COLLEGE OF AGRICULTURE AND LIFE SCIENCES VIRGINIA TECH.

CENTER FOR AGRICULTURAL TRADE

A Cross-Country Stock-Taking of GHG Emission Footprints in Major Agricultural Commodities

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USDA OFFICE OF THE CHIEF ECONOMIST

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Introduction

- Agriculture and LU/LUC emissions amounted to 13 Gt CO_2 equivalent per year globally, accounting for 24% of total GHG emissions (Crippa *et al*., 2021)
- (COP 28) Sustainable agriculture as a part of actions to address climate change
  - COP28 UAE Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action (endorsed by nearly 160 countries, including the United States)
- Globally, ag. production and trade is much more widely dispersed than it was historically
- Need for accurate understanding of our assumptions regarding emission intensities across countries and products

Research Objectives

1. **Agricultural Emissions Stocktaking**: what is the range of GHG emission intensity estimates currently being used (literature, international modeling communities, and subscription-based LCA database)?

2. **Key Sources of Variation**: what are main sources of variation of emission intensities in agriculture?

   - Across emission intensities currently being used/modeled
   - GHG emission footprints across countries

3. **(Future) Role of Trade**: can trade policy reduce global GHG Emissions by encouraging sustainable production practices and/or sourcing products from lower-carbon footprint countries

   - While at the same time meeting SDG goals for food and nutrition security

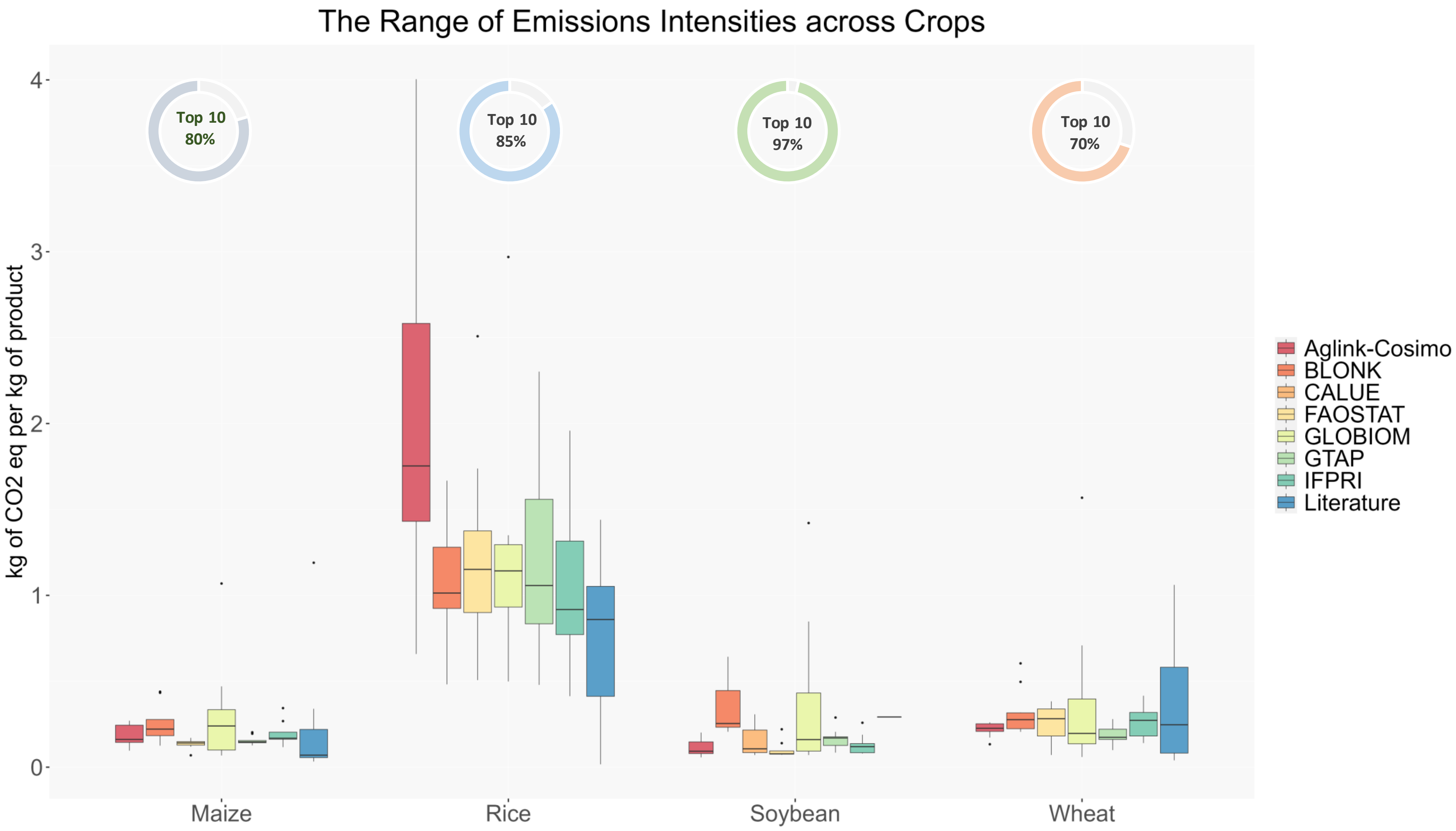
Data Collection

- Collected emissions from 10 different sources
  - Literature: 45 studies, 55 individual emission intensity factors
  - Subscription-based LCA database: BLONK-Agri-Footprint v6
  - International modelling communities: FAO, CALUE, GCAM, GLOBIOM, GTAP, IFPRI, OECD
  - National accounting framework: UNFCCC
- Major agricultural products
  - CROPS: Maize, wheat, soybean, rice
  - LIVESTOCK: Beef, chicken, pork, milk
- Country Selection:
  - Currently - major countries based on production and export (top 10 countries in each category)

