Global Carbon Fluxes Induced by Management Practices on Agricultural Land

Xiaoming Xu

Shijie Shu, Prateek Sharma, Atul K. Jain

University of Illinois at Urbana-Champaign

Collaborators

Katherine V Calvin (PNNL), Xiaojuan Yang and Daniel M Ricciuto (ORNL)

Acknowledgements
DOE (No. DE-SC0016323)

Overall Objectives of Our E3SM Project

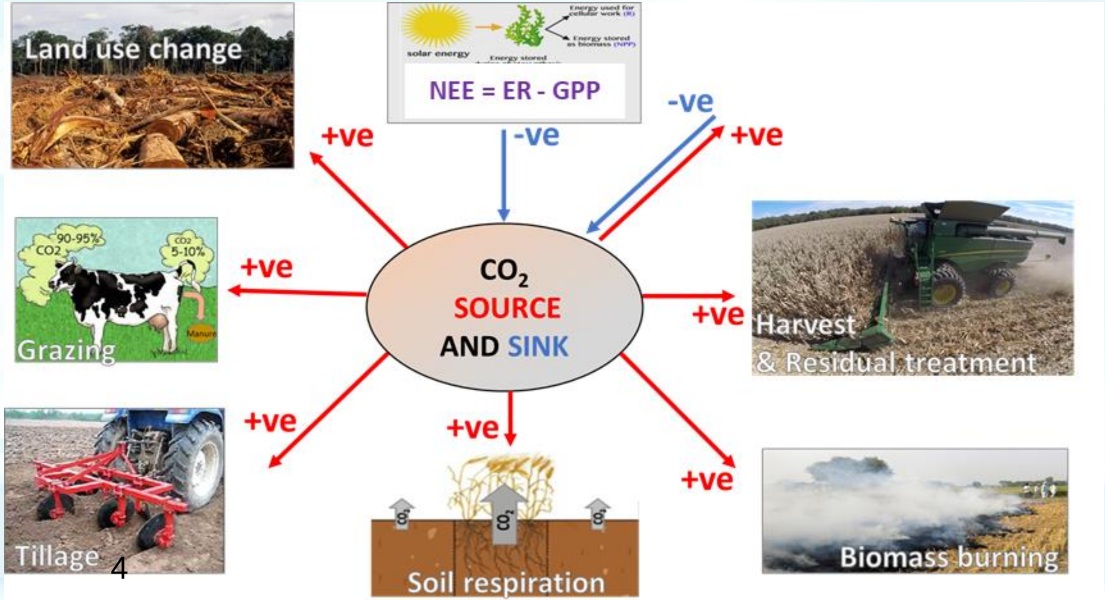
- Advance the treatment of land disturbance, particularly LULCCs and land management practices, within an IAM and couple it with E3SM to fully explore the potential contribution of
  - LULCC and land management practices to carbon emissions and mitigation opportunities
  - Terrestrial carbon sources and sinks, and climate change
- Tasks:
  - Improving the historical distribution of LULCC in E3SM
  - Implementation of Global-Scale Spatial Dynamic Allocation Model (SDAM) of agricultural land use change in GCAM-E3SM coupled modeling framework
  - Modeling land management practices that influence carbon sinks in terrestrial agriculture and forest ecosystems and mitigate climate change

Representation of Land Management in Current Land Models

- Missing components of current land models:
  - Most land models have a very simple or no representation of land management practices
  - Carbon and nitrogen dynamics of the livestock feed-manure cycle have not been accounted for
- In this talk
  - Implement land management practices into a land surface model to estimate carbon fluxes
  - We make a distinction between agricultural land use change emission ($\boldsymbol{E_{luc}}$) and agricultural land management emissions (farmland emissions, $\boldsymbol{E_{farm}}$)
  - $\boldsymbol{E_{farm}}$ is assumed to be neutral and being associated to annual cycles of carbon fixation and oxidation through photosynthesis in IPCC AR5 (*IPCC, 2014*) and FAOSTAT (*FAO, 2020*) AFOLU GHG emission estimates

