Instructions for AgMIP Wheat Phase 4

Global wheat yield potential assessment

9 March 2020

Deadline: 30 April 2020

Update #2 – 22 May 2020

The following modifications were applied:

- New values of soil lower limit and drained upper limit are provide for site #32 (Valdivia, Chile). See AgMIPWheat4_soils_34_Global_sites_update2.xlsx on the shared Google Drive folder.
- In the soil description the *Initial water content* is given in mm and not in $cm^3 cm^{-3}$. The unit has been correct AgMIPWheat4_soils_34_Global_sites_update2.xlsx.

Update #1 – 25 March 2020

The following modifications were applied:

- Anthesis and maturity dates were corrected for site # 2 were corrected to be consisted with the phenology provided with the CIMMYT in Phase 4.
- Anthesis and maturity dates for site # 26 were advanced (based on USDA data) to reduce the risk of low temperature during the grain filling period.
- Anthesis and maturity dates for site # 15 were corrected.
- The code for RCP 4.5 is not G and not K as previously indicated in Table 1.
- Site # 3 is rainfed and not irrigated, while sites #19 and #34 are irrigated and not rainfed (see Table 3).
- New soil profile descriptions are provided for sites # 1, 2, 5, 9, 10, 14, 15, 16, 17, 18 (see AgMIPWheat4_soils_34_Global_sites_update1.xlsx).

Description

Here, we will assess global wheat yield potential under baseline climate and two climate change scenarios (RCP4.5 and RCP8.5) from five GCMs for a period centered in the 2050s at 34 global sites The **sites** are the 30 high rainfall / irrigated sites we have simulated in Phase 2 and Phase 3 (sites no. 1 to 30), plus the four experimental sites we have simulated in Phase 4 (sites no. 31 to 34). The **weather data** for the baseline and RCP8.5 for sites no. 1 to 30 are those used in Phase 2 and Phase 3, while new data are supplied for RCP4.5 and sites 31-34 for both RCPs. We use locally adapted **cultivars** at each locations. For locations no. 1 to 30, the cultivars (and average anthesis and physiological maturity dates are in

Table 3) are those we used in Phase 2 and 3. For locations no. 31 to 34, the cultivars are those we used in Phase 4 for the experimental data. The **combination of five traits** we have simulated so far in Phase 4 are to be simulated for 30 years for the baseline and all five GCMs and two RCPs for all sites. In total, **22 treatments are to be simulated for 34 locations and 30 years** (Table 1). All simulations should be executed with **unlimited N supply**. At the irrigated sites (Table 3), simulation should be executed with automatic irrigation or by applying enough irrigation to avoid any water stress. No irrigation should be applied in the rainfed sites.

Table 1. Layout of the 22 treatments to be simulated in Step 1.

Treatment	Baseline or RCP		GCM		CO_2	Trait	
#	Code	Name	Code	Name	(ppm)	Code	Name
1	0	Baseline	-	-	360	N	Normal
2	0	Baseline	-	-	360	T	High-yield
3	G	RCP4.5	K	HadGEM2-ES	499	N	Normal
4	G	RCP4.5	O	MIROC5	499	N	Normal
5	G	RCP4.5	R	MPI-ESM-MR	499	N	Normal
6	G	RCP4.5	1	GFDL-CM3	499	N	Normal
7	G	RCP4.5	2	GISS-E2_R	499	N	Normal
8	G	RCP4.5	K	HadGEM2-ES	499	T	High-yield
9	G	RCP4.5	O	MIROC5	499	T	High-yield
10	G	RCP4.5	R	MPI-ESM-MR	499	T	High-yield
11	G	RCP4.5	1	GFDL-CM3	499	T	High-yield
12	G	RCP4.5	2	GISS-E2_R	499	T	High-yield
13	I	RCP8.5	K	HadGEM2-ES	571	N	Normal
14	I	RCP8.5	O	MIROC5	571	N	Normal
15	I	RCP8.5	R	MPI-ESM-MR	571	N	Normal
16	I	RCP8.5	1	GFDL-CM3	571	N	Normal
17	I	RCP8.5	2	GISS-E2_R	571	N	Normal
18	I	RCP8.5	K	HadGEM2-ES	571	T	High-yield
19	I	RCP8.5	O	MIROC5	571	T	High-yield
20	I	RCP8.5	R	MPI-ESM-MR	571	T	High-yield
21	I	RCP8.5	1	GFDL-CM3	571	T	High-yield
22	I	RCP8.5	2	GISS-E2_R	571	T	High-yield