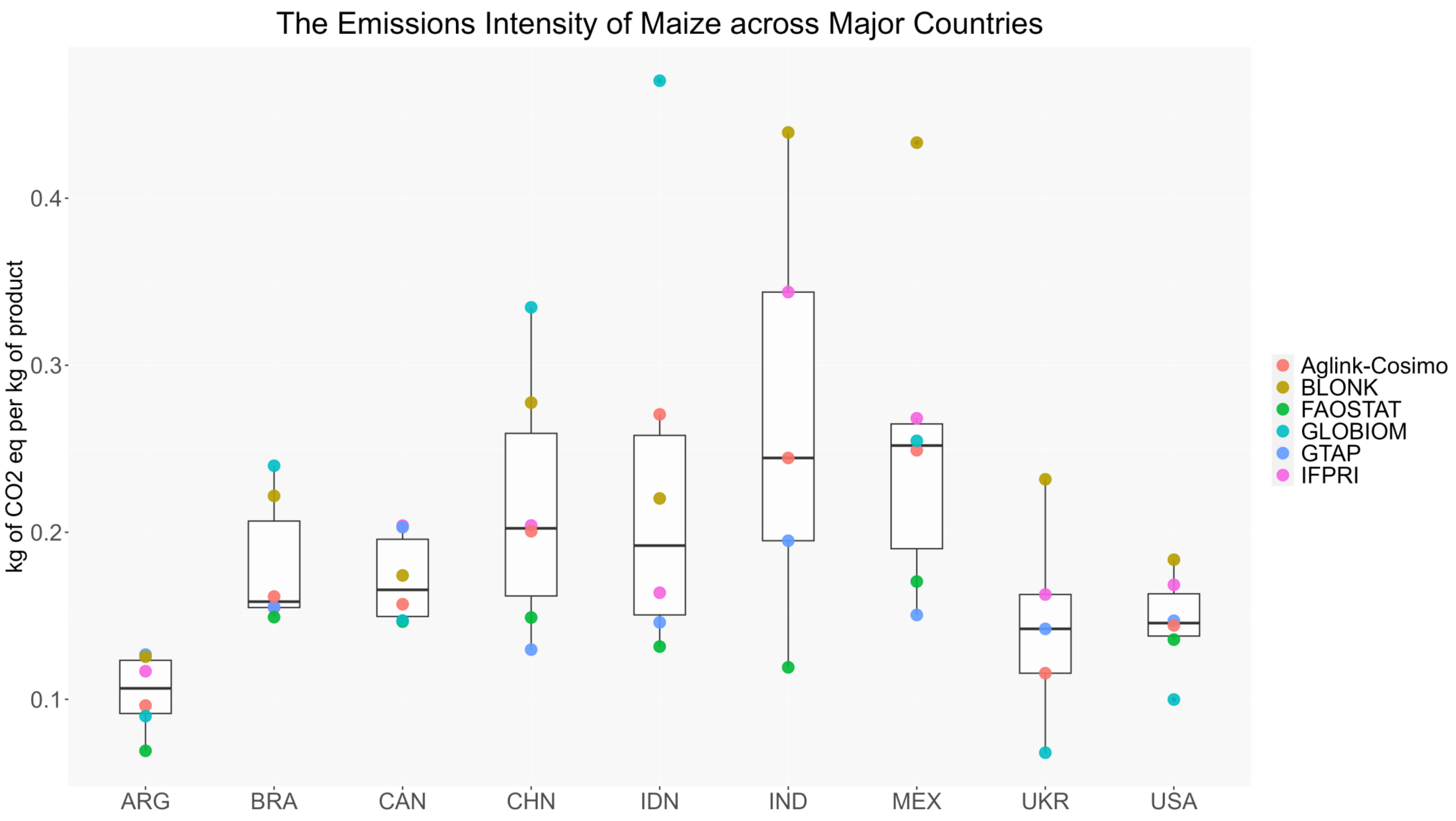
Crops: Database Sources and Key Differences

Data Source	Accounting Method	Modelling method	GWP	Underlying data	Crops / crop groups
Blonk	IPCC 2019 Tier 1	LCA	AR5	Literature, FAOSTAT, Eurostat, etc.	Maize, Rice, Wheat, Soybeans
CALUE	IPCC 2019 Tier 1	Formula based	AR5	FAOSTAT	Cereals and Oil seeds
FAOSTAT	IPCC 2019 Tier 1	Formula based	AR5	FAOSTAT	Maize, Rice, Wheat, Soybeans
GCAM	IPCC 2019 Tier 1	Model based	AR5	EDGAR, FAOSTAT, CEDS	All crops
GLOBIOM	IPCC 2006 Tier 1	Modelled based	AR5	FAOSTAT	Maize, Rice, Wheat, Soybeans
GTAP	IPCC 2006 Tier 1	Model based	AR4	FAOSTAT	Maize, Rice, Wheat, Soybeans
IFPRI	IPCC 2006 Tier 1	Model based	AR2	FAOSTAT, IFASTAT	Cereals (includes corn), Rice, Wheat, Soybeans
Literature	Variable	Variable	Variable	Variable	Maize, Rice, Wheat, Soybeans
Aglink-Cosimo	IPCC 2006 Tier 1	Model based	AR4	FAOSTAT, IFASTAT	Maize, Rice, Wheat, Soybeans
UNFCCC	IPCC 2006 & 2019 Tier 1 - 3	Formula Based	AR5	Variable by country	All crops (GHG emissions for rice cultivation associated only with rice)