Framework: agricultural land management

- Implementation of the livestock feed-manure cycle
  - Harvest process for crop grain
  - Crop residual treatment
  - Livestock grazing
  - Manure
- N fertilizer (Chemical)
- Tillage process
- Irrigation
- Burning



E3SM Energy Exascale Earth System Model

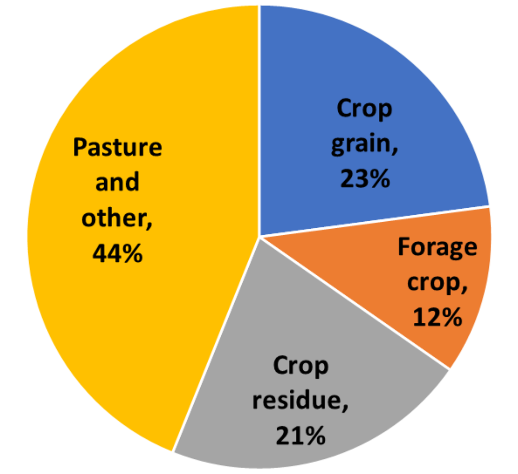
Livestock feed-manure cycle and its impact on C and N dynamics

1. Estimation of country scale feed demand (carbon) based on the feed requirement (*Krausmann et al, 2008*) for 16 major livestock (*FAOSTAT, 2020*)

$$\sum Livestock\ head\ \times Feed\ demand\ per\ animal\ \ (unit\colon carbon)$$

2. Quantification of the feed sources
 (cropland and grazing land)

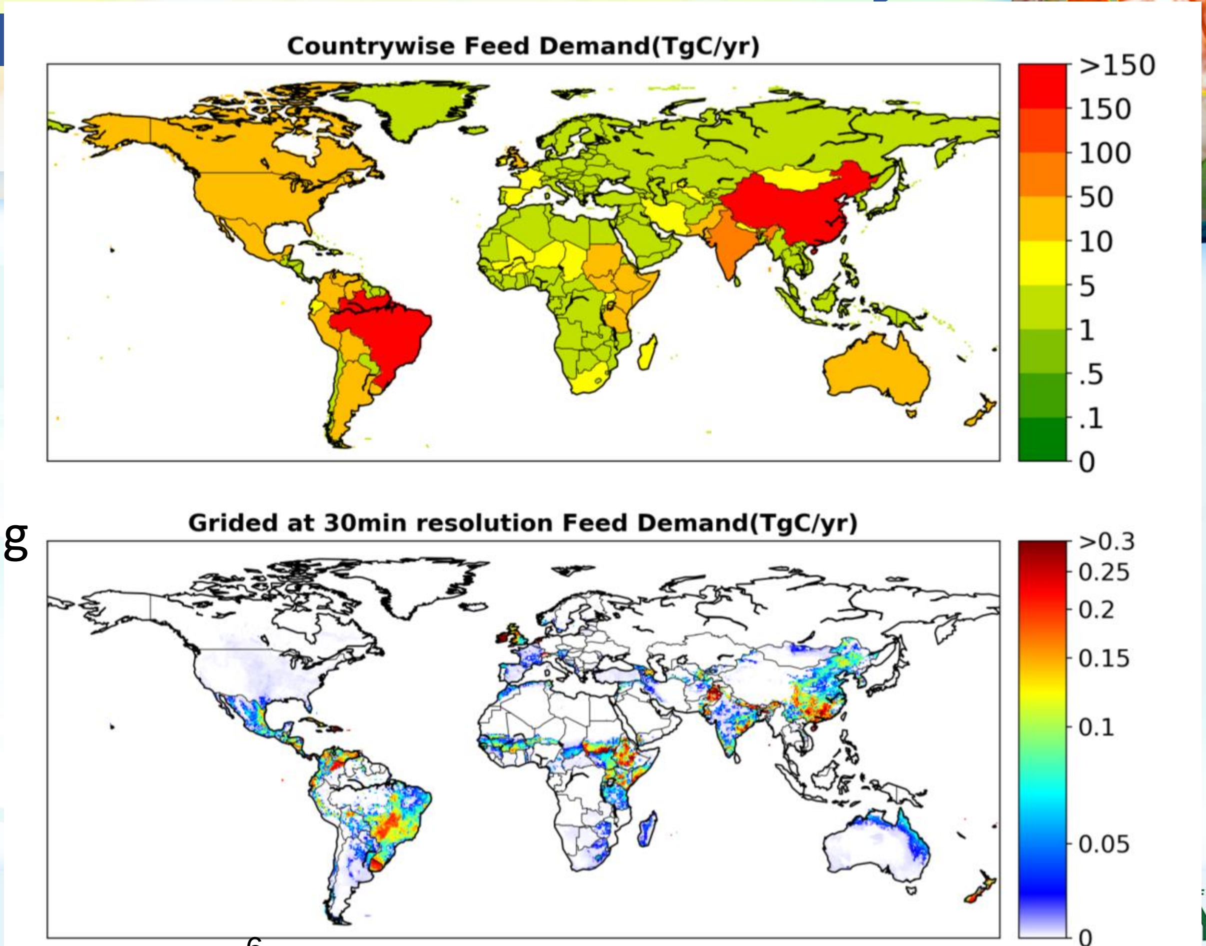
Total livestock feed demand
2,450 Tg C/yr



