GHG Emissions from Agriculture Land

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Xiaoming Xu, Prateek Sharma, Shijie Shu, Tzu-Shun Lin
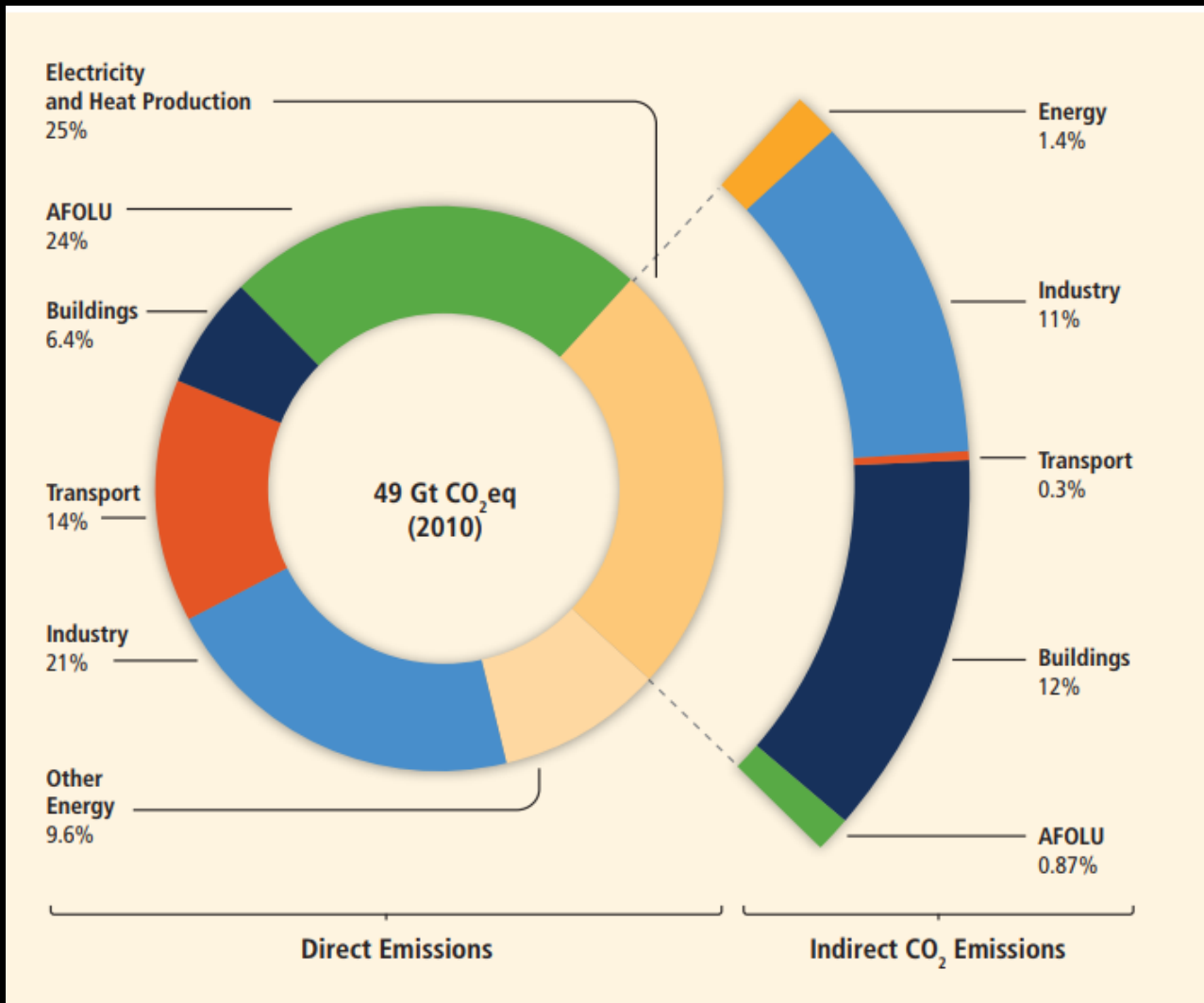Philippe Ciais, Francesco N. Tubiello, Pete Smith, Nelson Campbell

My research related to LCLUCs and their impacts

❑ 2008-2012: LCLUC and Its Effects on Carbon Dynamics in Monsoon Asian Region (NASA LCLUC)

❑ 2014 – 2018: A Synthesis Study of LCLUC and their Effects on Carbon Dynamics in SSES: (NASA LCLUC)

❑ 2023 – cont.: Decoding Land Transitions across the Urban-Rural Continuums (URC): A Synthesis Study of Patterns, Drivers, and Socioenvironmental Impacts in Southeast Asia – PI: Peilei Fan (Tufts University, USA)

  ▪ How have ecosystem functions changed with LCLUC across the URC, particularly in green infrastructure (vegetation and soils) and blue infrastructure (i.e., water quantity and quality and wetlands)?

  ▪ How have ecosystem changes induced environmental problems, such as greenhouse gas (GHG) emissions, microclimate extremes (drought, flood and heatwaves), and air pollution, especially for vulnerable communities?

  ▪ What are the specific biophysical and socioeconomic drivers that created the observed spatiotemporal patterns (RQ1) and associated impacts (RQ2) across the URCs in SEA?

Motivation for Today's Presentation Research?

➢ (1) What is the carbon footprint of my food, and (2) how can I control my carbon footprint?

➢ The answers to these questions depend on:

  ➢ how much land is used

  ➢ what food commodities are produced (plant- and animal-based, and other utility)

  ➢ what means (methods and management practices) are used to produce and process the food products

  ➢ what type of food do we consume (plant vs. animal-based food)

  ➢ where the food is produced (export/import)

➢ At the policy stage, we need a framework to address these questions and study the control options from the food sector.

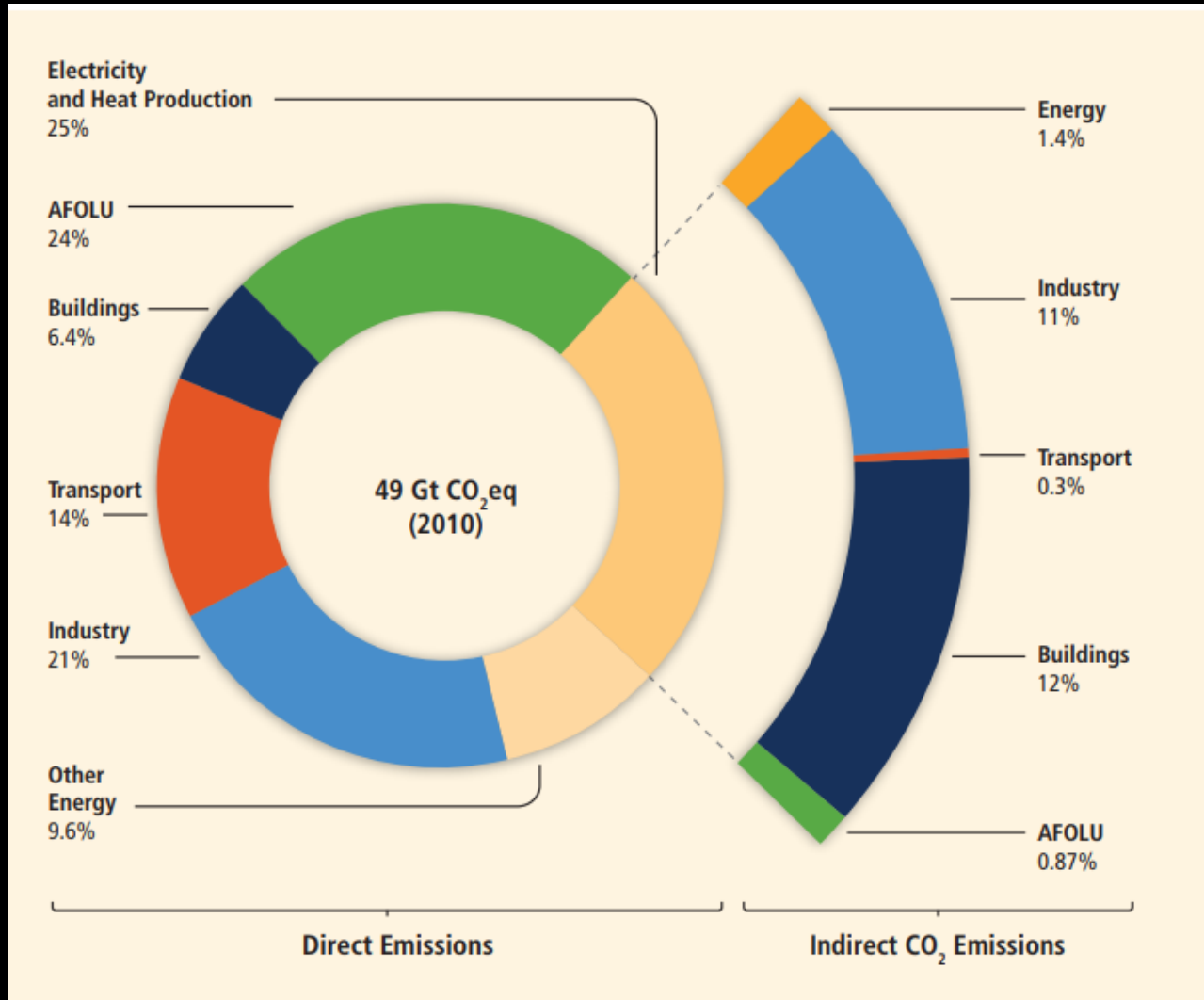# Current Global Anthropogenic GHG Emissions by Economic Sectors