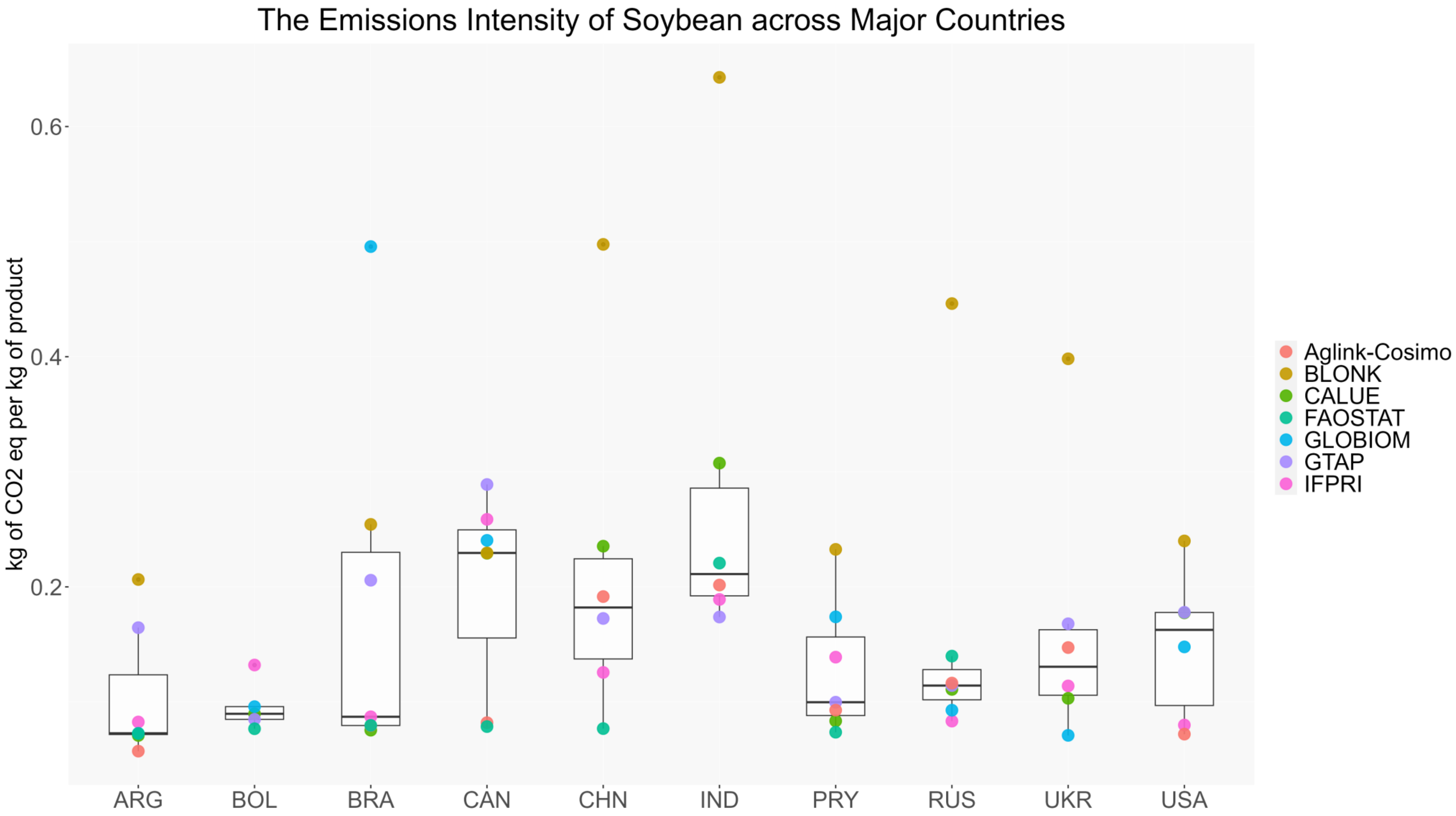
Range of Crop Emission Intensities



Source: Aglink-Cosimo (2018), BLONK (2017), FAOSTAT (2017), GLOBIOM (2020), GTAP (2018), IFPRI (2017), Literature (various).
Note: The box plot includes top 10 countries in production based on the average production quantity between 2017 and 2021. The box plot shows the inter-quartile range of lower quartile and upper quartile, median (solid line inside the box), and whiskers (solid line outside the box, 1.5 times the interquartile range). The emission intensity for soybean in FAOSTAT is calculated with emission data on crop residues and synthetic fertilizer application, following its methodological note for cereal grains. The emissions intensity of oil seeds in CALUE is used for soybean. For GTAP and IFPRI, emissions from the sector, *gro*, is used to estimate the emission intensity of maize with the production quantity of cereal grains categorized in the sector; similarly, oil seeds in the sector, *osd*, is used to estimate the emission intensity for soybean with the production quantity (FAOSTAT). The pie chart refers to the share of top 10 producing countries in the total production quantity. Only farm gate emissions are considered (land use change emissions are excluded).



Source: BLONK (2017), FAOSTAT (2017), GLOBIOM (2020), OECD (2018).
Note: The box plot includes only top 10 countries based on the average production quantity between 2017 and 2021. The box plot shows the inter-quartile range of lower quartile and upper quartile, median (solid line inside the box), and whiskers (solid line outside the box, 1.5 times the interquartile range). For GTAP and IFPRI, emissions from the sector, *gro*, is used to estimate the emission intensity of maize with the production quantity of cereal grains categorized in the sector. Countries with the emission intensity greater than 0.9 kg of CO2 eq per kg of maize are excluded in the box plot. Only farm gate emissions are considered (land use change emissions are excluded).