Xu et al., 2020

Redistribution of feed demand from country scale to grid level

Pasture feed (1,076 Tg C/yr) produced on grazing land



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Feed and Manure C and N

Feed

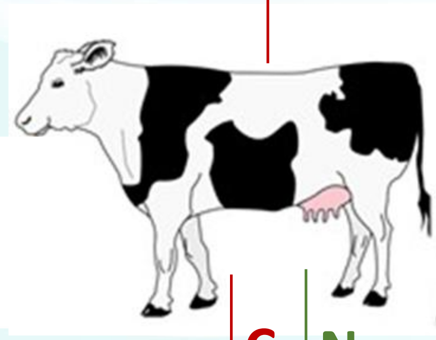
Crop

Pasture

C

N

CO_2, CH_4



C N

Products

CH_4 N_2O

Manure

C

N

Solid and liquid

Manure C

- Manure C in organic form is treated the same as litter

Manure N

- Manure N returned back to the soil is in both organic and inorganic forms
- Organic manure N is treated the same as litter
- Most inorganic manure N is in ammonium form

Our analysis make a distinction between E_{luc} and E_{farm} carbon flux calculation

$$Net\ agriculture\ carbon\ flux = E_{farm} + E_{luc}$$

1) $E_{luc} = E_{p\_1yr} + E_{p\_10yr} + E_{p\_100yr} + E_{p\_1000yr} + E_{soil}$

