RegioCrop documentation

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Author: Delphine Deryng, Quentin Lejeune

Contact:
Delphine Deryng: delphine.deryng@mail.mcgill.ca
Quentin Lejeune: quentin.lejeune@climateanalytics.org

The ISIMIP data archive

The crop yield impact projections are computed from the ISIMIP Fast-Track archive. ISIMIP[1] was launched to integrate climate impact assessments across multiple sectors. The ISIMIP fast-track exercise, which took place between January 2012 and January 2013, consisted in the integration of climate impact models representing several sectors among water, agriculture, ecosystem, health, infrastructure and the economy at the global scale (Warszawski et al., 2014). The ISIMIP data archive for the agricultural sector includes global gridded data of agricultural productivity, growing season evapotranspiration and other crop growth-relevant outputs produced by an ensemble of six global gridded crop models (GGCMs) simulating more than fifteen crops (Rosenzweig et al., 2014[2]) driven by downscaled climate data from five general circulation models (GCMs) of the Coupled Model Intercomparison Project Phase 5 (CMIP5) run under four radiative concentration pathways (RCPs 2.6, 4.5, 6.0 and 8.5) of greenhouse gases emission scenarios for the 21st century (Table 1; Hempel et al., 2013). See below for more background information on the RCPs.

The current version of RegioCrop includes data on four crops: maize, rice, wheat and soybean for the full ensemble of GGCMs. Data for additional crops were also produced by two GGCMs and are shown in the RegioCrop summary table. Results consider effects of elevated atmospheric CO_2 concentrations as prescribed under RCP 8.5, as well as differences between irrigated – assuming full irrigation - and rainfed cropping systems (Rosenzweig et al., 2014, Deryng et al., 2016). Crop specific irrigated and rainfed areas are defined according to global maps of irrigated and rainfed crop areas around the year 2000 (Portmann et al., 2009). In respect to sub-Saharan Africa, crops presented in RegioCrop are predominantly grown under rainfed conditions (see Table A-2).

Crop yield data presented in RegioCrop focus on warming levels compared to pre-industrial global annual average temperature. Here, 20-year averages were used, centred on both present-day (circa year 2000, i.e. +0.61ºC above preindustrial) and respective warming levels in the range of [+1ºC; +4ºC], to estimate changes in crop yield outputs from the GGCMs. Results are presented for the median change across five GCMs and six GGCMs combination, totalising 30 ensemble members.

[1] www.isimip.org

[2] Please see the Supplemental Information of Rosenzweig et al. (2014) for a full technical description of the GGCMs (i.e. reference, simulated processes, calibration and validation methods). http://www.pnas.org/content/suppl/2013/12/16/1222463110.DCSupplemental/sapp.pdf

Table 1: List of GCMs and GGCMs from the ISI-MIP archive, as well as simulated crops included in this study (additional crops relevant for sub-Sahara Africa and not provided by all models are shown in grey).

GCM	
HadGEM2-ES IPSL-CM5A-LR MIROC-ESM-CHEM GFDL-ESM2M NorESM1-M	
GGCM	**CROP**
EPIC	Maize, Wheat, Soybean, Rice (Millet, Sorghum, Sugarcane, Beans, Cassava, Cotton, Sunflower, Groundnut)
GEPIC	Maize, Wheat, Soybean, Rice
LPJmL	Maize, Wheat, Soybean, Rice (Millet, Cassava, Peas, Sunflower, Groundnut, Sugarcane)
LPJ-GUESS	Maize, Wheat, Soybean, Rice
pDSSAT	Maize, Wheat, Soybean, Rice
PEGASUS	Maize, Wheat, Soybean

Dataset visualisation

RegioCrop displays three maps, also available for download as pdf files:

1) Simulated crop yield (t/ha/yr) circa year 2000 (+0.61°C above preindustrial).
2) Projected change in yield (%) relative to 2000 (multi-model ensemble median). Yellow areas show small level of impacts (range [-5;5%]). For larger level of impacts, grid cells where the models do not agree in the sign of change are shown in grey.
3) Relative increase in yield (%) if irrigation is applied on present-day rainfed harvested areas, assuming no water limitation (note this does not account for actual irrigated water availability).

