10 Agriculture (crop modelling)

This section lays out the global output protocol for the agricultural sector's contribution to ISIMIP. For further details, please contact AgMIP (ag-grid@agmip.org) and ISIMIP (info@isimip.org).
Note that the variable names are chosen to comply with AgMIP conventions or are harmonized with the conventions used in the ISIMIP water sector (for irrigation water). They are given in lower-case letters only in order to prevent the use of mixed-case names in the file names (see Section 5.1.1). **Table** 6 provides an overview of all experiments to be run in the agriculture (crop modelling) sector in ISIMIP2a.

10.1 Experiments

Table 24: Experiment summary for crop models.

	Climate Data	Scenario	Management settings	Land use (LU)	Other settings (sens-scenario)	Irrigation	# Runs
Historical runs	WFD+WFDEI	hist	default (present day) (default) fully harmonized (fullharm) harmonized season, no N constraints (harmnon)	pure crop run (no LU specifier)	historical CO2 (no co2 specifier)	firr noirr	6
	GSWP3-W5E5	hist	default (present day) (default)	pure crop run (no LU specifier)	historical CO2 (no co2 specifier)	firr noirr	2
	GSWP3-EWEMBI	hist	default (present day) (default)	pure crop run (no LU specifier)	historical CO2 (no co2 specifier)	firr noirr	2
	GSWP3	hist	default (present day) (default)	pure crop run (no LU specifier)	historical CO2 (no co2 specifier)	firr noirr	2
	PGMFD v.2 (Princeton)	hist	default (present day) (default)	pure crop run (no LU specifier)	historical CO2 (no co2 specifier)	firr noirr	2
	WATCH (WFD)	hist	default (present day) (default)	pure crop run (no LU specifier)	historical CO2 (no co2 specifier)	firr noirr	2
							12 (per crop)

10.2 Sector-specific input

Some GGCMs require inputs on planting dates, crop variety parameters, fertilizer use and possibly other management specifics. While the agreement for the fast-track was to use each model's setting that best represents current management patterns, we'll have specific inputs on planting dates and maturity dates (to allow for spatially-explicit variety parameterization) as well as fertilizer use (N, P, K). Some experiments will be run with harmonized input data (validation and attribution studies), and some with default model settings.

Table 25: Crop-model-specific input data.

Variable	Source*	Units	Notes
Planting **dates**	(Sacks, Deryng, Foley, & Ramankutty, 2010), (Portmann, Siebert, & Döll, 2010), supplemented with a rule-based approach as implemented in LPJmL in regions without observational data (see Elliott et al. 2015).	Julian days (Jan 1st= 1,…)	Planting dates for primary seasons per crop and grod cell.
Approximate maturity	(Sacks, Deryng, Foley, & Ramankutty, 2010), (Portmann, Siebert, & Döll, 2010) , supplemented with a rule-based approach as implemented in LPJmL in regions without observational data (see Elliott et al. 2015).	days from planting	Growing season length in days.
Fertilizers and manure	(Mueller, et al., 2012), (Potter, Ramankutty,	kg ha-1 yr-1	Average nitrogen, phosphorus, and potassium application rates in each grid cell, with organic and inorganic amendments aggregated

	Bennett, & Donner, 2011), (Liu, et al., 2010), (Foley, et al., 2011)		and converted to an "effective inorganic application rate".
Historical [CO2]	Mauna Loa/RCP historical	ppm	Annual [CO2] values from 1900-2013.

10.3 Output data and definitions

Crop Priority and naming list:

1. Wheat[6], maize, soy, rice [whe, mai, soy, ric]
2. All others: Sugarcane, sorghum, millet, rapeseed, sugar beet, barley, rye, oat [sug, sor, mil, rap, sgb, bar, rye, and oat] + managed grass [mgr], field peas [pea], cassava [cas], sunflower [sun], groundnuts [nut], bean [ben], potato [pot], bioenergy crops such as poplar [pop], eucalyptus [euc], miscanthus [mis] ... **Note:** planting and maturity dates for bioenergy crops shall only be reported if meaningful (i.e. not for perennials).

Reporting per growing seasons:

To resolve potential double harvests within one year, crop yields should be reported per growing season and not per calendar year. Thus, in the NetCDF output files, do not use a time dimension but instead a unitless coordinate variable with integer values; more information on how to construct these files in **Section** 5.1.6 and in our ISIMIP website (https://www.isimip.org/protocol/preparing-simulation-files/). Cumulative growing season variables such as, e.g., actual evapotranspiration or precipitation are to be accumulated over the growing season. The first season in the file (growing-season=0) is then the first complete growing season of the time period provided by the input data without any assumed spin-up data, which equates to the growing season with the first planting after this date. To ensure that data can be matched to individual years in post-processing, it is essential to also provide the actual planting dates (as day of the year), actual planting years (year),

[6] There will be no distinction between winter and spring wheat.

anthesis dates (as day of the year), year of anthesis (year), maturity dates (day of the year), and year of maturity (year). This procedure is identical to the GGCMI convention (Elliott, et al., 2015).

Table 26: Output variables for crop models.