E_{p_1yr}: emissions from 1-year product pool

E_{p_10yr}: emissions from 10-year product pool

E_{p_100yr}: emissions from 100-year product pool

E_{p_1000yr}: emissions from 1000-year product pool

E_{soil}: emissions from soil disturbance caused by land use change

2) $E_{farm} = NEE + E_{h\_CO2} + E_{t\_CO2} + E_{w\_CO2}$

$$NEE = R_a + R_h - GPP$$

NEE: Net Ecosystem Exchange

GPP: Gross Primary Productivity

R_a: Autotrophic Respiration

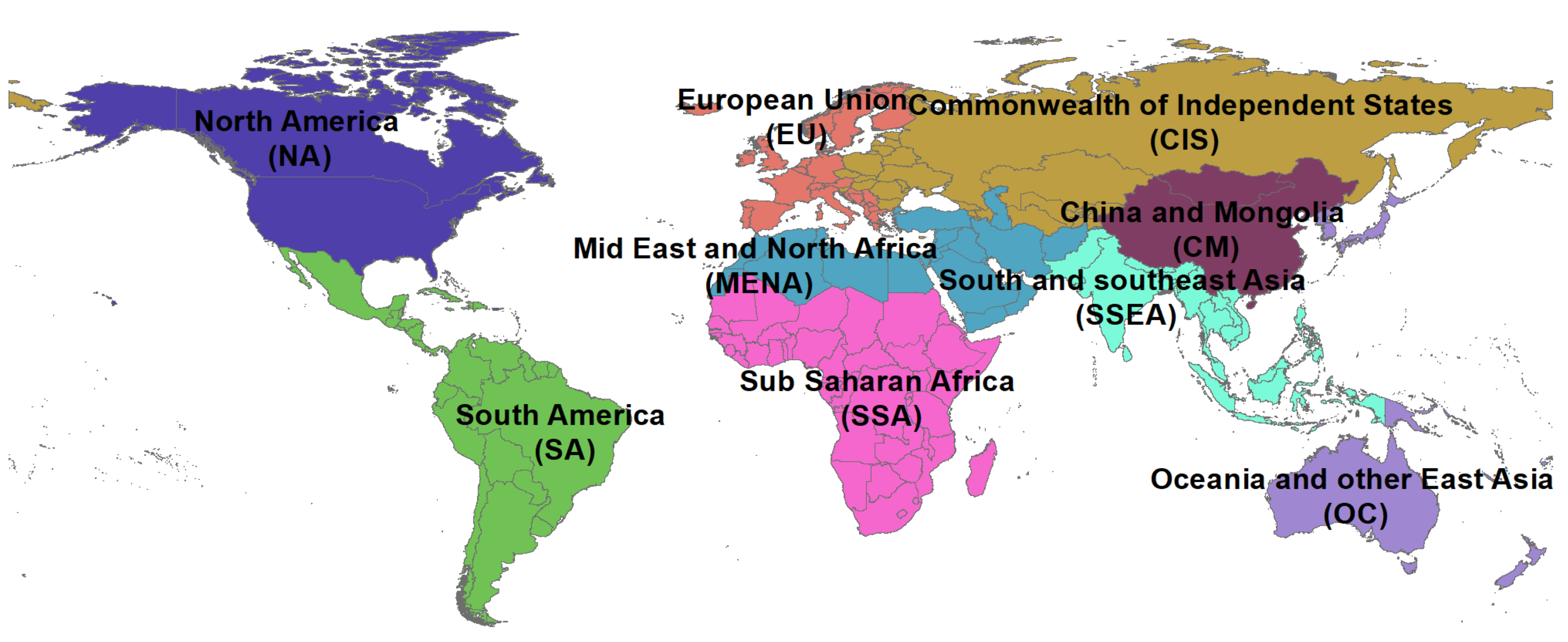
R_h: Heterotrophic Respiration

E_{h_CO2}: Carbon loss due to harvest of biomass

E_{t_CO2}: Carbon loss due to soil tillage

E_{w_CO2}: Carbon loss due to burning

Results (discuss based on 9 macro-geographical regions)