Source: Aglink-Cosimo (2018), BLONK (2017), CALUE (2017), FAOSTAT (2017), GLOBIOM (2020), GTAP (2018), IFPRI (2017).
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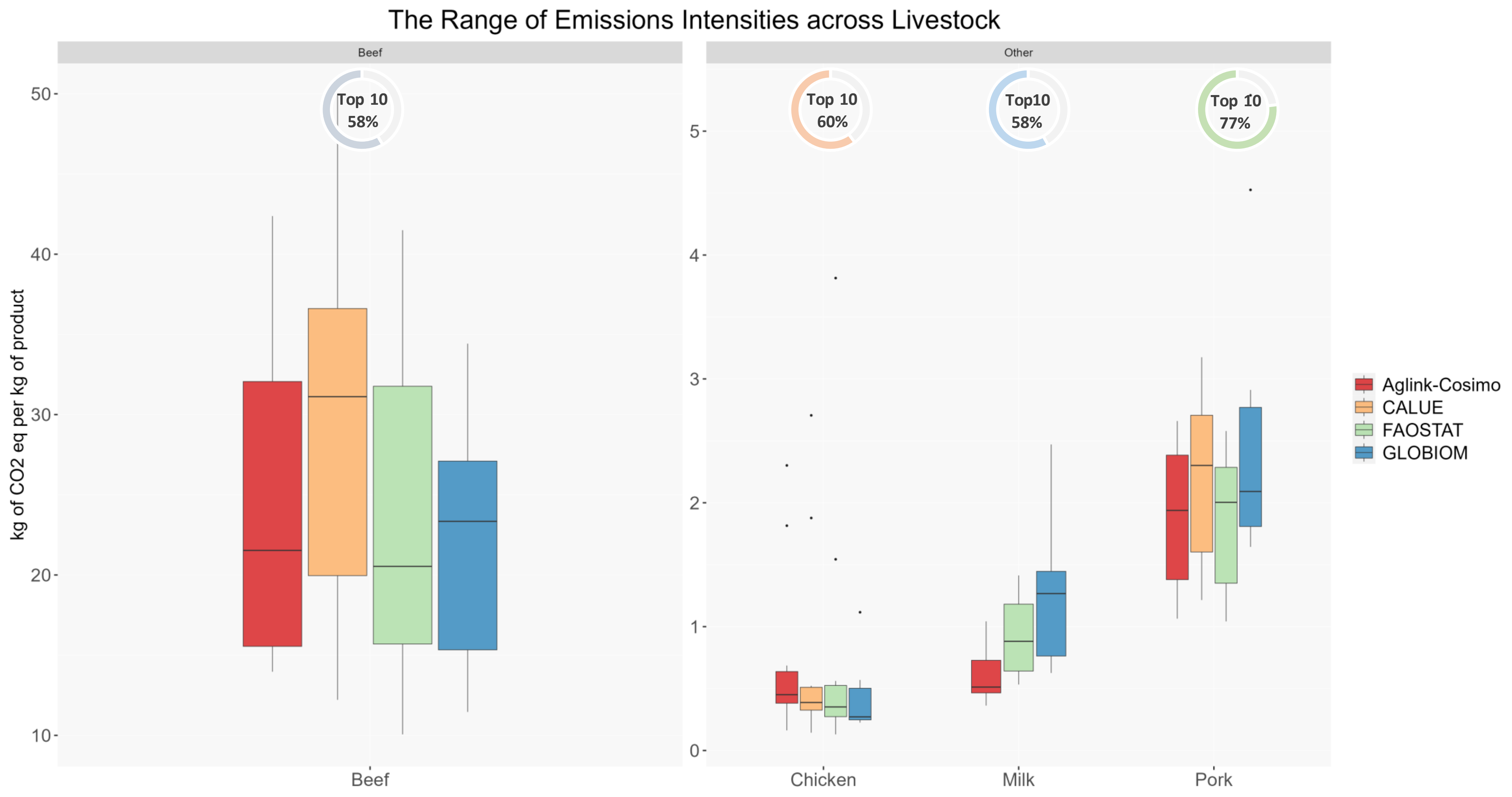
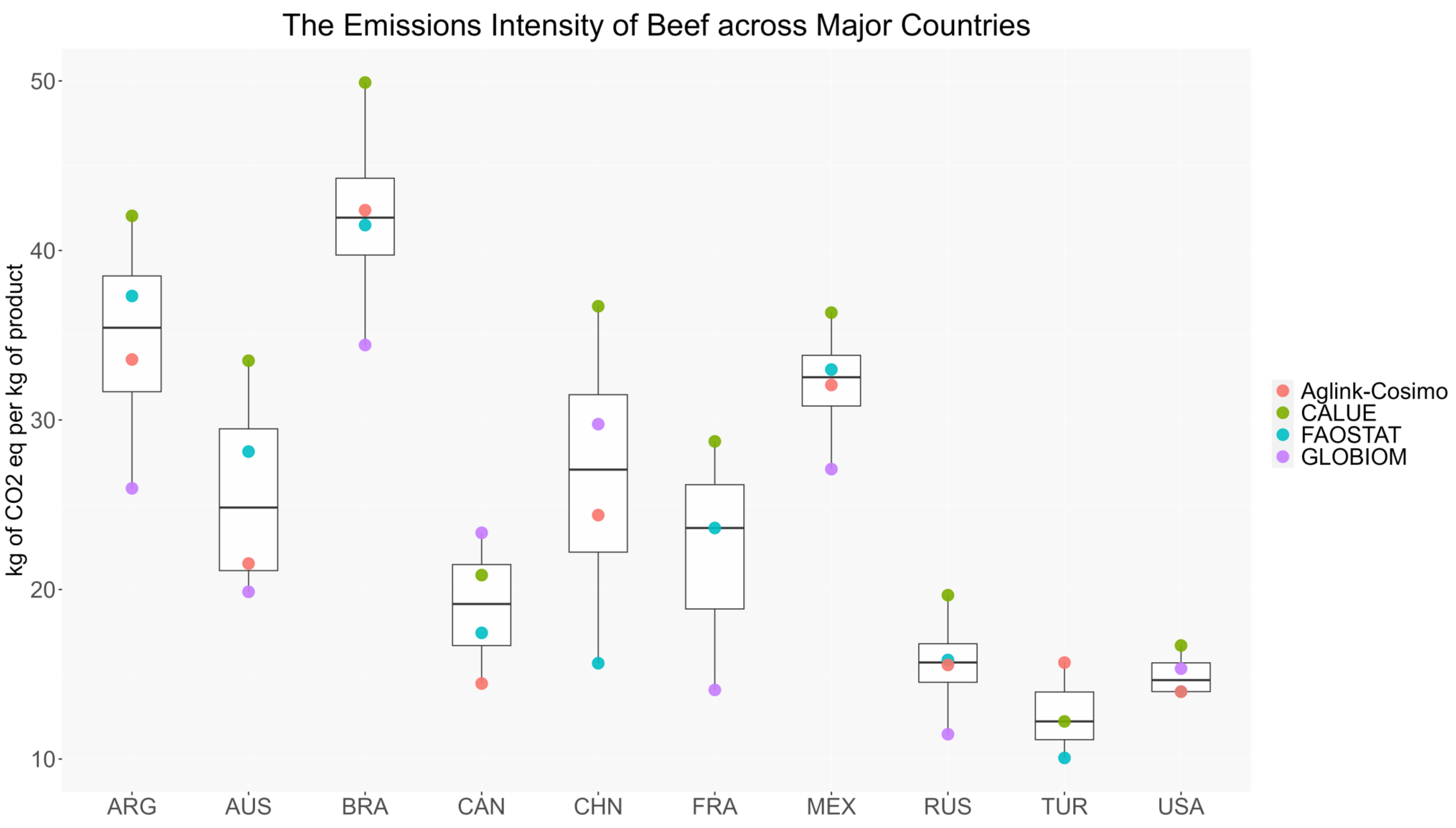
Range of Livestock Emission Intensities

