

# Challenges of simulating agriculture in land models

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with thanks to

Jonas Jägermeyr, Danica Lombardozzi, Christoph Müller,  
and pretty much all preceding presenters

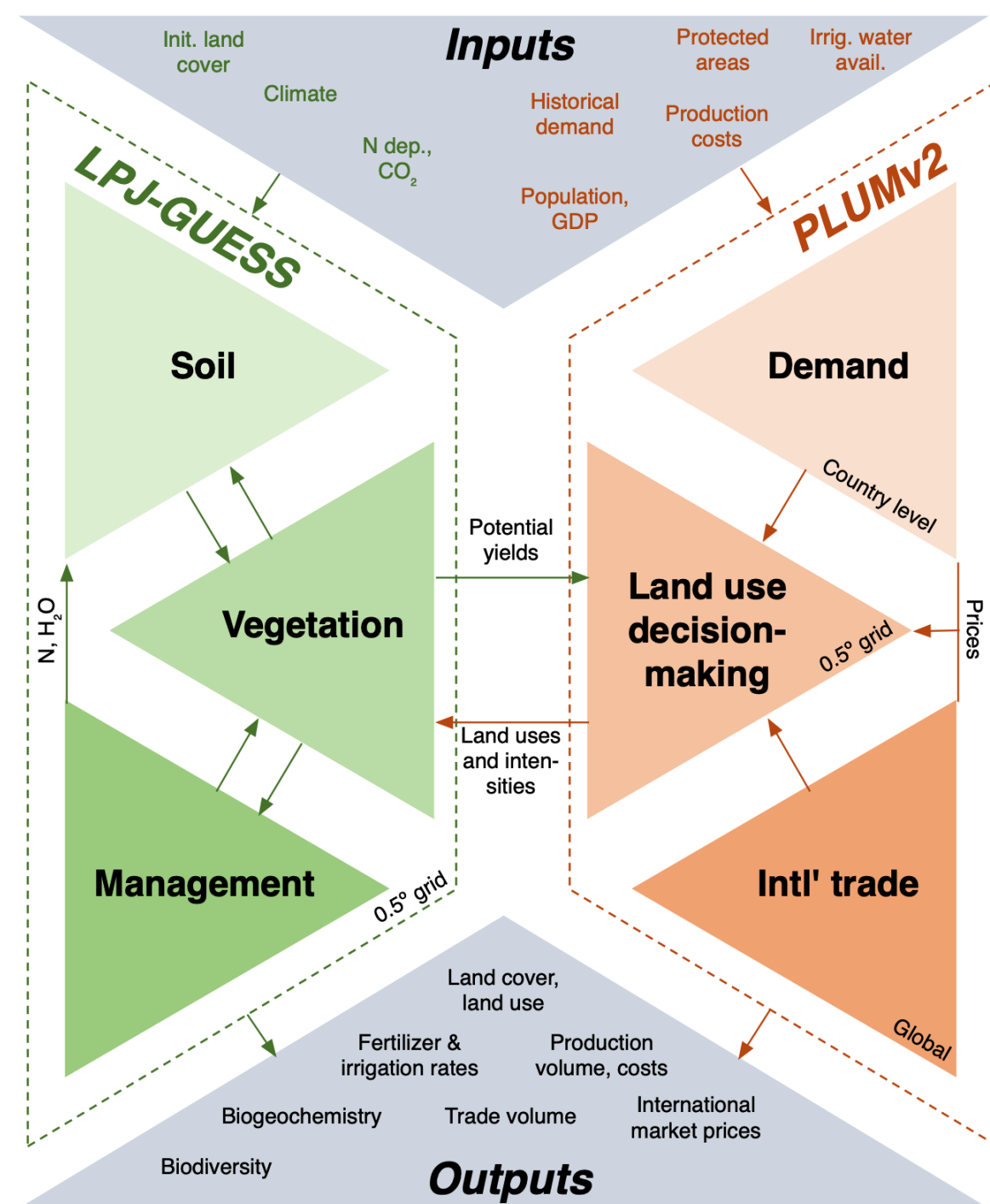
GFDL-LM (land-use fire)

LPJ-GUESS (land use, fire)