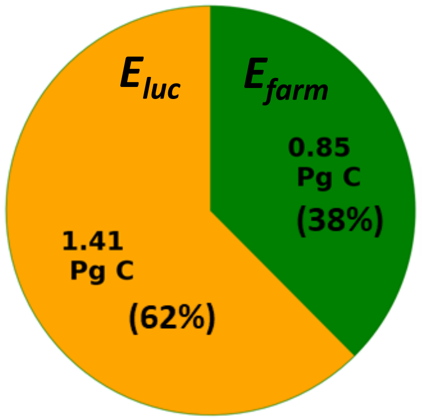


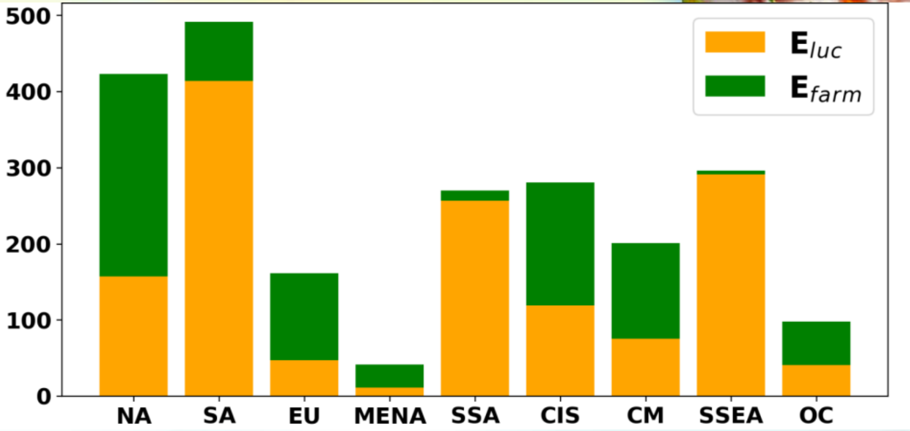
E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

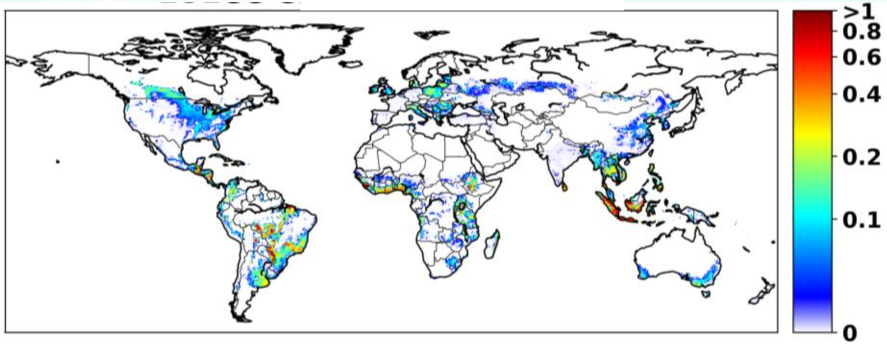
E_{luc} and E_{farm} fluxes in 2010

Total Agriculture net carbon flux: 2.26 Pg C/yr

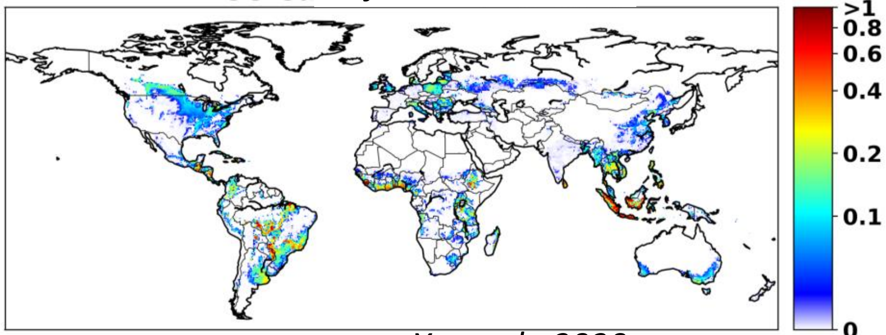




E_{luc} (Tg C/yr)



E_{farm} (Tg C/yr)