The proposed traits (Table 2) are simulated in **full combination only**. The aim of this study is not to analyze the contribution of the various individual traits, nor to explore the full range of traits which could possibly assist in an adaptation strategy. For each cultivar, parameters directly related to the five traits should be changed by the relative amount indicated in Table 2 (as done for previous CIMMYT - Chile/Argentina/Mexico exercise).

Please do not change any other process, as the approach should be as consistent as possible across the models, unless a model has no other way to represent any of the suggested traits. Please provide a brief description of your modifications and complete the Excel file "*Parameter for 34 global sites_Step 1.xlsx*" with the values of the parameters you have modified for each cultivar/site.

Table 2. Traits related to potential grain yield. The traits below are provided as a guideline for wheat crop growth models to simulate the high yielding cultivars based on the % change from calibrated locally adapted cultivars.

Type	Trait	Units	Calculation	% change vs. adapted cultivars
Source	Radiation use efficiency (RUE)	g (above-ground DM) MJ^{-1} (PAR)	Slope of above ground biomass (GS10 to GS 89) vs. cumulative intercepted PAR	**34**
	Light extinction coefficient at GS31 (K)	m^2 (ground) m^{-2} (leaf)	Exponential coefficient of cumulative PAR (pre-anthesis) vs LAI	**10**
Sink	Fruiting efficiency (FEspike)	grain g^{-1} (spike DM)	Grain number divided by anthesis spike DM	**-5**
	Potential grain filling duration (GFD)	°Cdays	Thermal time (base temperature 0°C) between anthesis and physiological maturity	**-4**
	Potential grain filling rate (GFR)	mg (DM) $grain^{-1}$ $°Cd^{-1}$	Potential grain size divided by thermal time (base temperature 0°C) between anthesis and physiological maturity under potential growth conditions	**21**
	Potential grain size (GWpot)	mg (DM) $grain^{-1}$	Average single grain DM under potential growth conditions	**16**

Please carefully follow the steps described below to set up your model and execute the simulations.

1) **Set up and run simulations for the 34 global locations using baseline weather**. Locations are labeled 1 to 34 (Table 3). Reset the soil water, soil nitrogen, soil carbon and residues each year 10 days before the supplied mean sowing date at the values indicated below. Use **360 ppm CO_2** for baseline simulation. Report at harvest year and supply output data for 1981 to 2010.

    a. **Soils** – Use individual soil profiles for each location described in "*AgMIP_Wheat_Soil_34Sites.xlsx*".

    b. **Surface residues** – Set surface residues to 1000 kg DM / ha (wheat) with a C to N ratio of 80.

    c. **Initial soil mineral N content** – Set initial soil mineral N to 33 kg N- NO_3^- / ha and 5.8 kg N NH_4^+ / ha with 65%, 25%, and 10% in the 0-60, 06-90, and > 90 cm soil layers or use the values for each soil profile given in "AgMIP_Wheat_Soil_34Sites.xlsx".

    d. **Initial soil water content** – Set initial soil water of the entire soil profile at 75% of total plant available water (i.e. 0.75 x (DUL – LL), or use the values for each soil profile given in; see "*AgMIP_Wheat_Soil_34Sites.xlsx*".