Variable (long name)	Variable name	Unit	Resolution	Comments
Key model output				
Crop yields	**yield-<crop>-<irrigation setting>**	dry matter (t ha-1 per growing season)	per growing season (0.5°x0.5°)	Crop-specific Yield may be identical to above-ground biomass (biom) if the entire plant is harvested, e.g. for bioenergy production.
Irrigation water withdrawal (assuming unlimited water supply)	**pirrww-<crop>-<irrigation setting>**	mm per growing season	per growing season (0.5°x0.5°)	*Irrigation water withdrawn in case of optimal irrigation (in addition to rainfall), assuming no losses in conveyance and application.*
Key diagnostic variables				
Actual evapotranspiration	**aet-<crop>-<irrigation setting>**	mm per growing season	per growing season (0.5°x0.5°)	portion of all water (including rain) that is evapo-transpired, the water amount should be accumulated over the entire growing period (**not** the calendar year)
Nitrogen application rate	**initr-<crop>-<irrigation setting>**	kg ha-1 per growing season	per growing season (0.5°x0.5°)	Total nitrogen application rate. If organic and inorganic amendments are applied, rate should be reported as effective inorganic nitrogen input (ignoring residues).
Actual planting dates	**plantday-<crop>-<irrigation setting>**	Day of year	per growing season (0.5°x0.5°)	

Anthesis dates	**anthday-<crop>-<irrigation setting>**	Days from planting date	per growing season (0.5°x0.5°)	
Maturity dates	**matyday-<crop>-<irrigation setting>**	Days from planting date	per growing season (0.5°x0.5°)	
Additional output variables (optional)				
Above ground biomass (dry matter)	**biom-<crop>-<irrigation setting>**	t ha-1 per growing season	per growing season (0.5°x0.5°)	The whole plant biomass above ground
Soil carbon emissions	**sco2-<crop>-<irrigation setting>**	kg C ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.
Nitrous oxide emissions	**sn2o-<crop>-<irrigation setting>**	kg N2O-N ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.
Total N uptake (total growing season sum)	**tnup-<crop>-<irrigation setting>**	kg ha -1 yr -1	monthly (0.5°x0.5°)	Nitrogen balance: uptake
Total N inputs (total growing season sum)	**tnin-<crop>-<irrigation setting>**	kg ha -1 yr -1	monthly (0.5°x0.5°)	Nitrogen balance: inputs
Total N losses (total growing season sum)	**tnloss-<crop>-<irrigation setting>**	kg ha -1 yr -1	monthly (0.5°x0.5°)	Nitrogen balance: losses
Growing season temperature sum	**sumt_<crop>**	deg c-days yr-1	per growing season (0.5°x0.5°)	Sum of daily mean temperature over growing season
Growing season radiation	**gsrsds_<crop>**	w m-2 yr-1	per growing season (0.5°x0.5°)	Average growing season shortwave solar radiation
Growing season precipitation	**gsprcp_<crop>**	mm ha-1 yr-1	per growing season	Total growing season precipitation per crop

			(0.5°x0.5°)	

Note: The reporting periods for some output variables were changed from “yearly” to “per growing season” in April 2019. Please be aware that model outputs submitted before this date, may still contain yearly data. Some models (e.g., LPJmL) report outputs for additional crops ("cas" cassava, "mil" millet, "nut" groundnut, "pea" peas, "rap" rapeseed, "sgb" sugar beet, "sug" sugarcane, "sun" sunflower, "mgr" managed grass). The model EPIC-BOKU provides outputs for alternative PET equations (Hargreaves (hg), Penman-Monteith (pe), Priestley Taylor (pt), Baier-Robertson (br)).

10.4 Experiments

10.4.1 Historic runs and validation experiment

Specification of the historical run

Simulations for the historical period should be provided as pure crop runs (i.e. assuming the crop growing all over the world), based on the climate input described in Section 4. For each crop, there should be a full irrigation run (firr) and a no-irrigation run (noirr). Within ISIMIP2a we also ask for historical runs with three different degrees of harmonization as given in **Table** 27.

Table 27: Scenario settings for crop model simulations

Simulation	Comments
Default	Model should use their individual “best representation” of the historical period with regard to sowing dates, harvesting dates, fertilizer application rates and crop varieties.
Fully harmonized	Simulations based on prescribed “present day” fertilization rates (available for download) and fixed planting and harvesting dates (also available for download). Modelers should have planting as closely as possible to these dates, but it may be admissible to use these dates as indicators for planting windows (depending on model specifics).
Harmonized seasons with no N constraints	For models with an explicit description of the nitrogen cycle: harmnon simulations should be run with nitrogen stress turned off completely or (if that’s not possible) with very high N application rates to make model results comparable between those GGCMs that have explicit N dynamics and those that do not. For models without the nitrogen cycle: harmnon and fullharm simulations are the same and do not need to be duplicated.

Each of these three variants should be combined with a no-irrigation and full irrigation assumption, resulting (for the models with an explicit representation of the nitrogen cycle) in 6 runs for the respective climate input data set (cf. **Table** 6).

Specification of PET equation

Running simulations with different PET equations implicate submitting different version of your model, with a consequent different model name; i.e. if you create a second set of simulations using Priestley Taylor PET equation, you shall use your <model-name> in the initial version, and <model-name>-pt in the second run. We recommend you these abbreviations: 'hg' for Hargreaves, 'pe' for Penman-Monteith, 'pt' for Priestley Taylor, and 'br' for Baier-Robertson.

Specification of the validation procedure

For the validation task the pure crop simulations should

1) be masked by the following LU patterns: "Dynamic MIRCA" (reconstruction of historical LU based on HYDE and MIRCA2000, see Section 4.3.

2) averaging and aggregation will be performed in the post-processing and depending on what data we compare to. It could include de-trending (to compare with possibly de-trended observations).

15 References

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