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Climate Change and Integrated Resource Management: A Multi-Scale Modeling Framework for Water and Food Security in Argentina

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Outline

- 1. Motivation
- 2. The SIMPLE-G-AR model
- 3. Building the SIMPLE-G-AR database
- 4. Simulation design
- 5. Conclusions and next steps

Argentina: agriculture, water & climate variability

- **Agriculture is macro-critical:** 6.9% of GDP and 19% of total exports in 2024; one of the world's top exporters of soybeans, corn and wheat (INDEC).
- **Production is overwhelmingly rainfed:** only 5.2% of cropland is irrigated (vs. ~20% world average) and just 6.7% has adequate irrigation equipment (FAO).
- **The 2022-23 La Niña drought:** delayed campaigns and cut planted area and yields of wheat, corn and soybeans; primary exports fell 38.3% y/y and agro-industrial manufactures 26.7% (Jan-Sep 2023, INDEC).
- **Adaptation lever:** expanding irrigation and water infrastructure is key but spatially uneven; impacts are highly location-specific, requiring grid-level data and models that link biophysical heterogeneity to economic outcomes.

Research questions and contributions

Assess technological and policy measures, at different levels of government, to improve the resilience and sustainability of Argentine agriculture under rising climate variability.

Q1 How resilient is Argentine agricultural production to unexpected climate events such as droughts and floods?

Q2 To what extent can investments in water infrastructure mitigate those impacts?

The gap: no spatially explicit, georeferenced database of crop production and water use exists for Argentina.

Database
The first 10x10 km georeferenced agricultural database for Argentina.

Model
The first country-level SIMPLE-G with rainfed/irrigated and surface/groundwater detail.

Policy tool
Spatially explicit analysis for a high-exposure, middle-income exporter.

From SIMPLE to SIMPLE-G-AR

SIMPLE-G-AR builds on more than a decade of SIMPLE / SIMPLE-G development across global and country-level implementations.

2011
Economic framework of the SIMPLE model

2013
First SIMPLE model
Baldos & Hertel (2013)

2017
SIMPLE-G-Global (30 arc min)
Liu et al. (2017)

2020
SIMPLE-G-US (5 arc min)
Baldos et al. (2020)

2020/21
SIMPLE-G-China (5 arc min)
Wang et al. (2020, 2021)

2022
SIMPLE-G-Brazil (5 arc min)
Wang et al. (2022)

2023
SIMPLE-G-Global (5 arc min)
Haqiqi et al. (2023)

2024
SIMPLE-G-Italy
previous model by the authors with the Roma Tre team

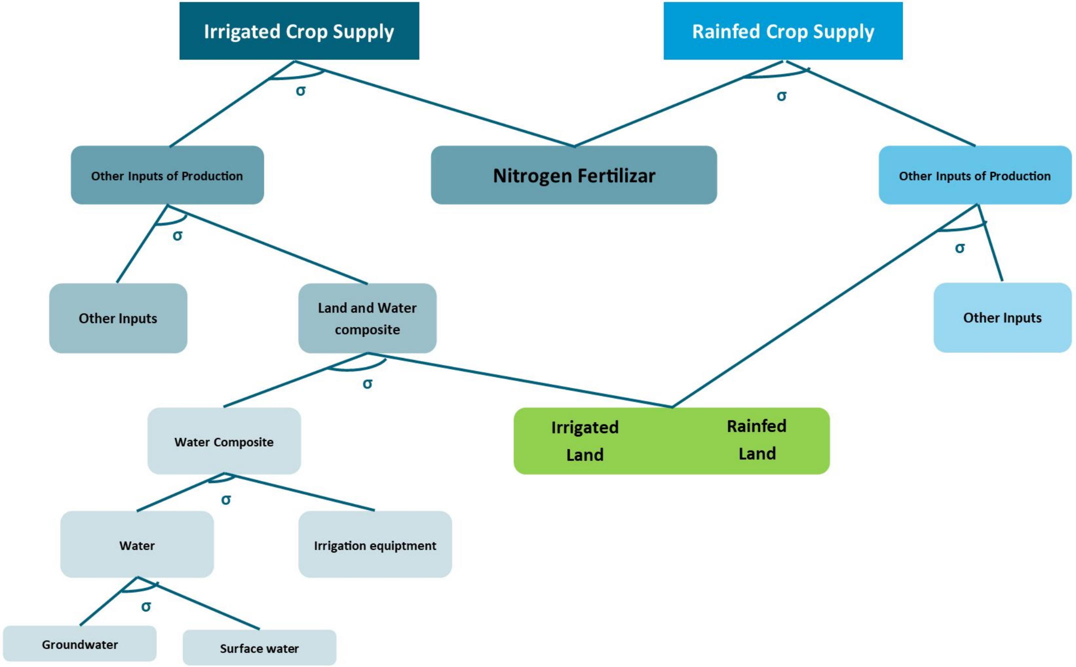
2026
SIMPLE-G-AR
current development (this paper)