In addition, RegioCrop displays in a table the first and third quartiles and the median values in the 30-member ensemble, also available for download as a csv spreadsheet.

Note on irrigation assumption in ISI-MIP

Crop simulations in ISI-MIP include rainfed and fully irrigated simulations on all suitable crop growing areas defined by each GGCMs according to agro-climatic parameters such as crop-specific temperature and soil moisture thresholds. These gridded results were processed to focus on current rainfed and irrigated growing areas using global masks of rainfed and irrigated cropping areas for the year 2000 (Portmann et al., 2008). Irrigated and rainfed areas were held constant to present-day. Furthermore, although climate change may reduce water resources, thus threatening irrigated crop yields, no account was made of future changes in water availability in all the irrigated simulations.

It must be noted that irrigation as an adaptation measure will not necessarily counteract the negative impacts of climate change. In fact, in several instances, we find that yields of irrigated crops could decrease even more in absolute terms than that of rainfed crops as a result of extreme temperature stress. This is because irrigated crops typically have higher yields than rainfed crops under similar growing conditions, and when temperatures reach a certain upper threshold, crops can be hit dramatically, independently of irrigation. This could therefore totally cancel out benefits of irrigation. On the other hand, irrigation could partly alleviate extreme temperature stress as it increases soil moisture and thus enhances the cooling effect of plant transpiration and soil evaporation (Müller et al. 2016, Thiery et al. 2017). This potential effect is however not included in the presented model results.

Warming-attribution calculator

Instead of using fixed time periods and different emission scenarios, one can look at time periods for which a certain global warming level above pre-industrial is reached. For each model we estimate the 20-year time period reaching a certain warming level. When presenting the ensemble mean projections for differences between warming levels, different periods are used for the different models:

Table 2: Corresponding period for warming levels under RCP 8.5

	1ºC	*1.5ºC*	*2ºC*	*2.5ºC*	*3ºC*	*3.5ºC*	*4ºC*
GFDL-ESM2M	2006-2025	2028-2047	2044-2063	2059-2078	2074-2093		
HadGEM2-ES	1996-2015	2010-2029	2022-2041	2033-2052	2042-2061	2051-2070	2059-2078
IPSL-CM5A-LR	1998-2017	2016-2035	2029-2048	2037-2056	2047-2066	2055-2074	2064-2083
MIROC-ESM-CHEM	1999-2018	2010-2029	2022-2041	2033-2052	2041-2060	2050-2069	2058-2077
NorESM1-M	2005-2024	2022-2041	2038-2057	2051-2070	2062-2081	2075-2094	

The warming levels were computed using the Warming Attribution Calculator[3].

Radiative Concentration Pathways (RCPs)

RCPs are scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover changes. The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasises that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome (Moss et al., 2010). RCP8.5 is one high pathway for which radiative forcing reaches greater than 8.5 W m^{-2} by 2100 and continues to rise for some amount of time[4].

Model validation

[3] http://wlcalc.climateanalytics.org

[4] http://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html

The performance of GGCMs in reproducing inter-annual yield variability over the historical period was assessed under the AgMIP initiative GGCMI phase 1 (Müller et al. 2017, Elliott et al, 2015).

The performance of GGCMs in simulating absolute yield is largely related to the availability and quality of national agriculture data, which tends to be more limited in sub-Saharan African countries, than in the top-10 crop producing countries in the world.

Nonetheless, crop models, such as GGCMs, are tools designed to assess cropping systems' sensitivity to changes in climatic conditions and can provide useful information on the bio-physical vulnerability of various crops to variations in temperatures and precipitation.

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