CLM (crop growing seasons)

## Land System Modular Model (LandSyMM)

- Biodiversity (Henry et al., 2019)
- Ecosystem services (Rabin et al., 2020)
- Food prices and health (Henry et al., 2021)





**Water (regional)**

Valentina Krivanova [🔗](#) [✉️](#)



**Water Quality (in development)**



**Fisheries & Marine Ecosystems**



**Energy Fluctuations and Extremes**



**Regional Forests**



**Global Biomes**



**Agriculture Sector**



**Agro-economic Modelling**



**Terrestrial Biodiversity**



**Permafrost**



**Coastal Systems  
Peat (in development)**

Sarah Chadburn [🔗](#) [✉️](#)

Angela Gallego-Sala [🔗](#) [✉️](#)



**Health**



**Lakes**



**Fire**



**Disorganized, incomplete  
list of challenges**

~~Disorganized, incomplete~~  
list of challenges

Modeling is hard

Do we have the inputs?

Are ours the right models?

**Not enough  
time, people, or  
funding**

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# Extreme event impacts

Heat waves, cold snaps/frosts  
Drought, inundation

- Wide variety of implementations
- Very **empirical**
- Sometimes not C-conserving
- **Inundation** isn't just a crop modeling problem

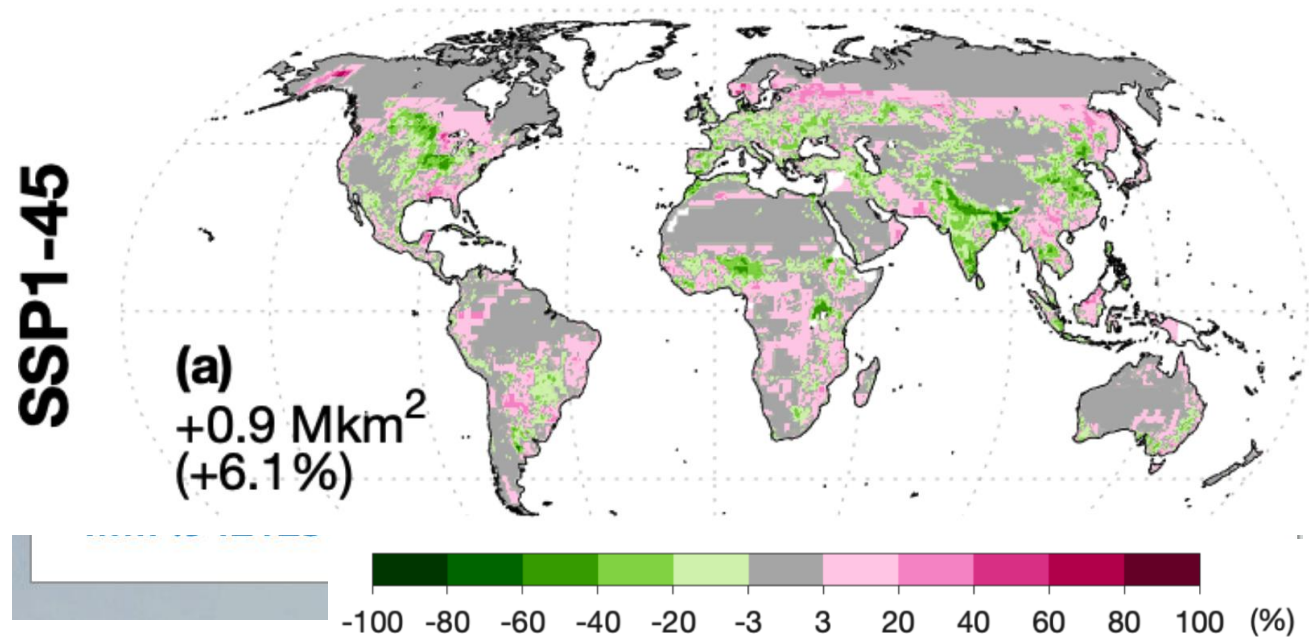
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 ACEA	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	Yes	Yes
 CROVER	<input type="checkbox"/>	<input checked="" type="checkbox"/>	No	Yes	No	No
 CYGMA	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	Yes	Yes
DSSAT-Pythia	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	Yes	
 EPIC-BOKU	<input checked="" type="checkbox"/>	<input type="checkbox"/>		Yes		
EPIC-IIASA	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	Yes	
 GEPIC	<input checked="" type="checkbox"/>	<input type="checkbox"/>		Yes		
ISAM	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	No	
LandscapeDNDC	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	No	
 LPJmL	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	No	No	No	Yes
 pDSSAT	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	Yes	
 PEPIC	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	No	
 PROMET	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	Yes	No	
SIMPLACE-LINTUL5+	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Yes	No	No	