Applications of SIMPLE-G

Liu et al. (2022)	SIMPLE-G-US-CS: analysis of nitrogen loss management policies in the US Corn Belt.
Haqiqi et al. (2023)	Future population growth and groundwater policies: effects on local crop production and demand.
Ray et al. (2023)	SIMPLE-G-US-CZ: labor mobility module to analyze agricultural labor markets at the gridded level.
Wang et al. (2022)	SIMPLE-G-Brazil with a transportation module: how lower transport costs affect production and cropland expansion.
Haqiqi et al. (2023)	Global model: impacts of COVID-19 and climate shocks on global crop production.

SIMPLE-G production function at the grid level

Nested CES structure: irrigated and rainfed crop supply with explicit land–water composites and groundwater / surface-water inputs.



Source: SIMPLE-G framework (Haqiqi et al., 2023), as implemented in SIMPLE-G-AR.

Data sources and processing

Source	Variable supplied (resolution, year)	Why it is the best choice for Argentina
GAEZ	Crop production & yields by water regime, irrigated/rainfed (~10 km, 2010)	Source giving agro-ecological output split by irrigation regime, matching the rainfed/irrigated model structure.
GFSAD30	Cropland area, 30 m aggregated to 10 km (2015)	High-resolution satellite cropland mask; pixel counting gives accurate cultivated area per cell.
GCWM	Crop water demand: blue (irrigation) vs green (rainfed) (~10 km, 2010)	Separates irrigation from precipitation water.
AQUASTAT	Agricultural water withdrawal by province (2010)	Grid-level irrigation intensity.
EarthStat	Nitrogen fertilizer balance per crop (~10 km, 2010)	Characterizes fertilizer intensity for the production-function calibration.
SIO Granos	Crop market prices, locality level (2017, deflated to 2010)	Finest available domestic Argentine prices.
IGN	Province / department boundaries (shapefile)	Official national geography; links each grid cell to its administrative units.
National Agricultural Census	Microdata are available for 2018, with responses at the producer level	Official agricultural sector survey, providing disaggregated data on multiple variables that explain producers' production processes and expenditures.

Processing

All rasters clipped and reprojected to the national 10x10 km grid (WGS84); zonal statistics per cell; GFSAD30 pixels converted to hectares; prices deflated 2017 -> 2010 (FAO index).

Base year: 2010

Climatically representative baseline across all sources; more recent complete-coverage years coincide with La Niña droughts and would bias the calibration.

Identifying the agricultural grid cells

- **Not all cells are agricultural:** the national grid has 31,049 cells; only a subset shows active cultivation.
- **Joint criterion:** keep a cell only if CROPLAND > 0 AND TOTAL_GAEZ > 0 - land cover and agro-ecological model must agree.
- **Rationale:** cells with cropland but zero GAEZ production are dropped, since the agro-ecology does not support economically meaningful cultivation.