Electricity and Heat Production 25%
AFOLU 24%
Buildings 6.4%
Transport 14%
Industry 21%
Other Energy 9.6%

49 Gt CO_2eq (2010)

Energy 1.4%
Industry 11%
Transport 0.3%
Buildings 12%
AFOLU 0.87%

Direct Emissions
Indirect CO_2 Emissions

- CO_2 Fossils (oil, gas and coal) and industrial processes accounted for about 60-65%
  - The agriculture sector accounted for part of total CO2 fossil emissions

- Agriculture, forestry, and other land use changed activities accounted for approximately 20-25%

- Rest 10-20%

Unit:
- *1 Gt (Giga tonne) = 1 Pg (Peta gram) = 1,000 Tg (Tera gram) = 10^{15} gram*
- *CO_2eq represents CO_2 equivalent (Combined all GHGs, including CO_2, CH_4, and N_2O)*

AFOLU: Agriculture, Forestry, and other Land Use

2010 Global and SEA Anthropogenic GHG Emissions

Electricity and Heat Production 25%
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Buildings 6.4%
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49 Gt CO_2eq (2010)

Energy 1.4%
Industry 11%
Transport 0.3%
Buildings 12%
AFOLU 0.87%

Direct Emissions

Indirect CO_2 Emissions

➢ Global Total   49.00 Gt CO2 eq/yr
➢ SEA (9%)   4.45 Gt CO2 eq/yr
                    4,450 Tg CO2 eq/yr

Unit:

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AFOLU: Agriculture, Forestry, and other Land Use

Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods

Xiaoming Xu[1], Prateek Sharma[1], Shijie Shu[1], Tzu-Shun Lin[1], Philippe Ciais[2], Francesco N. Tubiello[3], Pete Smith[4], Nelson Campbell[5] and Atul K. Jain[1]✉

Agriculture and land use are major sources of greenhouse gas (GHG) emissions but previous estimates were either highly aggregate or provided spatial details for subsectors obtained via different methodologies. Using a model–data integration approach that ensures full consistency between subsectors, we provide spatially explicit estimates of production- and consumption-based GHG emissions worldwide from plant- and animal-based human food in circa 2010. Global GHG emissions from the production of food were found to be $17,318 \pm 1,675$ TgCO$_2$eq yr^{-1}, of which 57% corresponds to the production of animal-based food (including livestock feed), 29% to plant-based foods and 14% to other utilizations. Farmland management and land-use change represented major shares of total emissions (38% and 29%, respectively), whereas rice and beef were the largest contributing plant- and animal-based commodities (12% and 25%, respectively), and South and Southeast Asia and South America were the largest emitters of production-based GHGs.

Full text available at: https://rdcu.be/cxF0z

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4087

Title	Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods
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Pubmed ID	37117472
Authors	Xiaoming Xu, Prateek Sharma, Shijie Shu, Tzu-Shun Lin, Philippe Ciais, Francesco N. Tubiello, Pete... [show]

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Today's study is mainly focused on our NASA synthesis project region (SEA)
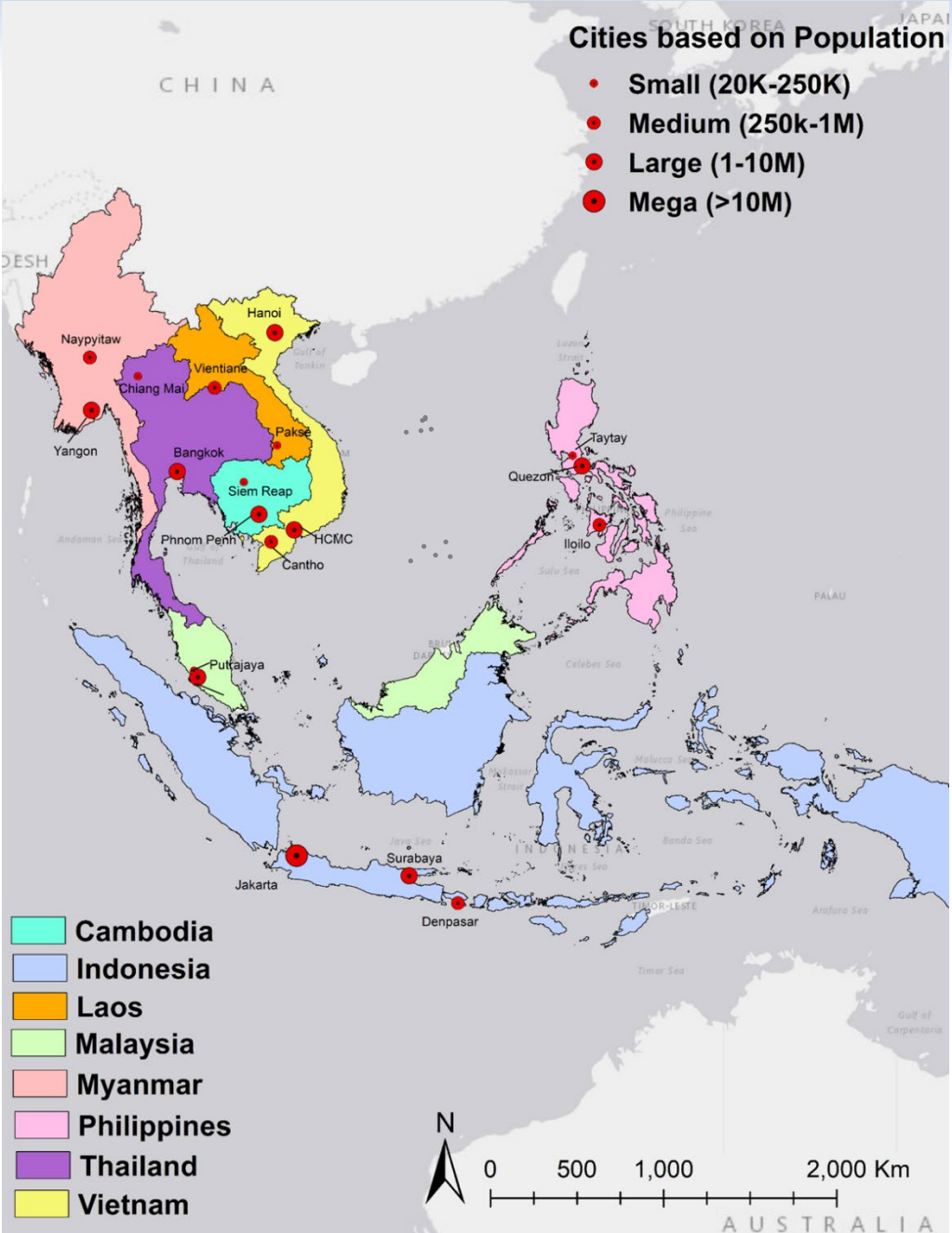
8

My presentation will address follow specific questions

➢ How does food production, plant-based and animal-based, contribute to greenhouse gas emissions?

➢ What methods are used to calculate food production greenhouse gas (GHG) emissions?

➢ How much does the food production contribute to GHG emissions?

➢ How much of the current land worldwide is used for food production?
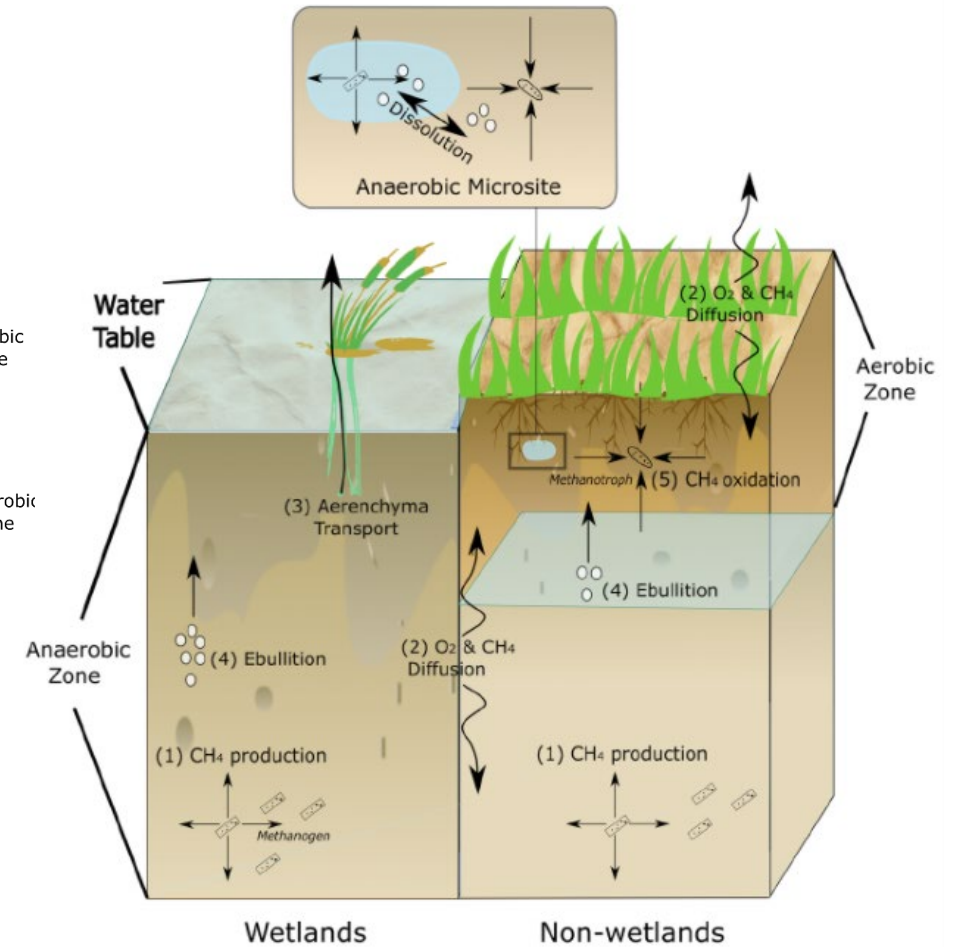
➢ What can we do to reduce food-related emissions?