- Higher emission impacts in livestock compared to crop; high share of CH_4 emissions from enteric fermentation



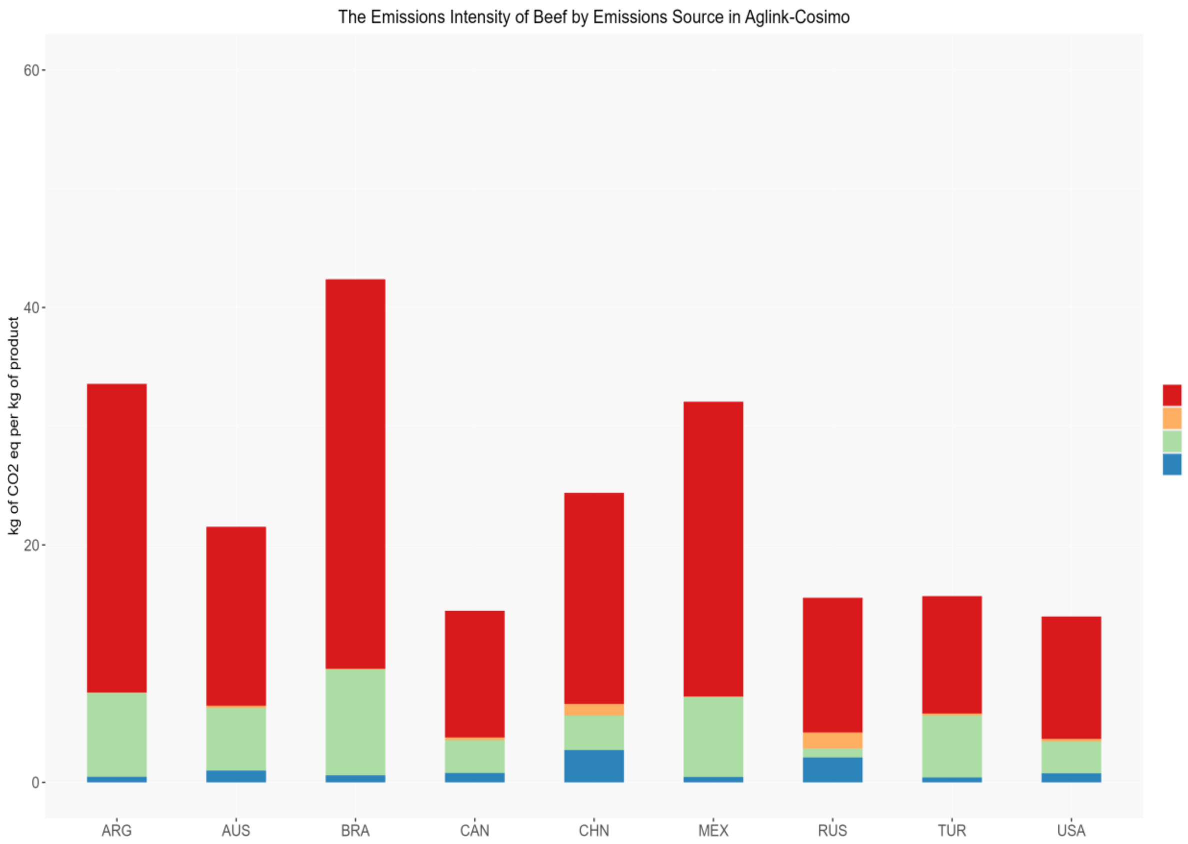
Source: Aglink-Cosimo (2018), CALUE (2017), FAOSTAT (2017), GLOBIOM (2020).

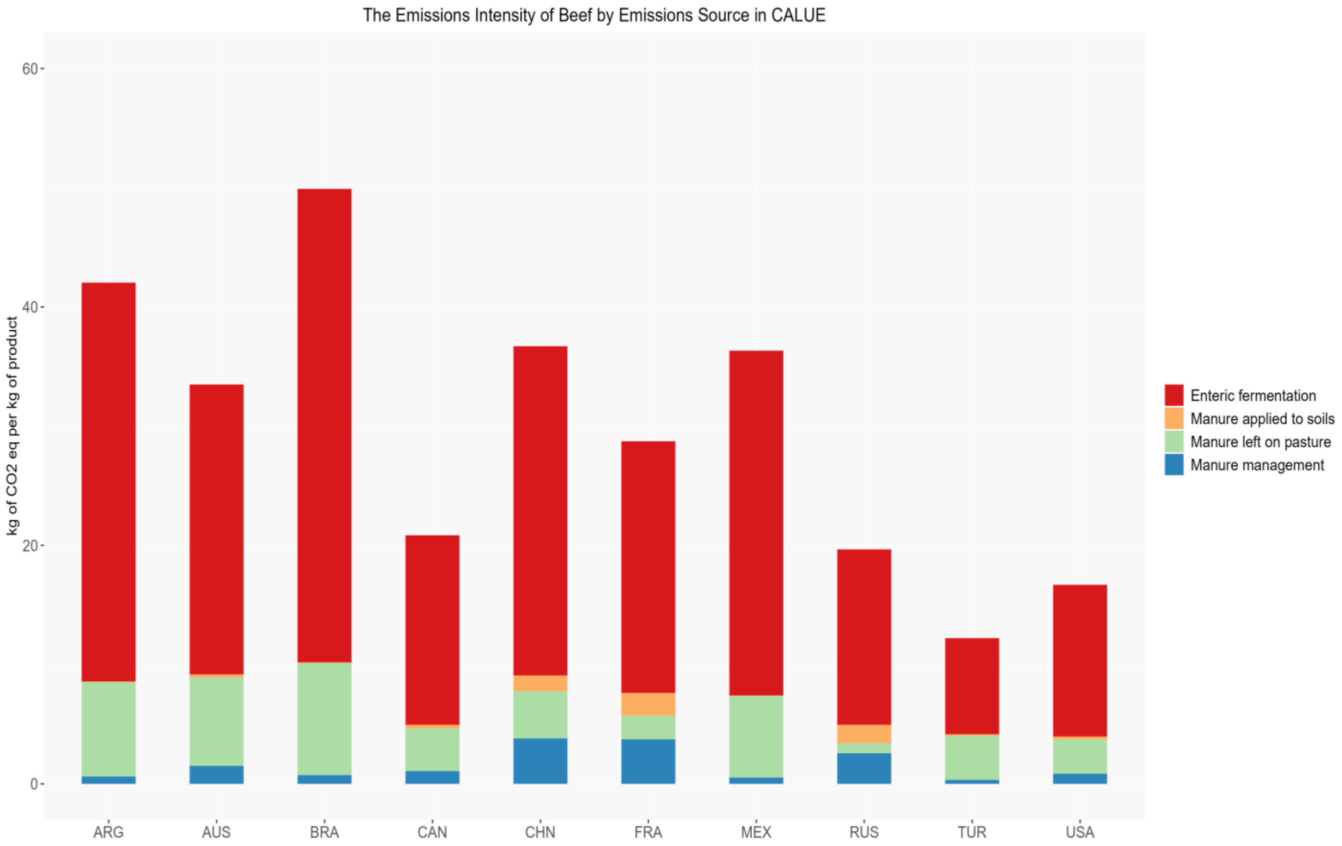
Note: The box plot includes only top 10 countries based on the average production quantity between 2017 and 2021. The box plot shows the inter-quartile range of lower quartile and upper quartile, median (solid line inside the box), and whiskers (solid line outside the box, 1.5 times the interquartile range). The pie chart refers to the share of top 10 producing countries in the total production quantity. Only farm gate emissions are considered (land use change emissions are excluded).



