**Supporting Information**

**Table S.1 Dynamic CO2 responses in APSIM v7.5-7.8 plant models**

**Table S.2 Variety in magnitude of CO2 responses in APSIM v7.5-7.8 plant models**

**Table S.3 Validation status of APSIM v7.5-7.8 plant models**

**Table S.4 Climate change impact assessments with APSIM plant models**

**Supporting information references**

**Table S.1 Dynamic CO2 responses in APSIM v7.5-7.8 plant models** a

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Code base** | **Plant b** | **Parameters with potential dynamic response c** | **Validation status of CO2 response** | **Functionality at elevated [CO2] without further parameterization** |
| **Models with dynamic CO2 response and ability to read [CO2] input** |
| *plant1* | Barley | **RUE, TE, CNC** | - | √ |
|  | Butterfly Pea | **RUE**, TE, CNC | - | - |
|  | Canola | **RUE**, TE, CNC | - | - |
|  | Centro | **RUE**, TE, CNC | - | - |
|  | Chickpea | **RUE**, TE, CNC | - | - |
|  | Cowpea | **RUE**, TE, CNC | - | - |
|  | Fababean | **RUE**, TE, CNC | - | - |
|  | Fieldpea | **RUE**, TE, CNC | - | - |
|  | Horsegram | **RUE**, TE, CNC | - | - |
|  | Lablab | **RUE**, TE, CNC | - | - |
|  | Lucerne | **RUE**, TE, CNC | - | - |
|  | Lupin | **RUE**, TE, CNC | - | - |
|  | Mucuna | **RUE**, TE, CNC | - | - |
|  | Mungbean | **RUE**, TE, CNC | - | - |
|  | Navybean | **RUE**, TE, CNC | - | - |
|  | Oats | **RUE, TE, CNC** | - | √ |
|  | Peanut | **RUE**, TE, CNC | - | - |
|  | Pigeonpea | **RUE**, TE, CNC | - | - |
|  | Potato | **RUE**, TE, CNC | - | - |
|  | Soybean | **RUE**, TE, CNC | - | - |
|  | Stylo | **RUE**, TE, CNC | - | - |
|  | Sweet Corn | **RUE, TE, CNC** | - | √ |
|  | Sweet Sorghum | **RUE, TE, CNC** | - | √ |
|  | Weed | **RUE**, TE, CNC | - | - |
|  | Wheat | **RUE, TE, CNC** | √ | √ |
| *cropmod* | Maize | TE, CNC | - | - |
|  | Sunflower | **RUE**, TE, CNC | - | √ |
| *plant2* | French Bean | **RUE** | - | √ |
|  | Oil Palm | - | - | √ |
| *Sorghum* | Sorghum | **RUE**, TE | - | - |
| *Sugar* | Sugarcane | **RUE, TE** | - | √ |
| *AgPasture* | Pasture | ***Amax*, PND**, *g*c | √ | √ |
| *APSIM-Oryza* | Rice | ***Amax*, EFF** | √ | √ |
| *OZCOT* | Cotton | ***Amax*** | - | √ |
|  |  |  |  |  |
| **Models without dynamic CO2 response and ability to read [CO2] input** |
| *growth* | Bambatsi | - | - | √ |
|  | Eucalyptus Grandis | - | - | √ |
| *GRASP* | Pasture | - | - | √ |
| *Millet* | Millet | - | - | √ |

**a** APSIM v7.5-7.8 is publically available from the APSIM website at the time of writing (http://www.apsim.info/Products/Downloads.aspx)
b References to individual plant models are given in Table 1 of Holzworth *et al.* (2014). Plant model documentation is available from the APSIM website (https://www.apsim.info/Documentation/Model,CropandSoil/CropModuleDocumentation.aspx)
c Parameters and abbreviations are described in Table S.2; responses that are activated in APSIM 7.7 without further need for parameterization are bold

**Table S.2 Variety in magnitude of CO2 responses in APSIM v7.5-7.8 plant models**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Plant models including the response a** | **Response direction and magnitude** For [CO2] 350 🡪 700 ppm(at 20°C) | **References** |
| **Photosynthesis/production responses** |  |
| radiation use efficiency (RUE, g MJ-1) | *plant1*-based**b**, FrenchBean, Sorghum, Sunflower, Sugar | ↑: +21% and + 5% for C3 and C4, respectively | Reyenga *et al.* (1999), Howden *et al.* (1999) |
| leaf light-saturated photosynthesis rate (*Amax*, g CO2 m-2 s-1) | AgPasture, Rice, OZCOT | ↑: +23-50% and +18% for C3 and C4, respectively | Cullen *et al.* (2009), Hearn (1994), Keulen & Seligman (1987), Bouman & van Laar (2006) |
| leaf light use efficiency (*E*, g CO2 m-2 s-1/J m-2 s-1) | Rice | ↑: +26% | Bouman *et al.* (2001) |
| **Stomata/transpiration responses** |  |
| transpiration efficiency (TE, g mm-1) | Barley, Oats, Sugar, SweetCorn, SweetSorghum, Wheat(other *plant 1*-based, Maize, Sorghum) [Sunflower] | ↑: +28-37% | Reyenga *et al.* (1999), Park *et al.* (2008), Webster *et al.* (2009) |
| stomatal conductance (gc, mmol m⁻² s⁻¹) | [AgPasture] | ↓: -42% | Cullen *et al.* (2009) |
| **N dynamics responses** |  |
| critical shoot nitrogen concentration, i.e. at maximum shoot yield (CNC, g kg-1) | Barley, Oats, SweetCorn, SweetSorghum, Wheat(other *plant 1*-based, Maize, Sorghum) | ↓: -7%  | Reyenga *et al.* (1999) |
| plant nitrogen demand (PND, kg ha-1) | AgPasture | ↓: -20% | Cullen *et al.* (2009) |

a (Models) between round brackets require parameterization before simulation at elevated [CO2] is possible; in [models] with square brackets, simulation at elevated [CO2] is possible but the response is not included by default unless users specify parameter constants (for Sunflower) or change code (for AgPasture)
b for a complete list of *plant1*-based models see Table S.1