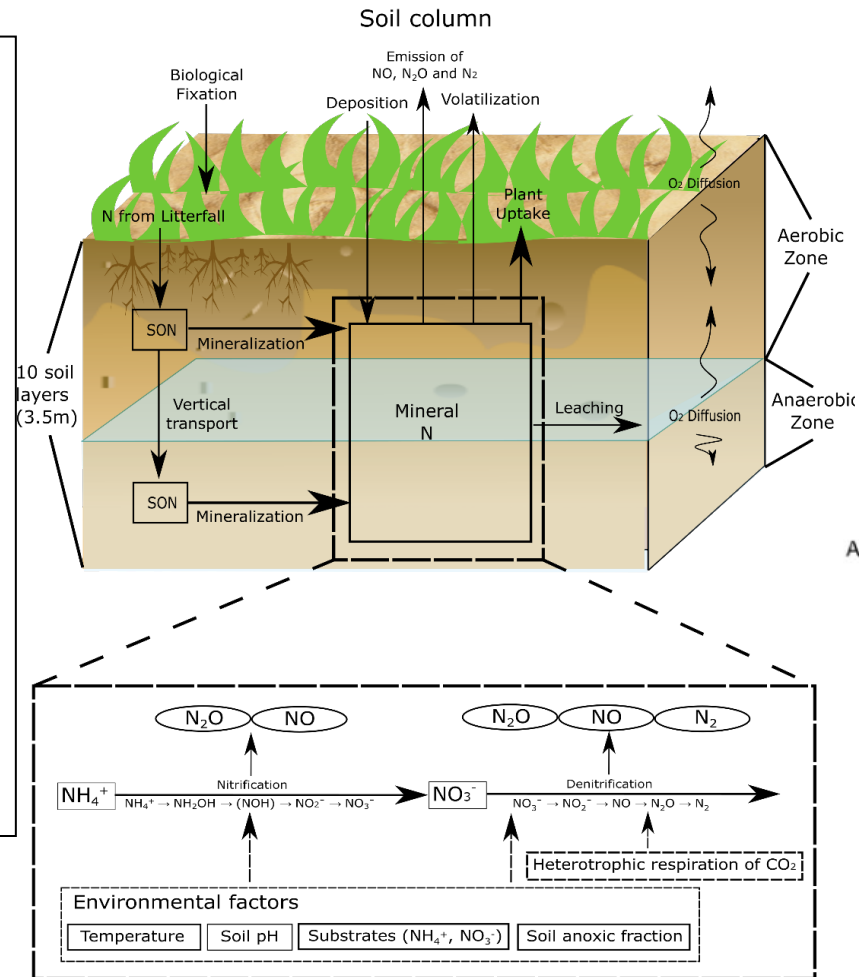# My presentation will address follow specific questions

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Production-Based GHG Emissions –
Plant-based Agriculture vs. Animal-based Agriculture

- Plant-based agriculture emissions:
  - Producing crops for human consumption, such as rice and wheat
- Animal-based agriculture emissions:
  - Producing crops for animal feed
  - Producing and maintaining grazing pastures
- To produce the same kg of food, animal-based food usually generates more GHG emissions than plant-based food
  - Wheat has emission intensity of ~2.6 kg CO_2 eq/kg and corn 2.0 kg CO_2 eq/kg
  - Beef has emission intensity of ~69.0 kg CO_2 eq/kg, and pork ~10.5 kg CO_2 eq/kg

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➢ **What methods are used to calculate food production greenhouse gas (GHG) emissions?**

➢ How much does the food production contribute to GHG emissions?

➢ How much of the current land worldwide is used for food production?

➢ What can we do to reduce food-related emissions?

Methods

- ➤ This study
  - ▪ Builds a consistent unified model-data integration framework, which calculates emissions from four sectors
    - o Beyond farmgate
      - – Mining, manufacturing, and transportation of fertilizers and pesticides
    - o LCLUC
    - o Farmland activities
      - – such as tilling the soil, planting crops, irrigation, harvesting grains, and recovering crop residues
    - o Livestock management
      - – Enteric fermentation and livestock management
  - ▪ Estimates major GHG (CO_2, CH_4, and N_2O) emissions from the production and consumption of the total and individual plant- and animal-based food at local, regional, and global scales
  - ▪ Estimates net emissions (sources – sinks) from 171 plant-based and 16 animal-based commodities