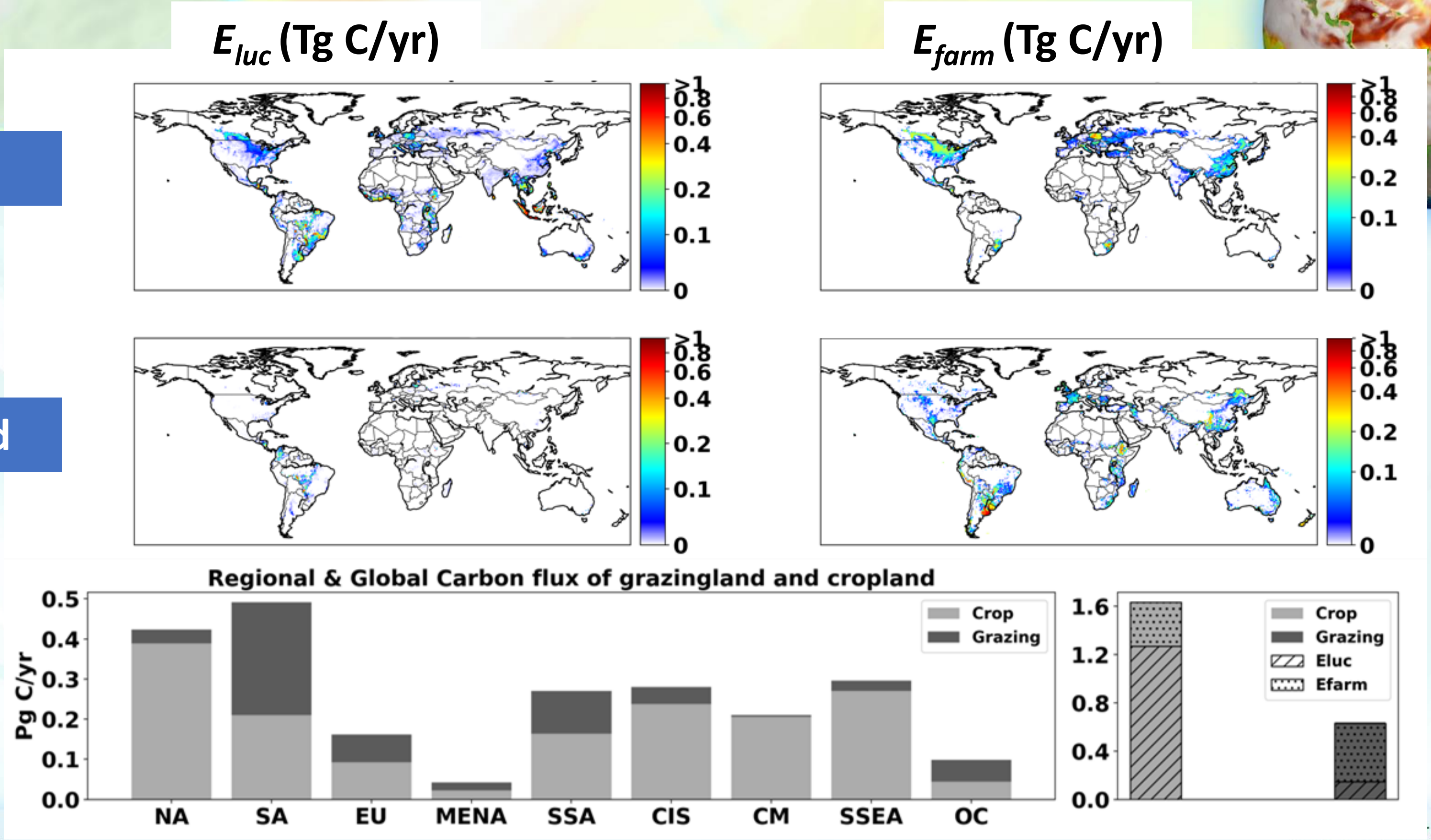


Xu et al., 2020

E_{luc} and E_{farm} on cropland and grazing land

Cropland

Grazing land

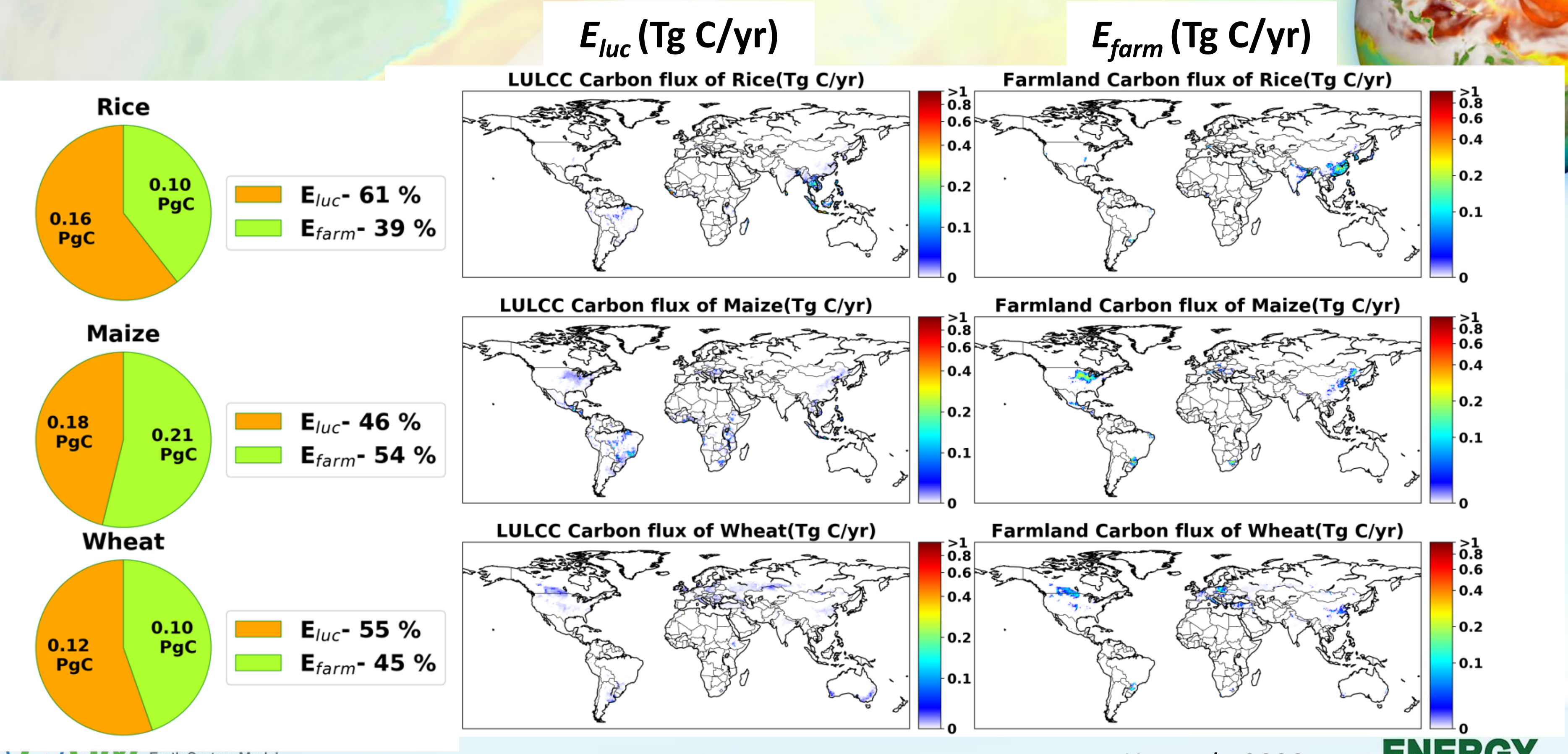


E3SM Energy Exascale Earth System Model

Xu et al., 2020

ENERGY

Top three contributing crops



Xu et al., 2020

Summary

- Agricultural land is a net carbon source with the flux 2.26 Pg C/yr in 2010
- Emissions from farmland management activities contribute to 38% and land use change contribute 62% to total emissions
- South America and North America are the largest emitting regions
- Cropland and grazing land contribute 72% and 28% to total emission
- Maize, rice and wheat are the major contributing crops

Next

- Implement the land management practices, especially the C and N dynamics caused by feed-manure cycle in the ELM
- Implement mosaic structure in ELM to calculate the soil properties
- Perform ELM simulations for the future to compare the carbon, water and energy fluxes between ISAM and LUH2 LULCC datasets

Thank you!