e. **Sowing date** – Sow at the dates indicated in Table 3. As the sites have high-rainfall or are irrigated, we use the same sowing dates for the baseline and future climates.

f. **Cultivars** – For locations no. 1 and 3 to 30, develop the location-specific cultivar parameter using the qualitative cultivar information from Table 3 and calibrate the parameters to be within ± 1 week of the supplied 50%-anthesis date and within ± 1 week of the supplied physiological maturity date for each location in Table 3. Average anthesis and maturity dates are supplied as a guideline in Table 3. For locations no. 2 and 31 to 34, use the calibration you have developed for the simulation of the experimental datasets.

g. **N fertilizer application** – Please ensure your simulations are conducted without N limitation.

h. **Irrigation** – At the irrigated locations (see Table 3) enough irrigation should be applied or models should be run with water stress turned off to avoid any significant limitation of yield due to soil water deficit. Please make sure that irrigation does not create N stress. At the rainfed locations, no irrigation should be applied.

i. **Weather data** –Weather file names are coded as XXYYI0XF, with:

- XX two-letters country code (see Table 3)
- YY = two-letters site code (see Table 3)
- I = one-character baseline or RCP code (see Table 1)
- 0 = one-character GCM code (see Table 1)
- X = no regional downscaling
- F = applied mean and variability shift with enhanced delta method.

Keys of the weather files are given in "*AgMIP_weather_keys.xlsx*".

2) Execute the simulations at the 34 sites for the 30 years with the **baseline climate with and without the high-yielding traits (Table 1, treatments 1 and 2)**. Use 360 ppm CO_2.

3) Execute the simulations at the 34 sites for the 30 years with the **future scenarios with and without the high-yielding traits (Table 1, treatments 3 to 22**). Use 571 ppm CO_2 for RCP8.5 and 499 ppm CO_2 for RCP4.5.

Simulation results files:

Once the simulation runs have been completed, please save the results into the provided template (*"AgMIP_Wheat_Template_Summary_Phase4_34Sites_Step1.txt")*. Keys for the simulated variables in the template are given in "*AgMIP_summary_template_keys.xlsx*". Do **not** report the daily simulation results.

Please follow the guidelines:

- Save all result files in **"TAB" limited text format**.
- One file has to be created for each site and treatment (i.e. 34 x 22 = **748 files in total**). Each file should contain 30 rows of data corresponding to 30 years (please verify that there is blank lines after the 30th year).
- All cumulative variables (WDrain, CumET, Runoff, Transp, Nleac, Nmin, Nvol, Nimmo, Nden, and cumPARi) should be **calculated from sowing to (physiological) maturity**, no matter if you initiate your model earlier or stop it after maturity. Report in the summary template the cumulative values at maturity.
- If your model does not simulate one of the output leave **"na"** in that column (please do not use any other character string for missing values).
- The naming of the result files should follow the structure: ModelCodelSiteRCP or baselineGCMTrait.txt, with,
  - ModelCodel = two letters model code (see Table 4)
  - Site = two letters location code (see Table 3)
  - RCP or baseline = one-letter RCP or baseline code (see Table 1)
  - GCM = one character GCM code – no character for the baseline (see Table 1)
  - Trait = one-letter trait code (see Table 1)

Examples of results file names for the APSIM-Next Generation model:

- AE010N.txt = for location 01, baseline climate and normal traits.
- AE01IRT.txt = for location 01, RCP8.5, GCM MPI-ESM-MR, and high yield traits.

All the files required to set up the simulations can be downloaded from Google Drive at the following address:

https://drive.google.com/drive/folders/1AxiuakubwkASRRM2nYYhDwSchGTgpFQD?usp=sharing

Please do not distribute this URL outside the wheat team (team members for Phase 4 are listed in Table 4 below).

Please return your result files by **30 April 2020** at the latest to Sibylle Dueri by e-mail [sibylle.dueri@inra.fr].