ISAM – Data - Modeling framework

CO2 Cycle Module

N2O Cycle Module

CH4 Cycle Module

Xu et al, 2021

Season 1

Season 2

Season 3

Total

Modeled rice production averaged for 2006-2015
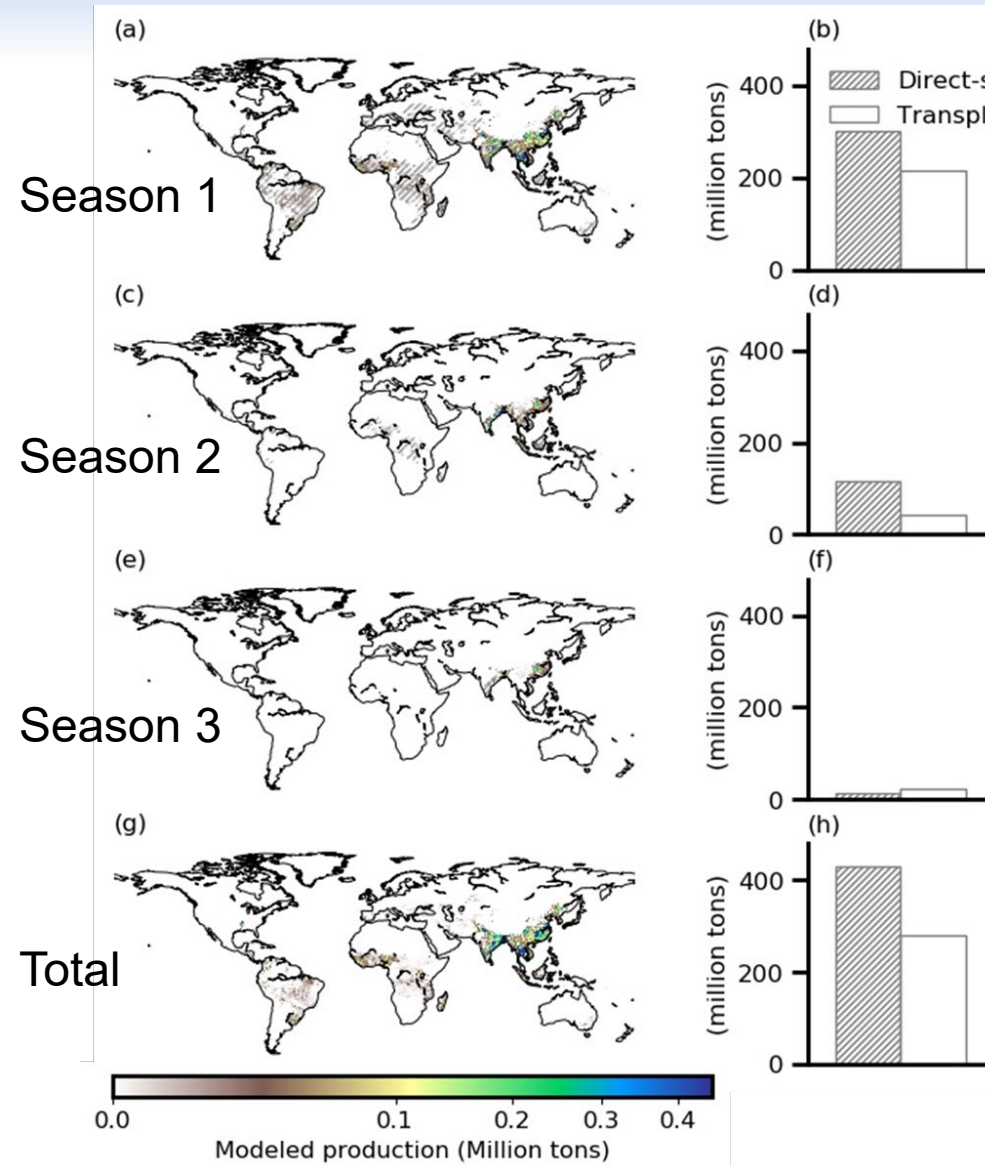
Changes in yearly global rice production due to various environmental and management factors averaged for 2006–2015*
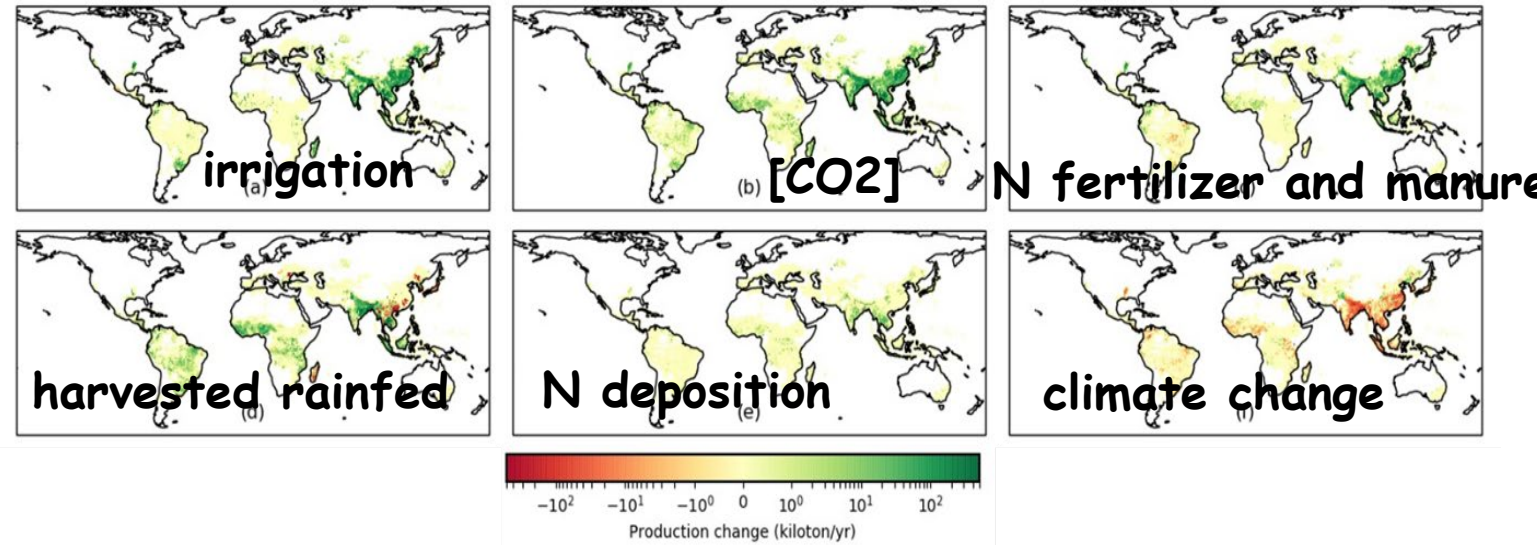
*Positive values indicate that the effect increases production

Lin et al. (2024)   15

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➤ What can we do to reduce food-related emissions?

Results at Different Scales
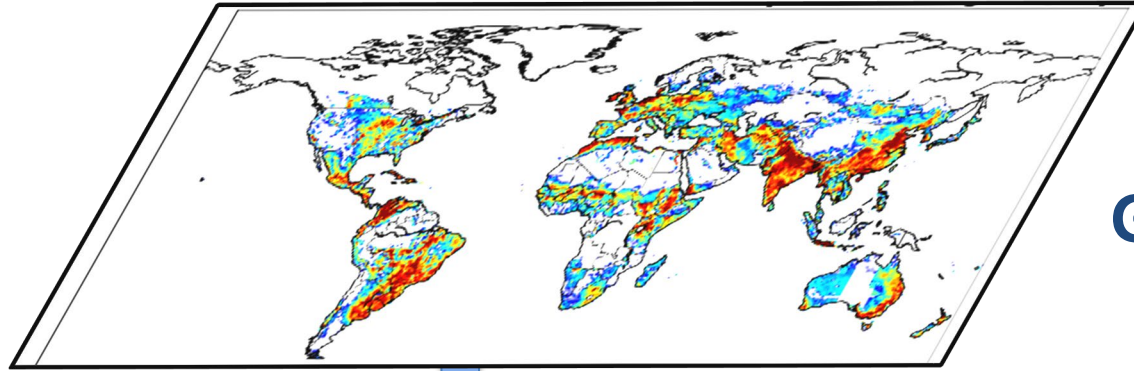
Grid, plot, or city scale
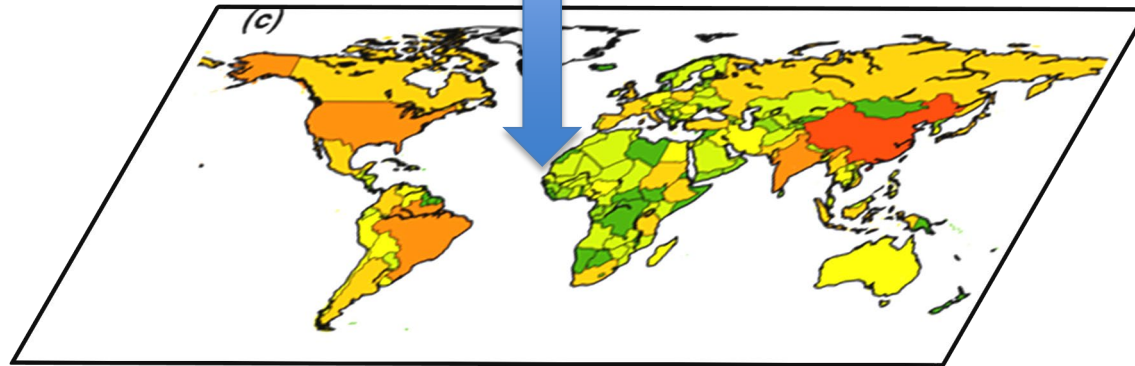
Country scale
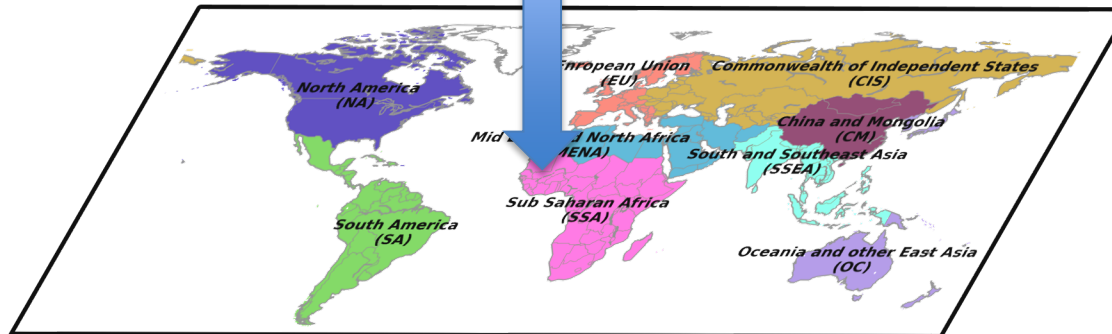
Regional scale

Results at Different Scales

Hanoi
6.33 Tg CO2 eq/yr
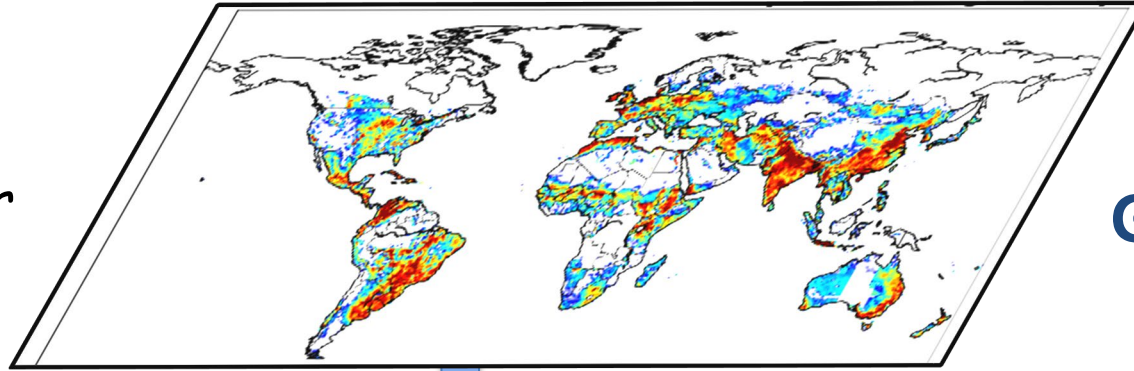
Grid, plot, or city scale

