------------------------------|--------------------------------|---------|
| Post harvest leaf residue | fraction | 0.1 |
| Post harvest stem residue | fraction | 0.1 |
| DR coefficient pre-flowering | day ⁻¹ | 0.04 |
| DR coefficient post-flowering | day ⁻¹ | 0.035 |
| Minimum development temperature | °C | 0 |
| Optimum development temperature | °C | 24 |
| Maximum development temperature | °C | 35 |
| Minimum temperature for vernalization | °C | -1.3 |
| Optimum temperature for vernalization | °C | 4.9 |
| Maximum temperature for vernalization | °C | 15.7 |
| Vernalization days | days | 22.5 |
| Self shading LAI | m ² m ⁻² | 4 |
| Maximum rate of self shading turnover | hour ⁻¹ | 0.00125 |
| Critical photoperiod | hours | 8.25 |
| Photoperiod sensitivity | - | 0.25 |
| Litter PAR reflectance | fraction | 0.30 |
| Litter NIR reflectance | fraction | 0.50 |

Table 4: Description of vegetation parameters required by WRF-SPA.

| Parameter | Unit | Description |
|---|--|--|
| Canopy height | m | Height of canopy top |
| Average Foliar N conc. | gN m ⁻² | Average foliar nitrogen concentration |
| Minimum leaf water potential | MPa | Minimum leaf water potential tolerated |
| Characteristic leaf dimension | m | Leaf diameter and / or cone diameter |
| Water use efficiency | - | Regulates maximum possible stomatal conductance |
| Leaf capacitance | mmol m ⁻² leaf area MPa ⁻¹ | Leaf water storage capacity |
| Stem Conductivity | mmol m ⁻¹ s ⁻¹ MPa ⁻¹ | Plant stem conductivity for water |
| Root resistivity | MPa s g mmol ⁻¹ | Root hydraulic resistance to water |
| Max root depth | m | Maximum soil depth that roots can reach |
| Root depth coefficient | gC m ⁻² | Root mass required to reach 50 % of max depth |
| Root radius | m | Average root radius |
| Foliar PAR reflectance | fraction | Leaf photosynthetically active radiation reflectance |
| PAR transmittance | fraction | Leaf photosynthetically active radiation transmittance between canopy layers |
| Foliar NIR reflectance | fraction | Leaf near infra-red radiation reflectance |
| NIR transmittance | fraction | Leaf near infra-red radiation transmittance between canopy layers |
| Soil PAR reflectance | fraction | Soil surface photosynthetically active radiation reflectance |
| Soil NIR reflectance | fraction | Soil surface near infra-red radiation reflectance |
| Litter decomposition rate | hour ⁻¹ | Litter decomposition rate constant |
| Soil heterotrophic temperature response | | Adjusts heterotrophic respiration based on mean daily temperature (Q10 = 2.0) |
| GPP allocation to autotrophic respiration | fraction | Fraction of gross primary productivity allocated for respiration for plant maintenance |
| NPP allocation to foliage | fraction | Net primary productivity allocated to foliage |
| NPP root | fraction | Net primary productivity allocated to roots after allocation to foliage |
| Foliage turn over | hour ⁻¹ | Hourly turnover rate of foliage carbon |
| Structural turn over | hour ⁻¹ | Hourly turnover rate for structural / wood carbon |
| Root turn over | hour ⁻¹ | Hourly turnover rate for fine root carbon |
| Leaf loss to litter | fraction | Fraction of foliar turn over that goes to litter, remainder to labile |
| Litter mineralisation | hour ⁻¹ | Hourly mineralisation rate for soil organic carbon |
| SOM mineralisation | hour ⁻¹ | Hourly mineralisation rate for soil organic carbon |
| Labile turn over | hour ⁻¹ | Hourly turnover rate for labile carbon |
| Labile cost | hour ⁻¹ | Fraction of labile carbon allocated to foliage lost through respiration |
| Autotrophic turnover | hour ⁻¹ | Hourly turnover rate for carbon allocated to plant maintenance |
| Growing degree days | °C day ⁻¹ | Threshold of accumulated daily mean air temperatures for development |
| Minimum temperature | °C | Temperature threshold below which foliage turnover begins |
| Max foliar carbon | gC m ⁻² | Maximum total foliar carbon allowed |

Table 5: Description for parameters specific to arable crops.

| Parameter | Unit | Description |
|---------------------------------------|--------------------------------|---|
| Post harvest leaf residue | fraction | Fraction of foliage carbon left as surface litter after harvest |
| Post harvest stem residue | fraction | Fraction of stem carbon left as surface litter after harvest |
| DR coefficient pre-flowering | day ⁻¹ | Development rate constant before flowering |
| DR coefficient post-flowering | day ⁻¹ | Development rate constant after flowering |
| Minimum development temperature | °C | Minimum temperature at which development occurs |
| Optimum development temperature | °C | Optimum temperature at which development occurs |
| Maximum development temperature | °C | Maximum temperature at which development occurs |
| Vernalization days | days | Number of days when plant is 50 % vernalized |
| Self shading LAI | m ² m ⁻² | Leaf area index at which foliage turnover occurs due to self shading |
| Maximum rate of self shading turnover | hour ⁻¹ | maximum rate of foliage turnover due to self shading |
| Critical photoperiod | hours | Minimum photoperiod required for development |
| Litter PAR reflectance | fraction | Post harvest litter reflectance for photosynthetically active radiation |
| Litter NIR reflectance | fraction | Post harvest litter reflectance for near infra-red radiation |

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