Source: Aglink-Cosimo (2018), CALUE (2017), FAOSTAT (2017), GLOBIOM (2020).
Note: The box plot includes only top 10 countries based on the average production quantity between 2017 and 2021. The box plot shows the inter-quartile range of lower quartile and upper quartile, median (solid line inside the box), and whiskers (solid line outside the box, 1.5 times the interquartile range). Only farm gate emissions are considered (land use change emissions are excluded).

Beef Emission Intensities by Emission Source





Variance Decompositions & International Trade

- Investigate variation of emission intensities across countries and versus sources of emissions data

Analysis of Variance of Emissions Across Data Source and Country

Product	Variable	Share	p-value
Maize	Dataset	0.33	0.05
	Country	**0.67**	0.01
Wheat	Dataset	0.20	0.30
	Country	**0.80**	0.01
Soybean	Dataset	0.50	0.00
	Country	0.50	0.01
Rice	Dataset	0.28	0.00
	Country	**0.72**	0.00
Beef	Dataset	0.05	0.00
	Country	**0.95**	0.00
Chicken	Dataset	0.03	0.06
	Country	**0.97**	0.00
Pork	Dataset	0.17	0.00
	Country	**0.83**	0.00
Milk	Dataset	0.35	0.00
	Country	**0.65**	0.01

Includes AgLink Cosimo, BLONK, CALUE, FAOSTAT, GLOBOIM, GTAP, IFPRI

Includes AgLink Cosimo, CALUE, FAOSTAT, GLOBOIM

Variation in emission intensities in the data more significant across countries

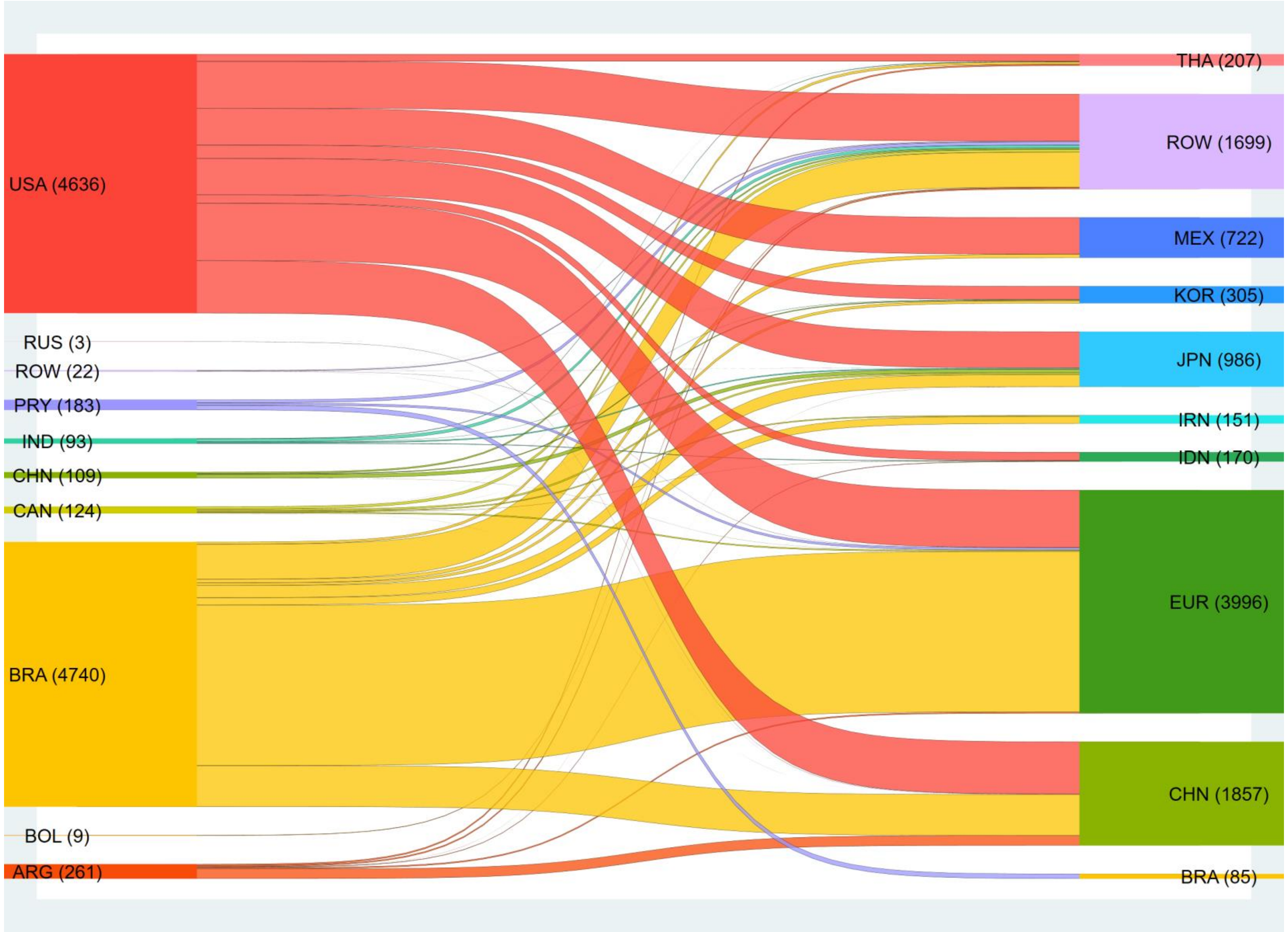
More cross-data source variation of emission intensities for soybeans