Vietnam
240 Tg CO2 eq/yr
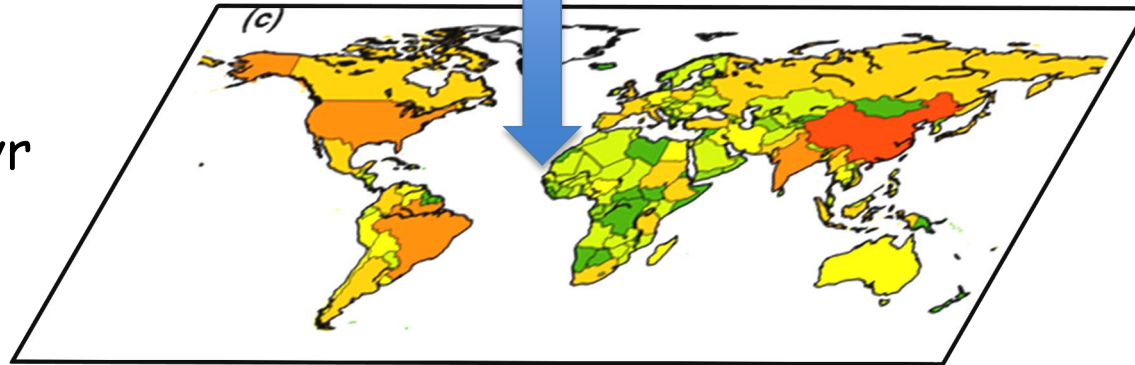
Country scale

SEA
760 Tg CO2 eq/yr
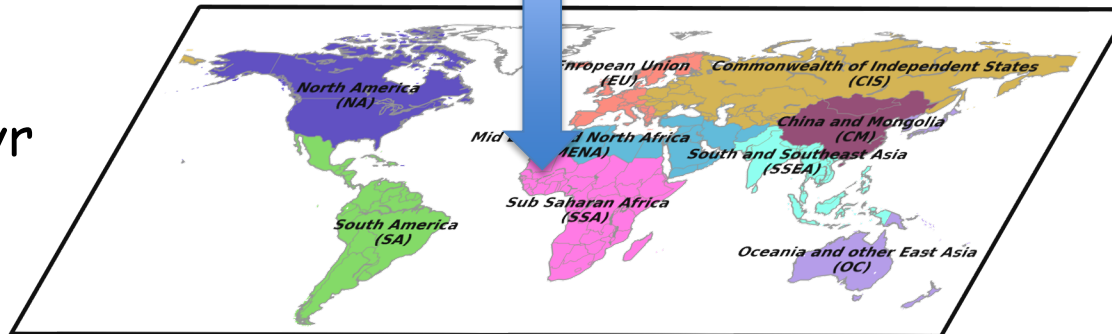
**Regional scale**

Important Facts about SEA

Total emissions

Per unit area emissions

Per capita emissions
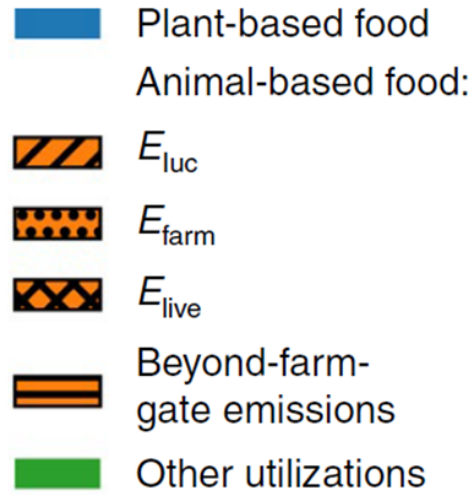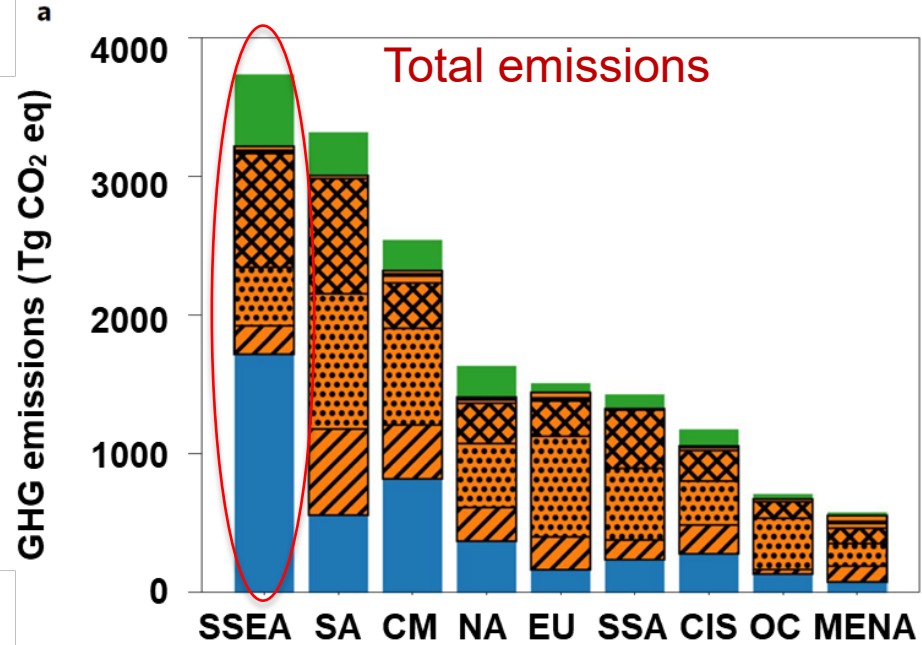
Emissions at regional levels

❑ South and Southeast (SSEA) emitted the greatest emissions (23%, SEA 11%, SA 12%)