Verification of the file format and interactions with individual groups to resolve file format errors take a considerable amount of time. To facilitate the analysis of the results, we kindly ask you to **fill in the checklist at the end of this document** (Table 5) before sending your results.

Table 3. 34 locations from high rainfall and irrigated wheat regions of the world.

Loc. no.	Site name Code	Site name Name	Country Code	Country Code	Latitude (°)	Longitude (°)	Irrigated / rainfed	Common modern cultivar Name	Growth habit	Vernalization requirement	Photoperiod sensitivity	Season crop sown in	Sowing date	50%-anthesis date (±1 week)	Physiological Maturity date (± 1 week)
01	MA	Maricopa	US	USA	33.06	-112.05	Irrigated	Yecora	Spring	No/low	No/low	Autumn	25 Dec.	5 Apr.	15 May
02	OB	Obregon	MX	Mexico	27.43	-109.92	Irrigated	Bacanora	Spring	Low	Low	Autumn	1 Dec.	27 Feb.	8 Apr.
03	TO	Toluca	MX	Mexico	19.40	-99.68	Rainfed	Tacupeto C2001	Spring	Low	Low	Spring	10 May	5 Aug.	20 Sep.
04	LO	Londrina	BR	Brazil	-23.31	-51.13	Irrigated	Atilla	Spring	Low/medium	Low/medium	Autumn	20 Apr.	10 Jul.	1 Sep.
05	AS	Aswan	EG	Egypt	24.10	32.90	Irrigated	Seri M 82	Spring	Low/medium	Low	Autumn	20 Nov.	20 Mar.	30 Apr.
06	WM	Wad Medani	SU	Sudan	14.40	33.50	Irrigated	Debeira	Spring	Low/medium	Low	Autumn	20 Nov.	25 Jan.	25 Feb.
07	DH	Dharwar	IN	India	15.43	75.12	Irrigated	Debeira	Spring	Low/medium	Low	Autumn	25 Oct.	15 Jan.	25 Feb.
08	DI	Dinajpur	BD	Bangladesh	25.65	88.68	Irrigated	Kanchan	Spring	Low VR	Low	Autumn	1 Dec.	15 Feb.	15 Mar.
09	WA	Wageningen	NL	The Netherlands	51.97	5.63	Rainfed	Aminda	Winter	High	High	Autumn	5 Nov.	25 Jun.	5 Aug.
10	BA	Balcarce	AR	Argentina	-37.75	-58.3	Rainfed	Oasis	Winter	Medium/high	High/medium	Autumn	5 Aug.	25 Nov.	25 Dec.
11	LU	Ludhiana	IN	India	30.90	75.85	Irrigated	HD 2687	Spring	No/low	No/low	Autumn	15 Nov.	5 Feb.	5 Apr.
12	IN	Indore	IN	India	22.72	75.86	Irrigated	HI 1544	Spring	No/low	No/low	Autumn	25 Oct.	25 Jan.	25 Mar.
13	MD	Madison	US	Wisconsin, USA	43.03	-89.4	Rainfed	Brigadier	Winter	High	High	Autumn	15 Sep.	15 Jun.	30 Jul.
14	MN	Manhattan	US	Kansas, USA	39.14	-96.63	Rainfed	Fuller	Winter	Medium	Medium	Autumn	01 Oct.	15 May	01 Jul.