# Soils

- Within-gridcell **soil heterogeneity** (parent material, texture, etc.) important for agriculture
- Same for **hydrology**: Tiling becoming more common, but it's expensive
- Limiting nutrients other than N, esp. P (enhanced weathering)
- As agriculture expands poleward—how good are our **permafrost** models?
- How to **spin up** to realistic agricultural soil?
- Are we confident enough to use our models for **cropland** → **water quality** work?



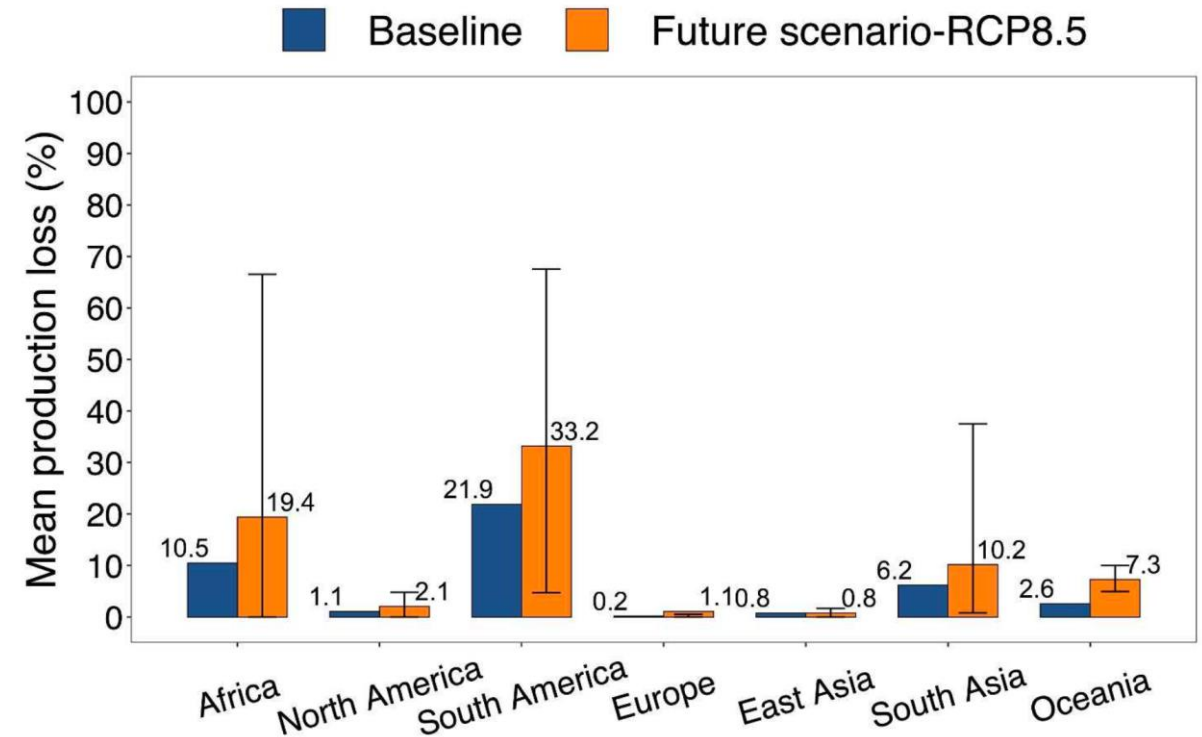
## $\Delta$ cropland area, 2010–2100



Rabin et al. (2020, *Earth Syst. Dyn.*)

# Pests, diseases, and weeds

- Need to model not just **outbreaks/severity** of individual pests/diseases, but also their **biogeography**
- Lots of variety, **regional variation**
- How to model “**black swan**” new emergence or range jumps?
- **Weeds:** *Another* kind of plant growing in the same field?