- Largest plant-based emissions (11%, SEA 6%, SA 5%)
- Largest per unit area emissions
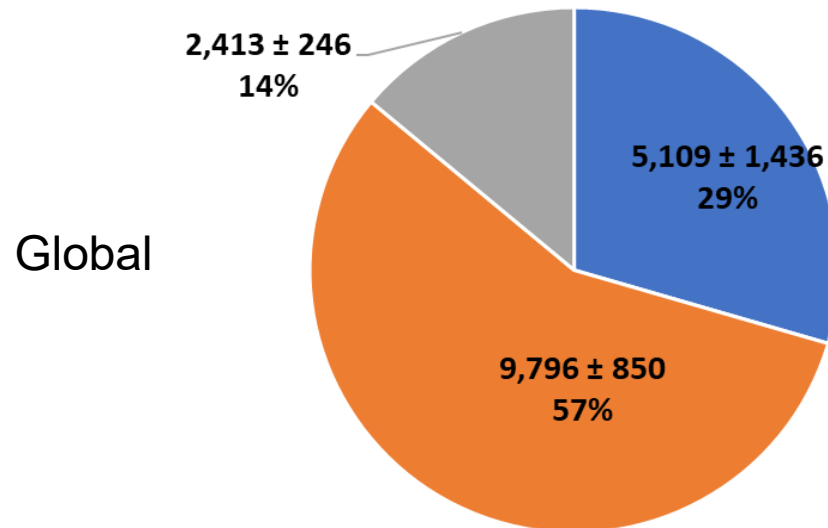- Lowest per capita emissions
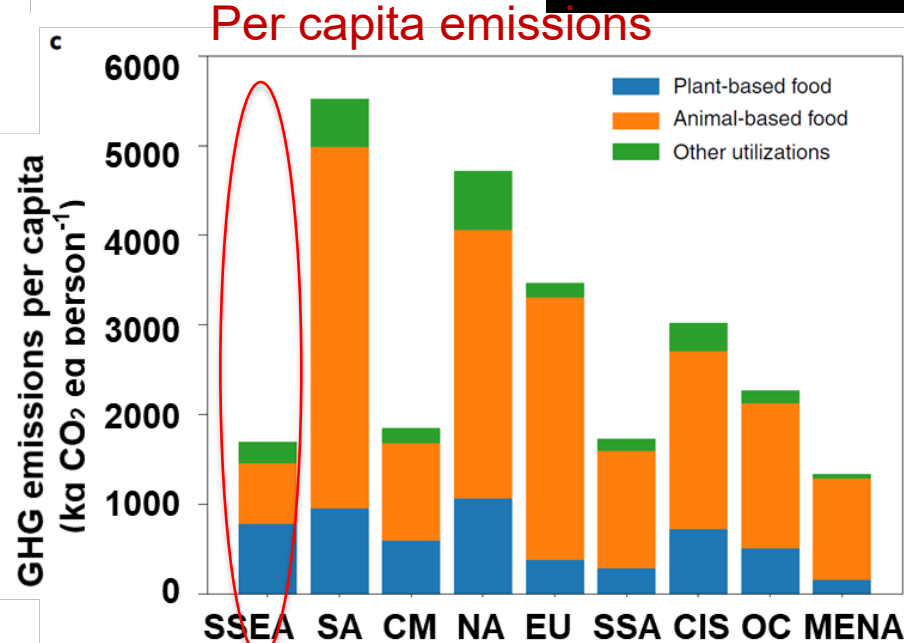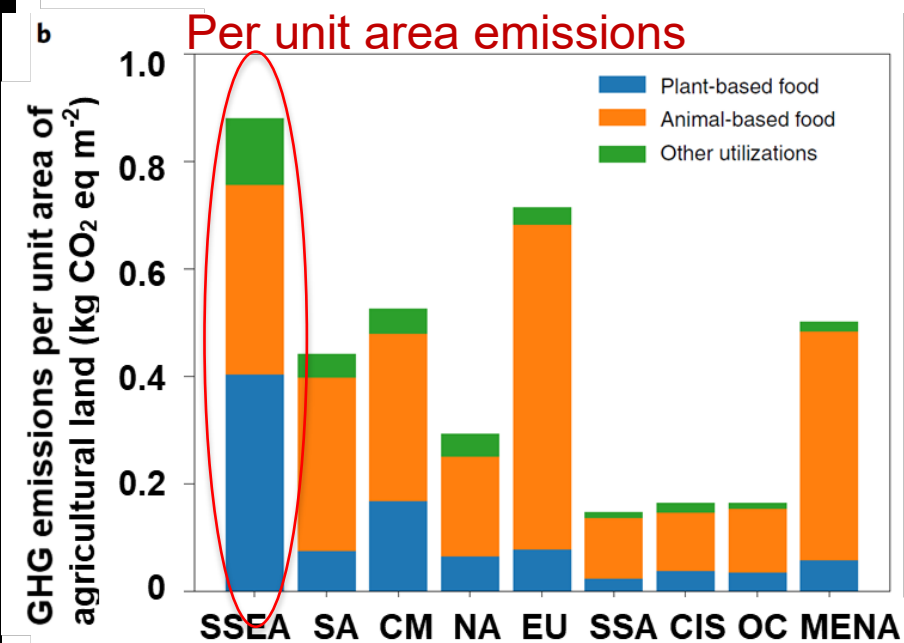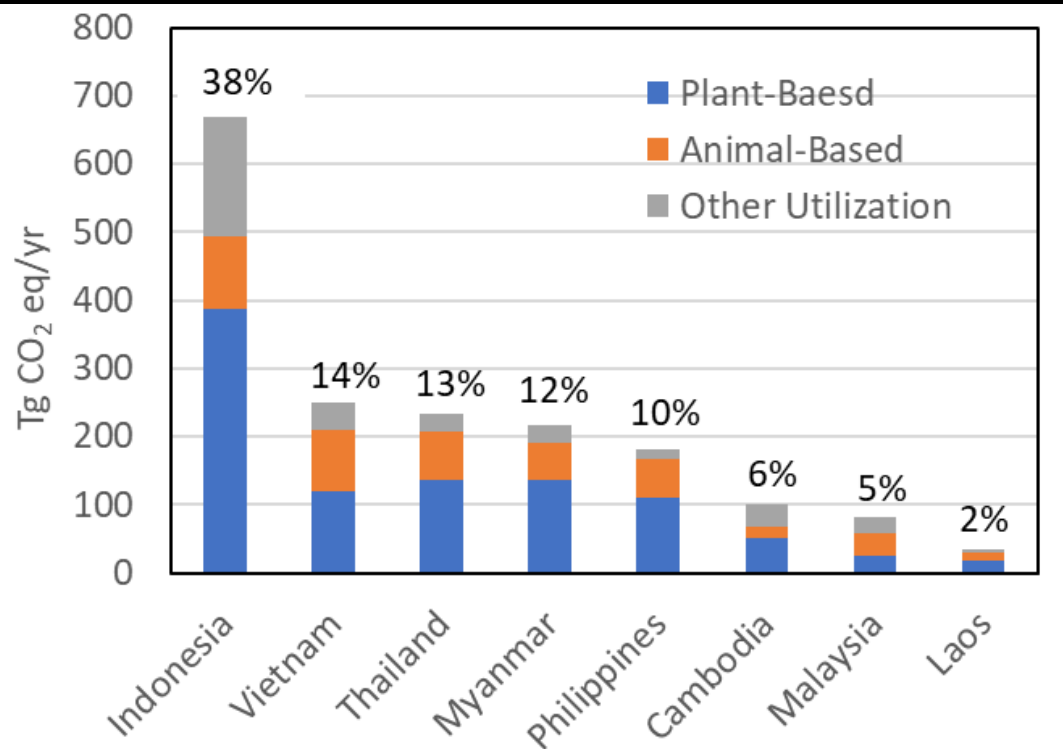
Total Emissions –SEA and Global

SEA

Global

- Plant-based food
- Animal-based
- Other utilizations
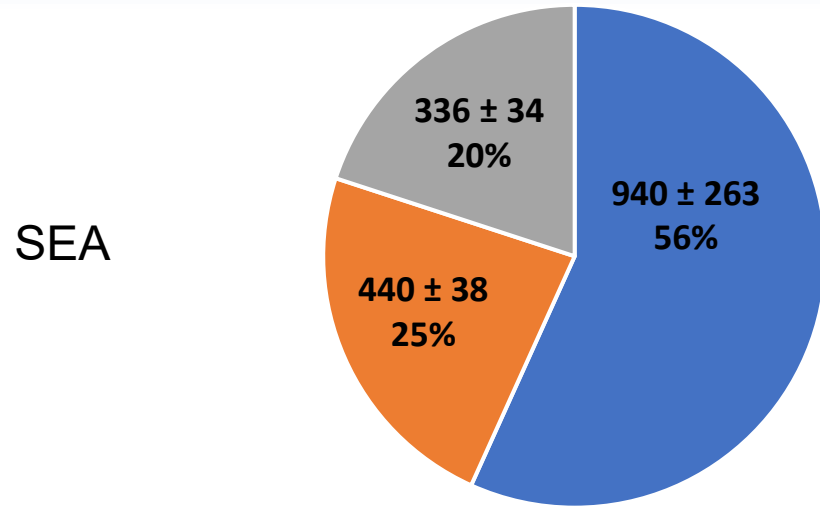
> SEA total food-related GHG emissions amount to 1,769 ± 165 $TgCO_2eq$ yr^{-1}, or 40% of total regional emissions (4,450), including:
>
> 60% CO_2 (28% PB*   11% AB**   21 O***)
> 37% CH_4 (27% PB*   10% AB**   )
> 4% N_2O (1.6% PB*   1.4 % AB**   1.0 O***)

* Plant-based **Animal-based
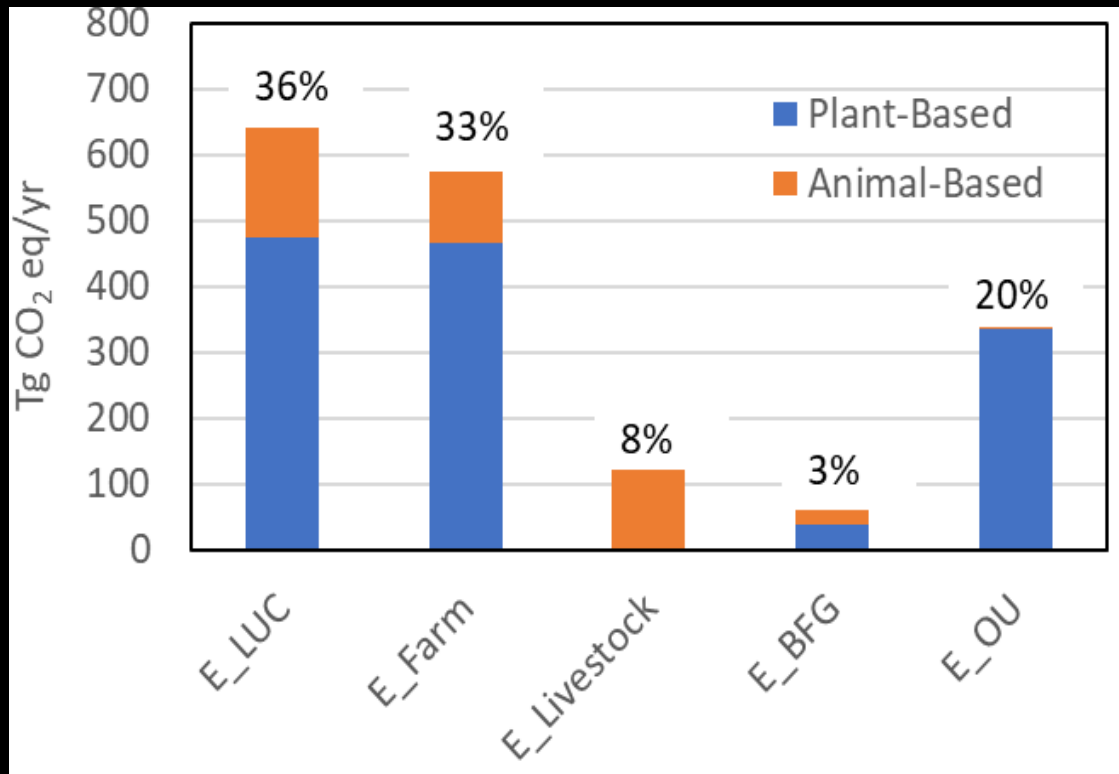
Xu et al, 2021   20