31,049
national grid cells

>

Joint filter
CROPLAND > 0 AND GAEZ > 0
25% cropland-area threshold

>

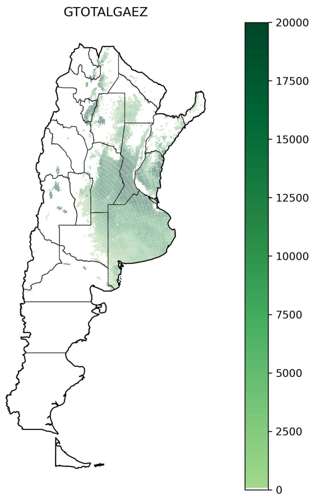
8,264
agricultural cells

Spatial layers (I): production, cropland and water regime

Each layer is harmonized onto the 10x10 km national grid (8,264 cells); GAEZ output is split by water regime, the core distinction in the SIMPLE-G-AR production structure.

Crop production (GAEZ)

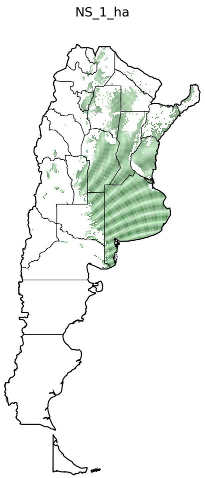
total, irr. + rainfed, ~10 km



Total agro-ecological output (54 production layers); kt converted to tonnes.

Cropland area (GFSAD30)

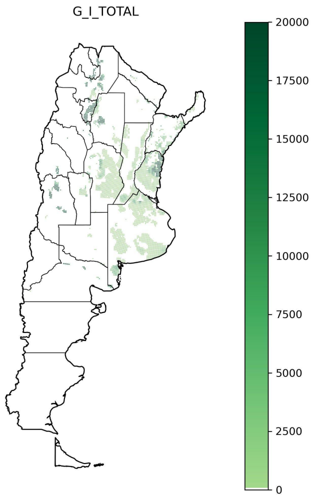
30 m aggregated to 10 km



Satellite cropland mask; hectares per cell via pixel counting (NS_2_ha).

Irrigated production (GAEZ)

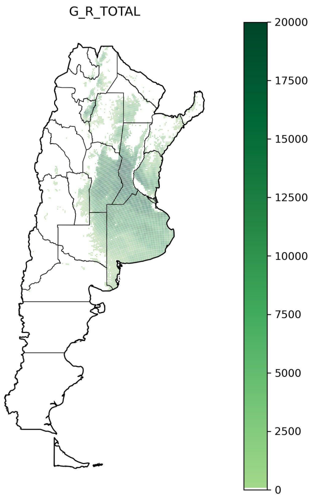
G_I_TOTAL, ~10 km



Concentrated in oases and the irrigated Pampa.

Rainfed production (GAEZ)

G_R_TOTAL, ~10 km



Dominates the Pampean core, the bulk of national output.

Biophysical crop model: WOFOST as an alternative to AgroIBIS

- SIMPLE-G needs a biophysical crop model to generate the grid-level Crop yield outcomes and N fertilizer application rates that feed the economic supply functions.

- AgroIBIS is the standard choice in existing implementations; WOFOST (Wageningen University) is an open-source alternative well suited to Argentina.