Source: Aglink-Cosimo (2018), BLONK (2017), CALUE (2017), FAOSTAT (2017), GLOBIOM (2020), GTAP (2018), IFPRI (2017).
Note: The results is based on the regression of the emission intensity of a crop on countries and datasets. Share is the ratio of the sum of squares for each variable to the explained sum of squares.

GHG emissions in crop and livestock trade

- Agricultural trade ↑ by 7-8% annually
  - (Soybean) 70-80% of production is exported to another place from where it was produced
- Ag. trade allows products produced in one country to be consumed elsewhere, separating consumption from its environmental impacts
  - Thus, trade can be either a mitigating or intensifying force driving global emissions.
  - Shifts in trade (changes in the composition of origins for import)
  - Trade policies can alter the level of imported emissions

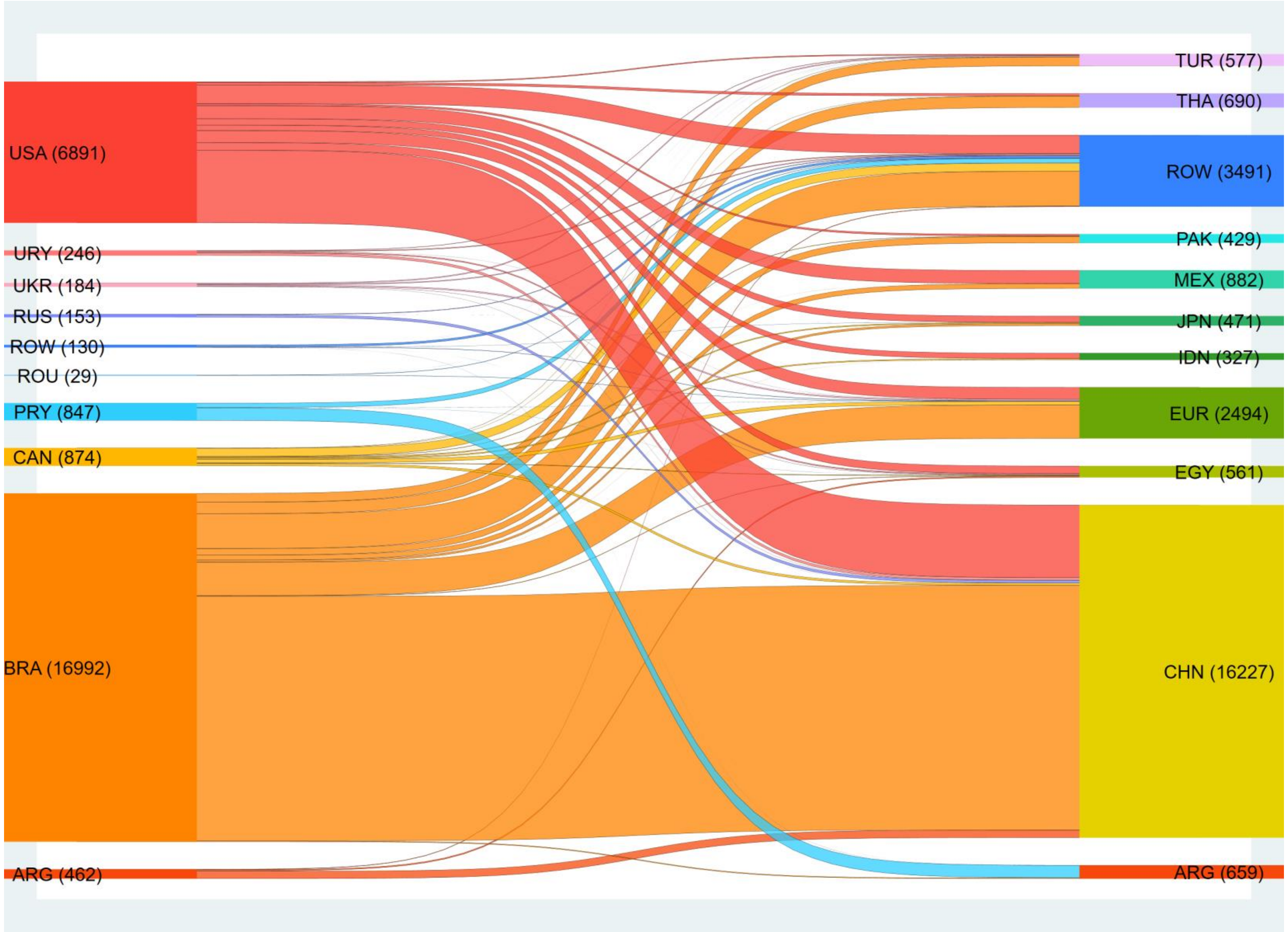
Flow of emissions (10 MMT) embodied in soybean trade in 2000



Source: FAOSTAT (2000), GLOBIOM (2000).