15	RO	Rothamsted	UK	United-Kingdom	51.82	-0.37	Rainfed	Avalon	Winter	High	Low/medium	Autumn	15 Oct.	15 Jun.	25 Jul.
16	EM	Estrées-Mons	FR	France	49.88	3.00	Rainfed	Bermude	Winter	High	High	Autumn	5 Oct.	31 May	15 Jul.
17	OR	Orleans	FR	France	47.83	1.91	Rainfed	Apache	Winter	High/medium	Medium	Autumn	20 Oct.	25 May	7 Jul.
18	SC	Schleswig	GE	Germany	54.53	9.55	Rainfed	Dekan	Winter	Medium/high	Low	Autumn	25 Sep.	15 Jun.	25 Jul.
19	NJ	Nanjing	CH	China	32.03	118.48	Irrigated	NM13	Winter	Medium	Medium	Autumn	5 Oct.	5 May	5 Jun.
20	LU	Luancheng	CH	China	37.53	114.41	Irrigated	SM15	Winter	High	Medium	Autumn	5 Oct.	5 May	5 Jun.
21	HA	Harbin	CH	China	45.45	126.46	Irrigated	LM26	Spring	Very low	Medium/high	Spring	5 Apr.	15 Jun.	25 Jul.
22	KO	Kojonup	AU	Australia	-33.84	117.15	Rainfed	Wyallkatchem	Spring	Low	Medium	Spring	15 May	5 Oct.	25 Nov.
23	GR	Griffith	AU	Australia	-34.17	146.03	Irrigated	Avocet	Spring	Low	Medium	Spring	15 Jun.	15 Oct.	25 Nov.
24	KA	Karaj	IR	Iran	35.92	50.90	Irrigated	Pishtaz	Spring	Low	Low	Autumn	1 Nov.	1 May	20 Jun.
25	FA	Faisalabad	PK	Pakistan	31.42	73.12	Irrigated	Faisalabad-2008	Spring	No	Low	Autumn	15 Nov.	5 Mar.	5 Apr.
26	KA	Karagandy	KZ	Kazakhstan	50.17	72.74	Irrigated	Steklov.-24	Spring	Low	Medium	Spring	20 May	15 Jul.	1 Sept.
27	KR	Krasnodar	RU	Russia	45.02	38.95	Irrigated	Brigadier	Winter	High	High	Autumn	15 Sep.	20 May	10 Jul.
28	PO	Poltava	UR	Ukraine	49.37	33.17	Irrigated	Brigadier	Winter	High	High	Autumn	15 Sep.	20 May	15 Jul.
29	IZ	Izmir	TR	Turkey	38.60	27.06	Irrigated	Basri Bey	Spring	Medium	Medium	Autumn	15 Nov.	1 May	1 Jun.
30	LE	Lethbridge	CA	Canada	49.70	-112.83	Irrigated	AC Radiant	Winter	High	High	Autumn	10 Sep.	10 Jun.	25 Jul.
31	RO	Rots	FR	France	49.20	-0.45	Rainfed	Apache	Winter	Medium	Moderate	Autumn	25 Oct.	30 May	11 Jul.
32	VA	Valdivia	CL	Chile	-39.80	-73.25	Rainfed	Bacanora	Spring	Low	Low	Autumn	25 Aug.	30 Nov.	15 Jan.
33	BU	Buenos Aires	AR	Argentina	-34.60	-58.50	Rainfed	Bacanora	Spring	Low	Low	Autumn	5 Jul.	15 Oct.	18 Nov.
34	LE	Leeston	NZ	New-Zealand	-43.7	172.3	Irrigated	Wakanui	Winter	Medium/high	High	Autumn	25 Mar.	26 Nov.	10 Jan.