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**Figure 4. Potential mean wheat production loss due to wheat blast damage simulated for the 1980-2010 baseline and for 2040-2070 under climate change.** Scenarios were simulated using five global climate models for Representative Concentration Pathway 8.5 for 2040-2070

From Pequeno et al. (2022, preprint ?)

Not enough

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# Cropland management

- Multiple growing seasons per year
- Crop rotations
- Intercropping
- Agroforestry
- Integrated crop/livestock systems
- Irrigation techniques, intensity, limits
- Tillage
- Fire (field prep, residue burning)

**We can add these, but will we have the data for global runs?**

Hard to get observations at global scale.

Future runs: Need for scenarios, collaboration with agro-economic modelers.

# Livestock

- **Browsers!**
- **Definitional uncertainty** in “pasture” vs. “rangeland”
  - Fire use and other field management?
  - Grazing intensity?
- **Biogeochemical impacts** other than plant consumption
  - Manure
  - Ammonia
  - Methane



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# More crop types

- The “Big Four” (wheat, maize, rice, soybean) are necessary but insufficient to understand food security
- **Fruit & vegetables** important for nutrition and as cash crops





# Nutritional content

- Protein, micronutrients:  
Translating **production** into **food security**
- Reduced nutrient density with  $\text{CO}_2$  fertilization (Smith & Myers, 2018, *NCC*)



Completenutrition.blog

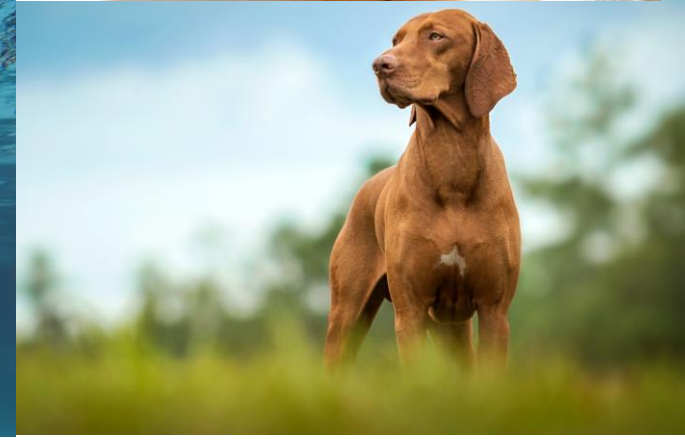
# More crop types

- The “Big Four” (wheat, maize, rice, soybean) are **necessary but insufficient** to understand food security
- **Fruit & vegetables** important for nutrition and as cash crops
- **Regional staple** crops (taro, teff, etc.)
- **Biofuels**—*Miscanthus*, willow coppicing
- Some require modeling of **new structures**
  - Tree crops
  - Perennial herbaceous crops
  - Explicitly model tubers—co-benefits for realism of non-crop PFTs?



# More crop *varieties*

- Most models can vary thermal requirement for maturity. (Realistically?)
- Lots of **regional variation** in cultivar needs, availability, and affordability
  - Pest/disease resistance?
  - Drought/heat resistance?
- How to model **introduction of new cultivars**? Scenarios?



# Land models vs dedicated crop models

	Land models	Crop models
Crop structures & phenology	Simplified	Detailed
# crop types	Fewer	More

E.g.:  
ACEA,  
APSIM,  
EPIC family,  
pDSSAT

What questions are we okay with leaving to dedicated crop models?

Can we supplement/replace our crop modules with dedicated crop models?

**Some guiding questions**

# How to prioritize w/ limited team sizes/budgets?

- Which do we need to endogenize (first)?
  - Which are we comfortable leaving to specialized agriculture models?
  - Which are we comfortable leaving impact models to handle in potentially hand-wavy ways?
- How can we engage researchers and developers outside our own groups?



# Which challenges would benefit from...

- New remote sensing data?
- Heroic literature reviews?
- Field experiments?
- MIPs—either new experiments or new output analyses?
- Scenario development?
- Coupling with land use / economic models?