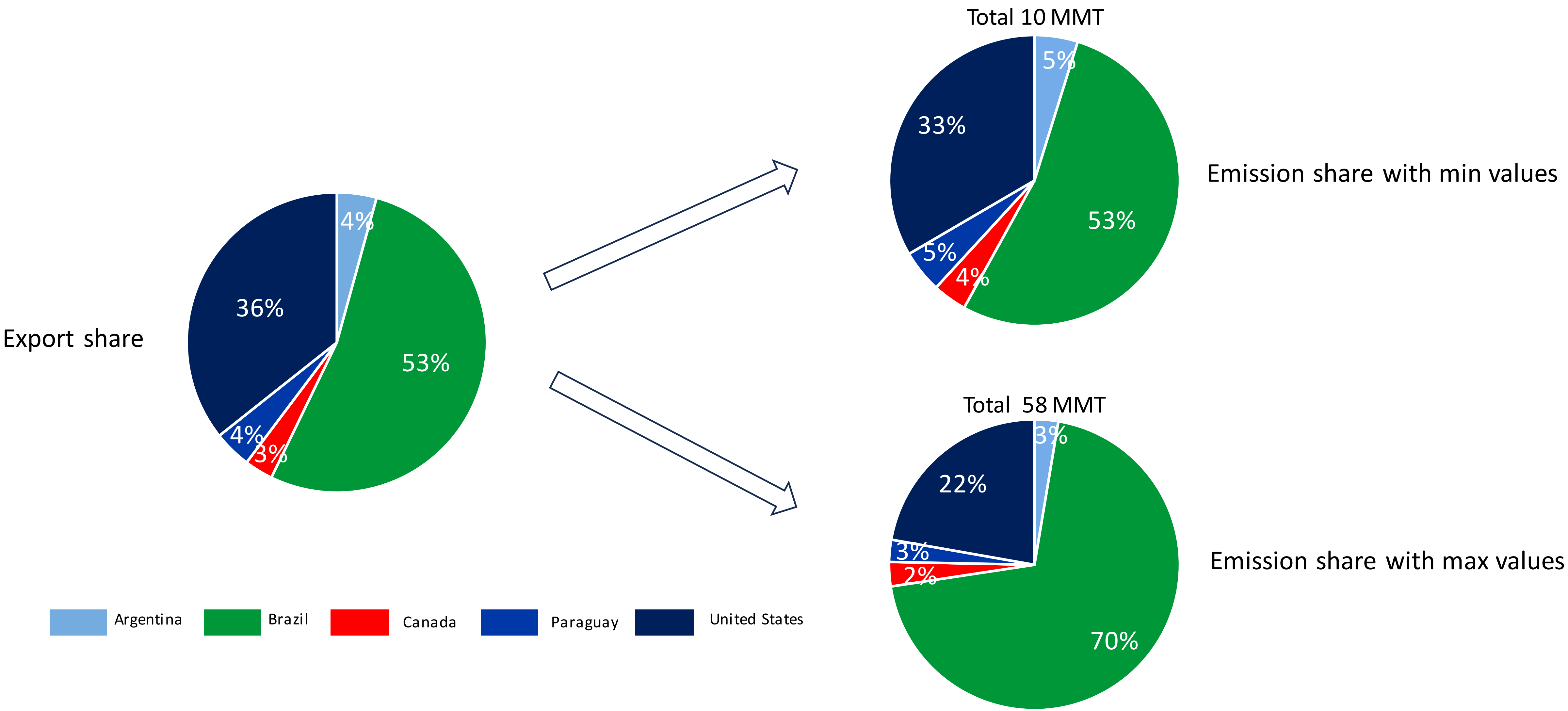
Note: **Emissions embodied in export are in parentheses in 1,000 Metric Tons**. Emissions embodied in export is the product of export quantity and emission intensity. The average value of emission intensities over datasets is used to estimate emissions embodied in export. The emissions intensity of oilseeds in CALUE is used for soybean. The emission intensity for FAOSTAT is calculated with emission data on crop residues and synthetic fertilizer application, following its methodological note for cereal grains. Only farm gate emissions are considered (land use change emissions are excluded).

Flow of emissions (27 MMT) embodied in soybean trade in 2021



Source: Aglink-Cosimo (2018), BLONK (2017), FAOSTAT (2021), GLOBIOM (2000), GTAP (2018), IFPRI (2017).
Note: **Emissions embodied in export are in parentheses in 1,000 Metric Ton**. Emissions embodied in export is the product of export quantity and emission intensity. The emission intensities of different years for Aglink-Cosimo, BLONK, GLOBIOM, GTAP, and IFPRI are used for the 2021 emission intensities. The average value of emission intensities over datasets is used to estimate emissions embodied in export. The emissions intensity of oil seeds in CALUE is used for soybean. The emission intensity for FAOSTAT is calculated with emission data on crop residues and synthetic fertilizer application, following its methodological note for cereal grains. For GTAP and IFPRI, emissions from the sector, *osd*, is used to estimate the emission intensity of maize with the production quantity of cereal grains categorized in the sector. Only farm gate emissions are considered (land use change emissions are excluded).

Share of export and GHG emissions from top soybean exporting countries



Source: Aglink-Cosimo (2018), BLONK (2017), CALUE (2017), FAOSTAT (2017), GLOBIOM (2020), GTAP (2018), IFPRI (2017).
Note: The export share of five countries is based on the average value between 2017-2021. The emissions intensity of oil seeds in CALUE is used for soybean. For GTAP and IFPRI, oil seeds in the sector, *osd*, is used to estimate the emission intensity with the production quantity (FAOSTAT). The emission intensity for FAOSTAT is calculated with emission data on crop residues and synthetic fertilizer application, following its methodological note for other cereal grains. The emission shar refers to the share of GHG emissions (excluding LUC) embodied in export. The min and max values are selected given a set of values across datasets.

Concluding remarks

- International efforts to mitigate GHG emissions are intensifying, and an increasing spotlight is on the role of agriculture & food systems to reduce its emission footprint

- Understanding the status of emission intensities being used and the scope of variation across major producing and trading partner is an important benchmarking exercise

- We find significant cross-country variation of emission intensities for most products
  - Varying technologies, agricultural practices, geographical/climatic realities, productivity, and input use

- Food and agricultural trade can be a mitigating or intensifying source of global GHG emissions
  - New era of trade policies to promote environmental sustainability could shift trade patterns, terms of trade, and “reward” countries/firms with lower carbon footprints

Thank You for the invitation to present at the 2024 FORAG Forum