Country-Specific GHG Emissions from Food Production
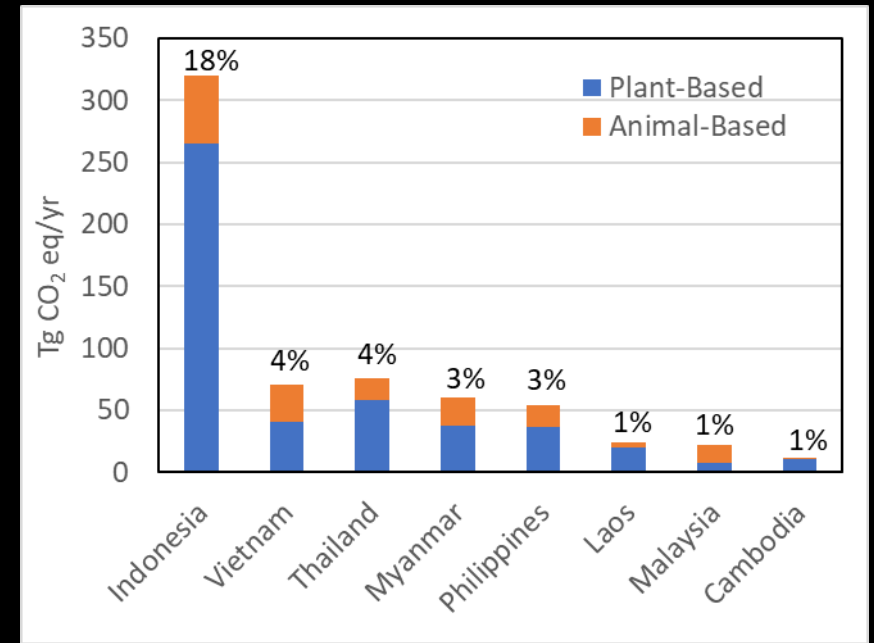

Emissions at Country level

☐ Countries with the largest plant-based emissions

- Indonesia (22%)
- Thailand (8%)
- Myanmar (8%)
- Vietnam (9%)

☐ Countries with the largest animal-based emissions

- Indonesia (6%)
- Vietnam (5%)
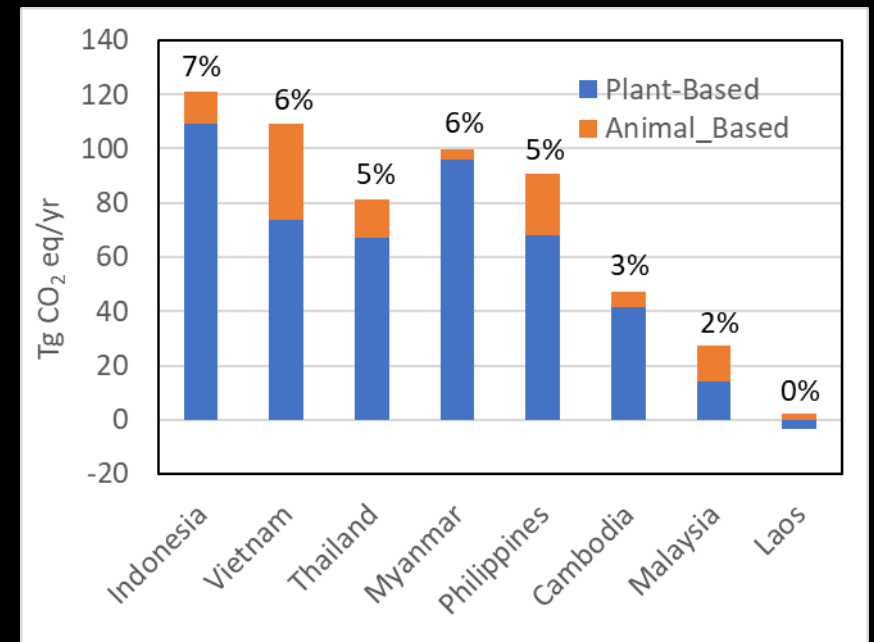- Thailand (5%)
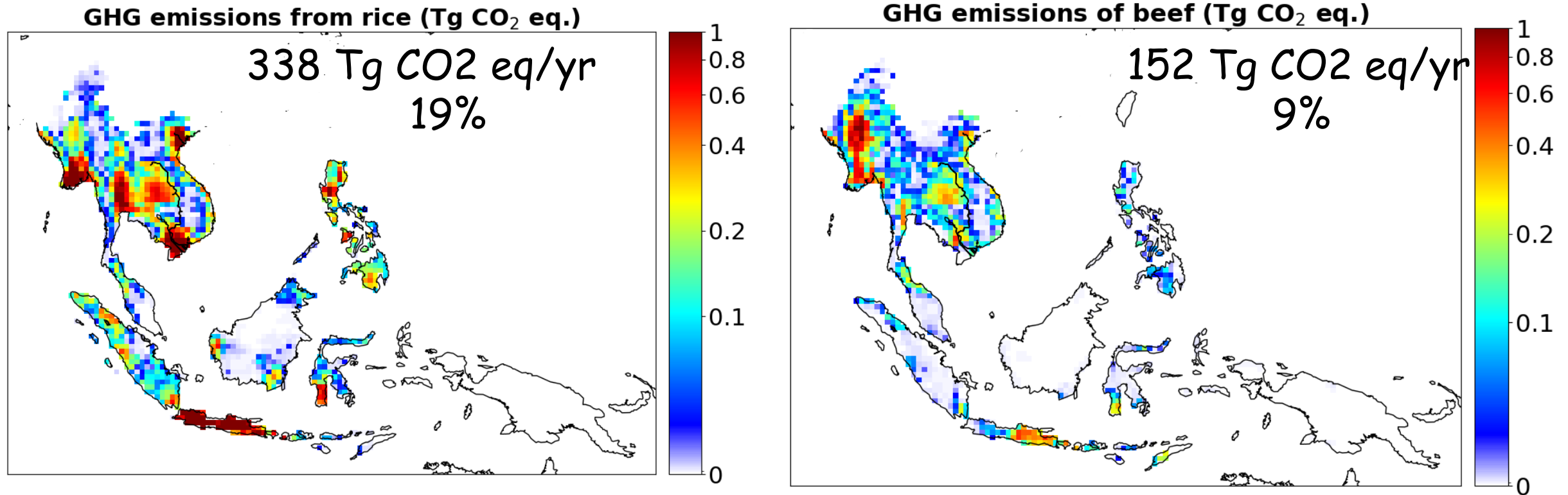- Myanmar (3%)

Emissions by sub-sectors and by country

E_LUC

E_Farm

Top Emitting Plant- and Animal-Based Food in SEA

GHG emissions from rice (Tg CO_2 eq.)

338 Tg CO2 eq/yr
19%

GHG emissions of beef (Tg CO_2 eq.)

152 Tg CO2 eq/yr
9%

These results are in contrast to the global scale number, which shows:
- Beef (25%) is the largest contributing animal-based food
- Rice (12%) is the largest contributing plant-based food

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Major Findings

- Largest per unit area emissions from the agriculture sector
- Lowest per capita emissions from the agriculture sector
- SSEA is the largest emitter of production-based GHG, particularly from the plant-based food
- Farmland activities and land use change represented major shares of total emissions (36% and 33%, respectively)
- SEA GHG emissions from the production of food were found to be 40% of total regional GHG emissions, of which 25% corresponds to the production of animal-based food and 56% to plant-based foods
- Rice and beef were the largest contributing plant- and animal-based commodities (12% and 25%, respectively)

Acknowledgements

Philippe Ciais   Francesco N. Tubiello   Pete Smith   Nelson Campbell

LSCE, France   *FAO, Italy*   *U. Of Aberdeen, UK*   *PlantPure, USA*

Extra Slides

Background: GHG Emissions from Food Production due to LCLUC and Farm *Activities*

E_{LUC} E_{FARM}

Net Primary Production (CO_2 uptake)