What WOFOST provides

Estimates agricultural production under different environmental and management scenarios

Data inputs

Climate — e.g. NASA POWER

Soil properties — e.g. SoilGrids

Crop management — sowing calendars, irrigation, nutrient application

Simulation scenarios

#	Scenario	Drivers / what it adds	Effect isolated
0	Baseline (2050)	BAU: rising food + biofuel demand (SSP2), TFP growth in all regions	Reference counterfactual
1a	+ Drought	Negative input-neutral tech shock (La Niña-type); rainfed cells hit harder	Gross cost of drought
1b	+ Flood	Negative tech shock + loss of effective cropland area in exposed cells	Gross cost of flood
2	Drought + incremental irrigation	Surface-water shock; irrigation 8% of cropland	Mitigation, incremental
3	Drought + moderate irrigation	Larger surface-water shock; irrigation 12%	Mitigation, moderate
4	Drought + full irrigation	Surface + groundwater; irrigation 15% (WB 2021 / FAO)	Mitigation ceiling

Source: own elaboration. Each scenario adds one element over the previous; effects are isolated by differencing adjacent scenarios. Climate shocks act through the input-neutral technological-change parameter at the grid level.

Conclusions and next steps

- **An original spatial database for Argentina**

8,264 agricultural cells on a 10x10 km grid integrate GAEZ production, GFSAD30/LGRIP30 land and water use, GCWM/AQUASTAT water demand, EarthStat nitrogen, and SIO Granos prices.

- **A policy-relevant simulation framework**

SIMPLE-G-AR links local agro-ecological conditions to national and global markets, enabling evaluation of irrigation expansion and climate adaptation at sub-provincial resolution.

- **Next steps**

Parameter estimation is being finalized; the immediate next steps are model calibration, validation, and estimation of the climate and irrigation scenarios.

Thank you

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6. Annex

Defining cropland and threshold sensitivity

- **Definition:** NA (LGRIP30) sets CROPLAND = irrigated Ha+ rainfed Ha.
- **What the threshold means:** each cell spans 10,000 ha, so a minimum NS_2_ha value fixes the minimum cultivated share a cell must have to be kept.
- **Sensitivity analysis:** retained cells computed at 0 / 2,000 / 2,500 / 3,333 / 5,000 ha (0/20/25/33/50%). The 0->20% step removes more than half the candidate cells; 25->33->50% changes coverage only marginally.
- **Selected rule:** 25% of cell area (Ha > 2,500) plus positive GAEZ production, balancing the removal of marginal/boundary cells against preserving the relevant agricultural area -> 8,264 cells.

Cell filtering: cropland-area threshold

Threshold	Interpretation	Cells retained
0 ha	Any cropland presence	19,570
2,000 ha	At least 20% of cell area	8,813
2,500 ha	**At least 25% of cell area (selected)**	**8,264**
3,333 ha	At least 33% of cell area	7,520
5,000 ha	At least 50% of cell area	6,416

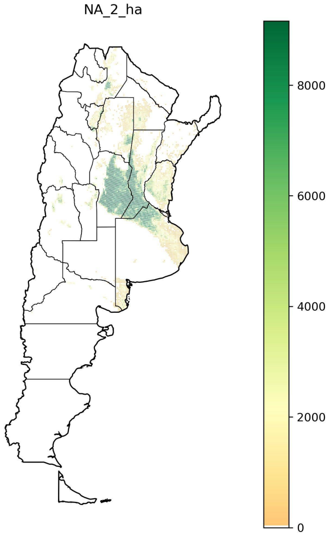
Source: own elaboration (LGRIP30/USGS). The final analytical dataset applies the 25% threshold together with positive GAEZ production (TOTAL_GAEZ > 0), yielding 8,264 agricultural cells. Raising the threshold to 33% or 50% changes the spatial coverage only marginally.

Spatial layers (I cont.): cropland by water regime

LGRIP30 (NA) irrigated/rainfed cropland, compared against GFSAD30 (NS) to validate cell selection.

Irrigated cropland (LGRIP30)

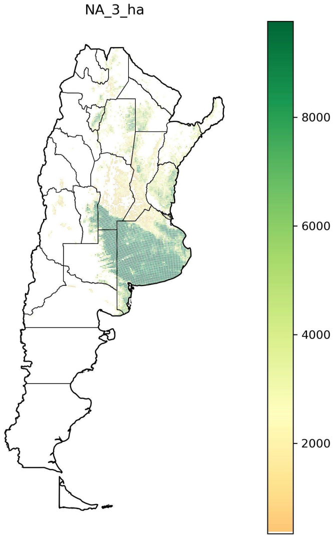
NA_2_ha, 30 m to 10 km



Irrigated area per cell; cross-checked with GFSAD30 (NA gives 15,219 cells at the zero threshold).