Table 4. Name, 2-letters code, and modelers for the 41 wheat models participating in AgMIP Wheat		
Model name	**Model 2-letter**	**Team member**
1. APSIM-Next Generation	AE	Enli Wang, Zhigan Zhao
2. AQUACROP	AQ	Elias Fereres Castiel, Margarita Garcia-Vila
3. AgES-SWAT	AS	Greg McMaster, Debbie Edmunds
4. AgES-UPGM	AU	Greg McMaster, Debbie Edmunds
5. AgES-WEPS	AG	Greg McMaster, Debbie Edmunds
6. APSIM-Wheat	AW	Peter Thorburn, Zvi Hochman
7. CLM	CL	Yaqiong Lu
8. CROPSYST	CS	Claudio Stöckle, Mukhtar Ahmed
9. DSSAT CSM-CERES-Wheat	D1	Gerrit Hoogenboom, Yujing Gao
10. DSSAT CSM-CERES-Wheat	D2	Amir Souissi
11. DSSAT CSM-CERES-Wheat	D3	Margarita Ruiz-Ramos, Alfredo Rodriguez
12. DSSAT CSM-CERES-Wheat	D4	Philip Alderman
13. DSSAT CSM-CERES-Wheat	D5	Saeid Soufizadeh
14. DSSAT-Nwheat	DN	Senthold Asseng, Chuang Zhao
15. DSSAT-CROPSIM	DR	Davide Cammarano, Leslie A Hunt
16. DAISY	DS	Johannes Pullens, Jin Zhao
17. Epic-I	EI	Juraj Balkovic, Marijn Van der Velde
18. EPIC-TAMU	EW	Roberto Izaurralde, Curtis Jones
19. HERMES	HE	Kurt C Kersebaum
20. INFOCROP	IC	Naresh Kumar Soora
21. SIMPLACE<LINTUL-5+>	L5	Tommaso Stella, Heidi Webber
22. SIMPLACE<LINTUL-5>	L6	Amit Kumar Srivastava, Thomas Gaiser
23. LINTUL	LI	Iwan Supit
24. MCWLA-Wheat	MC	Fulu Tao, Zhao Zhang
25. MONICA	MO	Claas Nendel
26. Expert-N-CERES	NC	Irene Witte
27. Expert-N-GECROS	NG	Tobias Weber
28. Expert-N-SPASS	NP	Sebastian Gayler
29. Expert-N-SUCROS	NS	Eckart Priesack
30. OLEARY	OL	Garry O'Leary
31. ORCHIDEE-crop	OR	Xuhui Wang
32. pyGECROS	PG	Andres Berger
33. SIRIUS	S2	Mikhail Semenov, Nimai Senapati
34. SPA-Crop	S3	Andrew Revill, Nina Buchmann
35. SALUS	SA	Bruno Basso, Benjamin Dumont
36. SIMPLACE<LINTUL-2>	SP	Ehsan Eyshi Rezaei, Stephan Siebert
37. SIRIUSQUALITY	SQ	Pierre Martre, Sibylle Dueri
38. SSM-Wheat	SS	Marco Bindi, Roberto Ferrise
39. WHEATGROW	WG	Yan Zhu, Liujun Xiao
40. WOFOST	WO	Taru Palosuo
41. WOFOST7_UGOE	WU	Reimund P Rötter, Gennady Bracho-Mujica

Table 5. Checklist for the Summary simulation result files.

	No	Yes	Not applicable
Summary results			
1. Simulation results **start line 8**	☐	☐	☐
2. File has **38 lines (30 lines of data)**	☐	☐	☐
3. File has **27 columns**			
4. Dates (“Planting.date”, “Emergence”, “Ant”, “Mat”) are reported as **YYYY-MM-DD**	☐	☐	☐
5. The model names (first column) is your **model two-letter code** given in Table 2 above	☐	☐	☐
6. The **Treatments** (third column) are integers from 1 to 22 (one per line) – leave “na” for the years not previously simulated.	☐	☐	☐
7. Missing values are reported as “**na**”	☐	☐	☐
8. “WDrain”, “CumET”, “Runoff”, “Transp”, “Nleac”, “Nmin”, “Nvol”, “Nimmo”, “Nden” , and “cumPARi” are **cumulative from sowing** and values at maturity are reported	☐	☐	☐
9. All values are within expected **ranges** and **units** are as indicated in line 7	☐	☐	☐
10. The file is a **tab delimited text** file	☐	☐	☐
11. The name of the file follows the following scheme ModelCodelSiteRCP or baselineGCMTrait.txt	☐	☐	☐