N_2O, NO_x

CH_4

CO_2, CO, NMVOC

N_2O

CH_4

Beyond Farm Gate Activities

CH_4

Harvest

Biomass

Fire

CO_2

Manuring

N fixation

Fertilizer

CO_2

Beyond Farm Gate Activities

HWP

Litter

Soil respiration

Rice

Soil Carbon
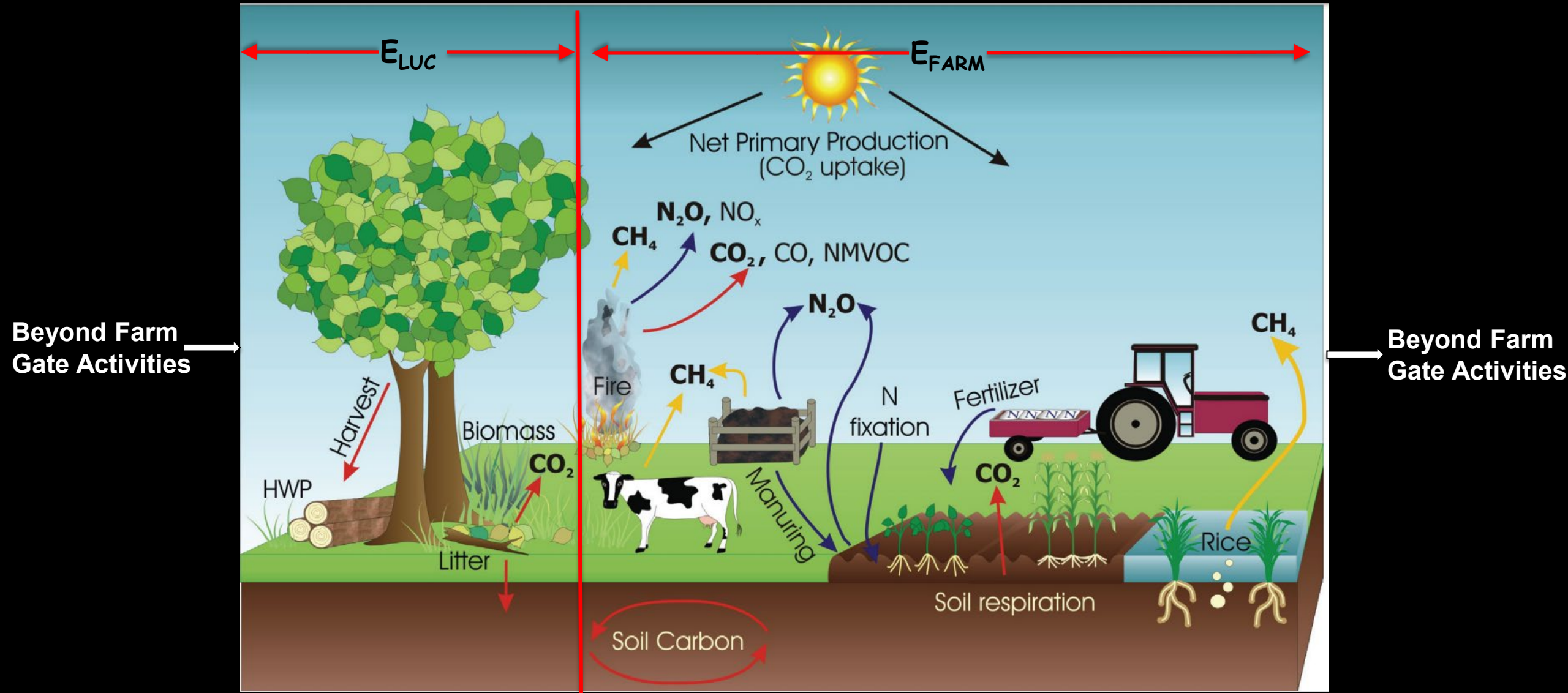
Production-based GHG Emissions: Sub-sectors

- **Beyond the farm gate (E_{bfg})**
  - Mining, manufacturing and transportation of fertilizers and pesticides
  - Food processing

- **Land use change (E_{luc})**
  - Cropland
  - Grazing land

- **Farmland activities (E_{farm})**
  - Farming practices, such as ploughing the soil, planting crops, irrigation, harvesting grains, and recovering crop residues
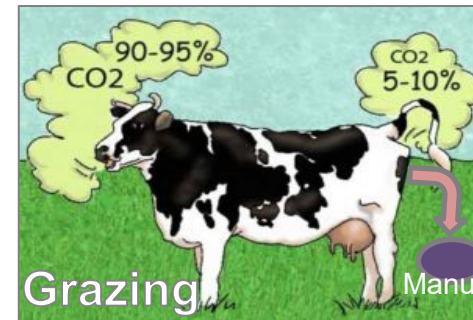

- **Livestock (E_{live})**
  - Enteric fermentation
  - Manure management

Xu et al, 2021

Background: Beyond Farm Gate Activities

Mining **Manufacturing** **Transporting**

Fertilizer
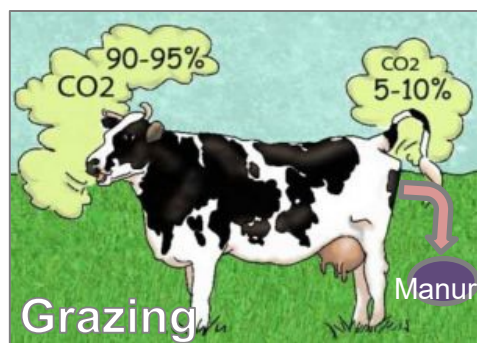
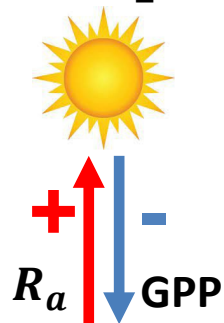**Farm Activities** **Processing**

Beyond Farmgate Activities (BFG) BFG
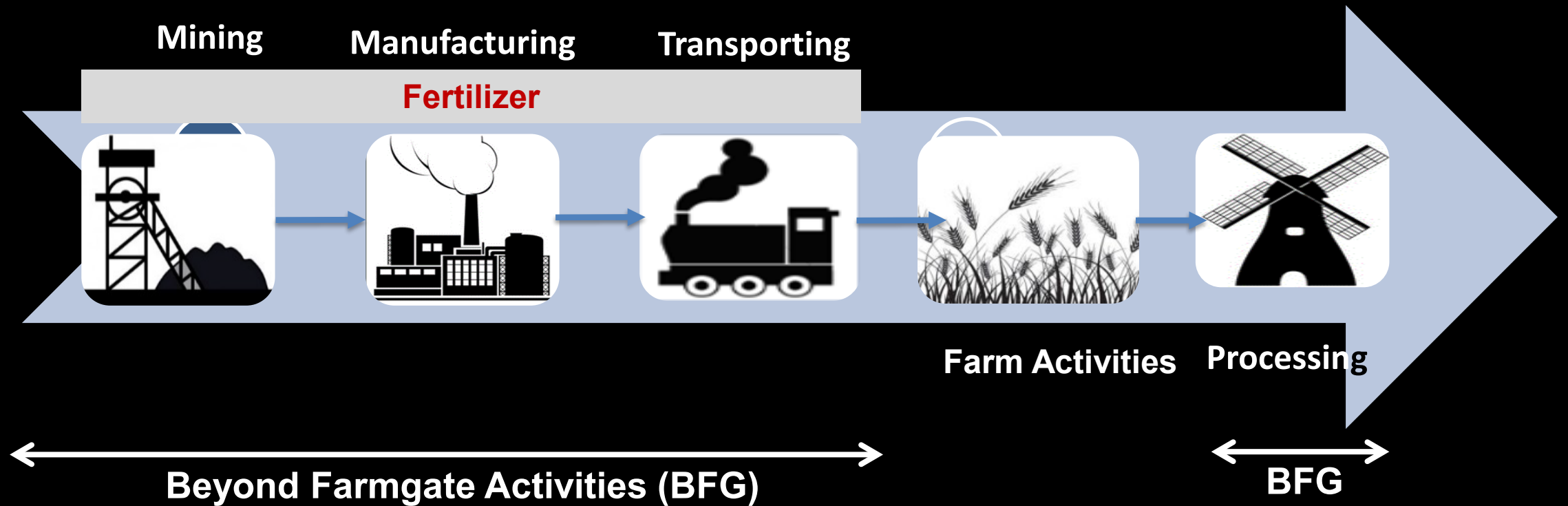
Production-based Emissions: Example of $E_{farm}\ CO_2$

$$E_{farm}\ CO_2 = R_a + R_h + E_{h\_CO2} + E_{t\_CO2} + E_{w\_CO2} - GPP$$

Net CO_2 flux
+ (Source)
- (Sink)

R_a GPP

E_{h_CO2} +

90-95% CO_2

CO_2 5-10%

Grazing

Manure

E_{t_CO2} +

Tillage

R_h +

CO_2 CO_2 CO_2

Soil respiration

E_{h_CO2} +

Harvest & Recovered Residue

E_{w_CO2} +

Left biomass burned

Xu et al, 2021
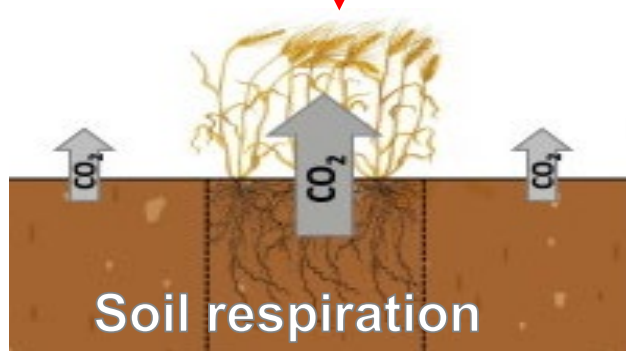
Land Management Practices on Cropland

❑ Harvested crop grain and residue treatment