**Table S.3 Validation status of APSIM v7.5-7.8 plant models**

|  |  |  |  |
| --- | --- | --- | --- |
| **Plant model** a | **FACE experiment** | **Validation** b | **References** |
| Wheat (I WHEAT), including responses of RUE, TE, CNC and SLA | Maricopa (AZ), US; 550 ppm; wheat; limited and severe water stress; 1992-93 and 1993-94 | validation of model responses: satisfactory simulation of RUE/TE responses to elevated [CO2] (+14.3/21.3% vs. observations +16.5/25.7%); CNC response not validated due to lack of observations | Reyenga *et al.* (1999) |
| Wheat (APSIM-Nwheat version 1.55s), including responses of RUE and TE | Maricopa (AZ), US;550 ppm; wheat; limited and severe water stress, with and without N stress; 1992-93, 1993-94, 1995-96; 1996-97 | validation of model performance: satisfactory simulation of LAI, biomass and grain yield dynamics at ambient and elevated [CO2] (RMSE = 0.9 m m-2, 1.6 and 1.1 t ha-1, respectively) with some biomass overestimation principally at elevated [CO2] and generally good simulation of yield responses to water and N supply | Asseng *et al.* (2004) |
| Wheat (APSIM 7.4), including responses of RUE, TE and CNC | Horsham, southern Australia; 550 ppm; wheat; rainfed and irrigated, N and temperature (by sowing date) treatments; 2007-09 | validation of model performance: satisfactory simulation of relative increase in LAI and biomass at anthesis, and final yield at elevated [CO2] (RMSE = 0.7 m m-2, 1.5 and 1.3 t ha-1; r² = 0.24, 0.56 and 0.20, respectively), but no clear response of water use and water use efficiency (RMSE = 31.4 mm, and 9.7 kg ha-1 mm-1; r² = 0.57 and 0.45, respectively) | O'Leary *et al.* (2015) |
| AgPasture (APSIM 7.7) including responses of Amax, PND and gs)  | North Island of New Zealand; 475 ppm; grazed pasture; 11-year long | validation of model performance: satisfactory simulation of seasonal and inter-annual production variation at elevated [CO2] (r³ = 0.62) but serious overestimation of mean annual plant production response (18.5% vs. 13.1%) | Li *et al.* (2014) |
| Rice (ORYZA2000 including response of *Amax* and *E*) | Shizukuishi, northern Japan; 595-663 ppm; rice; low, medium and high N; 1998–2000 | validation of model performance: large overestimation of LAI at anthesis and minor overestimation of final biomass and yield at elevated [CO2] (RMSE = 3.3 m m-2, 1.7 and 1.3 t ha-1 , respectively) with poor reproduction of CO2 response to N levels (N content at maturity: RMSE = 16.9 kg ha-1) | Bannayan *et al.* (2005) |
| Other *plant1* models, Maize, Sorghum, OZCOT | FACE data available for barley, potato, maize, sorghum and cotton  | None to date | e.g. Mauney *et al.* (1994), Miglietta *et al*. (1998), Conley *et al.* (2001), Magliulo *et al.* (2003), Leakey *et al.* (2004), Manderscheid *et al*. (2009, 2014) |

a Parameters and abbreviations are described in Table S.2
b r² is correlation coefficient and RMSE root means square error of observed vs. modelled responses to elevated [CO2]; for more details on validation results, see original references

**Table S.4 Climate change impact assessments with APSIM plant models**

|  |  |  |
| --- | --- | --- |
| **Plant model** | **Climate change assessments** | **References** a |
| Wheat | Worldwide applications | e.g. Luo *et al.* (2003, 2005, 2007), Foster *et al.* (2007), Crimp *et al.* (2008) , Wang *et al.* (2011), Yang *et al.* (2013), Sprigg *et al.* (2014), Ghahramani *et al.* (2015) |
| *Plant1*  | Application in New Zealand for crop rotation with wheat, barley and pea  | Teixeira *et al.* (2012a, 2012b) |
| Maize | Worldwide applications with different model versions (with/out TE response)  | Dimes *et al.* (2009), Tachi-Obeng *et al.* (2010), Fosu-Mensah (2013), Lobell *et al.* (2013), Bassu *et al.* (2014), Harrison *et al.* (2014), Makuvaro (2014) |
| Sorghum | Applications in West Africa, Northeast Australia and Ghana  | McCarthy & Vlek (2012), Sultan *et al.* (2014), Lobell *et al.* (2015) |
| Sugar | Applications for nitrogen losses in Australia | Webster *et al.* (2009), Biggs *et al.* (2013) |
| AgPasture | Applications in New Zealand with different parameterization of responses to [CO2] | Lieffering *et al.* (2012) , Newton *et al.* (2014) |
| Rice | Applications of the original ORYZA2000 and the APSIM Rice (APSIM-Oryza) model in Asia | e.g. Das *et al.* (2007), Krishnan *et al.* (2007), Liu *et al.* (2013) |
| OZCOT | Applications in China and Australia | Yang *et al.* (2014), Williams *et al.* (2015) |

*a For details on model versions, see original references*

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