Rainfed cropland (LGRIP30)

NA_3_ha, 30 m to 10 km



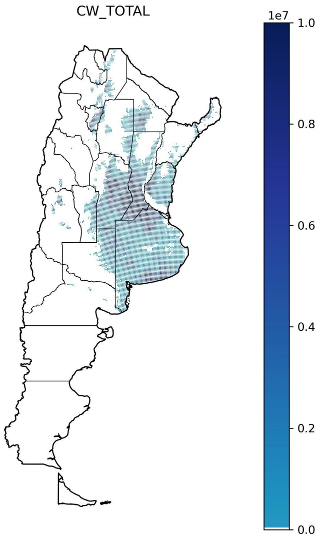
Rainfed area per cell; reveals algorithm-driven regional discordance vs GFSAD30.

Spatial layers (II): water and fertilizer

Water and input layers complete the production-function calibration inputs.

Water use (GCWM / AQUASTAT)

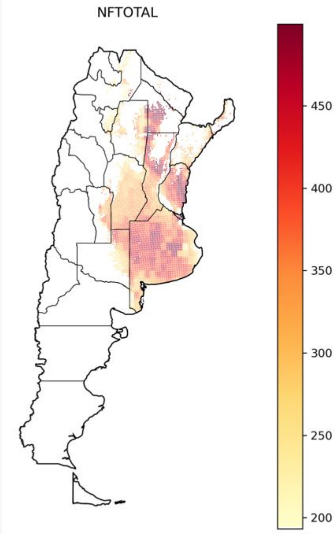
CW_TOTAL, m3, ~10 km



Total crop water demand (blue + green); reconciled with provincial withdrawals.

Fertilizer use (EarthStat)

nitrogen balance per crop, ~10 km



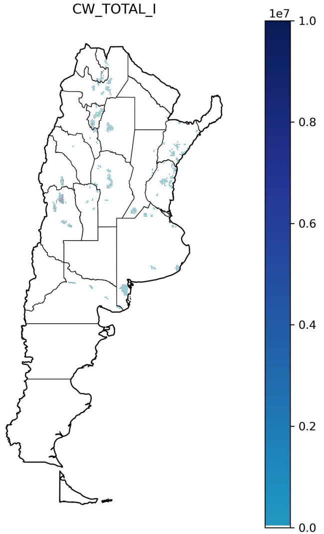
Nitrogen applied minus removed at harvest; fertilizer intensity per cell.

Spatial layers (II cont.): water demand by source

GCWM crop water demand split into blue (irrigation) and green (precipitation) water.

Blue water - irrigation (GCWM)

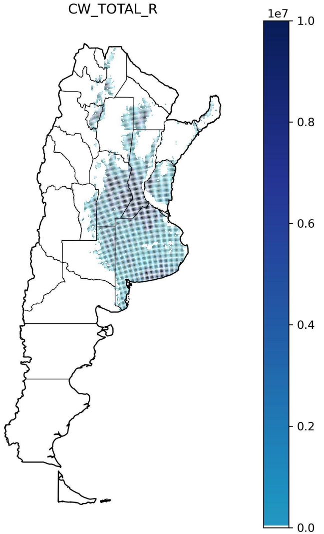
CW_TOTAL_I, m3, ~10 km



Irrigation water demand; calibrates the irrigated branch and surface/groundwater shocks.

Green water - rainfed (GCWM)

CW_TOTAL_R, m3, ~10 km



Precipitation water demand; dominant component, mirrors the rainfed production pattern.