

Estimating Global Food Waste Across Commodities and Supply Stages

Implications for Subsistence Agriculture

Jing Liu¹ Maksym Chepeliev¹ Alessandro Gatto² Marco Springmann³

¹Department of Agricultural Economics, Purdue University

²OECD

³Environmental Change Institute, University of Oxford

29th Annual GTAP Conference
June 19, 2026

Motivation

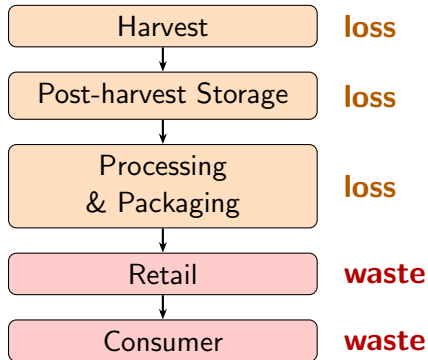
What Is Food Loss and Waste?

Food Loss Unintended reduction in food quantity or quality occurring *before* the retail stage

Food Waste Food discarded at the *retail and consumer* stage

FAO/UNEP (2024): **13.2%** of food is lost pre-retail; a further **19%** is wasted at retail and consumer stages — together $\approx$ **one-third** of all food produced.

Supply chain stages



This paper focuses on the **Waste** stage.

Why FLW Ratios Matter and What We Know

Why it matters

- It is a lot of food!
- **UN SDG 12.3**: halve food waste by 2030
- Interventions differ by stage and commodity

Direct measure:

$$FLW_{raw,it} = \frac{S_{it} - I_{it}}{S_{it}}$$

S_{it} : FAO food supply; I_{it} : net dietary intake

What the literature provides

- Gustavsson et al. (2011); HLPE (2014); FAO (2019): regional narratives and broad aggregates
- **Gatto & Chepeliev (2024)**: first synthesized database of FLW rates from 300+ sources by commodity, region, and stage
- **Sparse**: many country-commodity-stage cells are missing entirely
- **Heterogeneous**: values from different years and methods are not comparable across countries

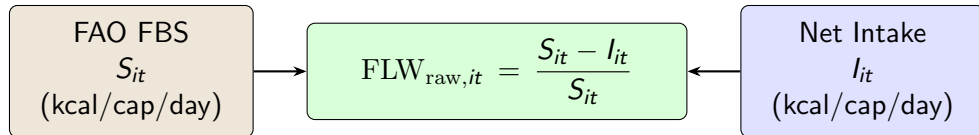
This Paper: Goals

- 1 Build a commodity $\times$ country $\times$ year $\times$ stage FLW panel
- 2 Identify countries where FAO supply understates true food availability
- 3 Derive implied subsistence production estimates

Methods

Data Sources

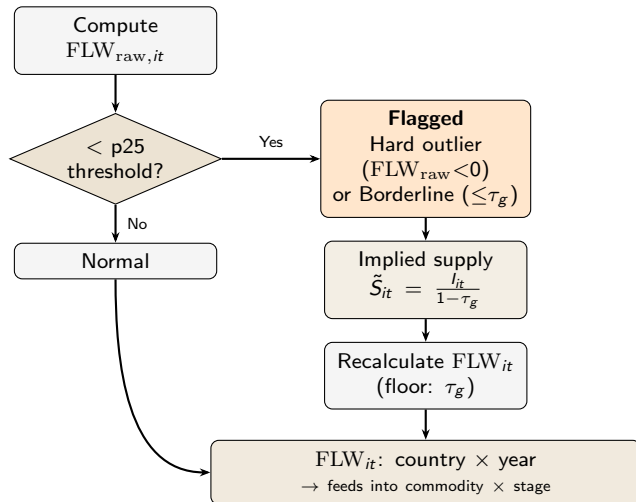
Source	Content	Coverage
FAO Food Balance Sheets	Supply by commodity	178 countries, 2010–2020
Springmann et al. (2020)	Net dietary intake	Country $\times$ year
Gatto & Chepeliev (2024)	FLW by stage & comm.	815 obs, 11 food groups, 11 reg.



Problem 1 — Implausible Country-Year FLW

Problem 1

Implausible FLW
at country $\times$ year level



Problem 2 — No Commodity or Stage Breakdown

Problem 2

No commodity or stage breakdown

Step 1: Hierarchical Bayesian

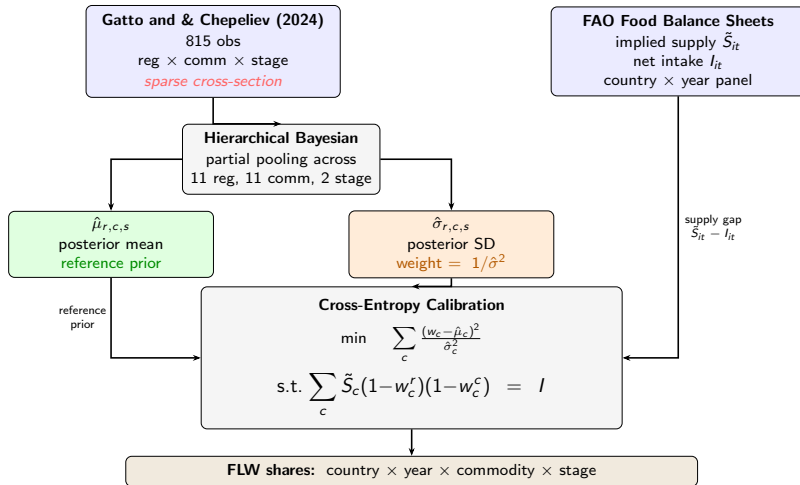
- (1) Fills empty region $\times$ comm $\times$ stage cells via partial pooling;
- (2) Outputs posterior distribution (mean *and* SD), not a single point estimate



Step 2: Cross-Entropy Calibration

Finds commodity $\times$ stage FLW shares that *exactly* satisfy the supply–intake identity while minimising deviation from Bayesian priors

How Bayesian Informs Cross-Entropy



Step 1: Hierarchical Bayesian Model

:

$$y_j \sim \text{Binomial}(n_j, \pi_j)$$

$$\text{logit}(\pi_j) = \mu + \alpha_{r[j]} + \beta_{s[j]} + \gamma_{c[j]}$$

Partial-pooling priors:

$$\alpha_r \sim \mathcal{N}(0, \sigma_\alpha^2), \quad \sigma_\alpha \sim \text{HalfNormal}(1)$$

$$\beta_s \sim \mathcal{N}(0, \sigma_\beta^2), \quad \sigma_\beta \sim \text{HalfNormal}(1)$$

$$\gamma_c \sim \mathcal{N}(0, \sigma_\gamma^2), \quad \sigma_\gamma \sim \text{HalfNormal}(1)$$

Index notation

- j : literature observation
- $r[j]$: region of obs. j
- $s[j]$: stage (retail / consumption)
- $c[j]$: commodity group
- μ : global intercept
($\hat{\mu} = -2.60 \Rightarrow \sim 7\%$ baseline waste)

Output

- Posterior mean $\hat{\pi}_{rsc}$ and SD $\hat{\sigma}_{rsc}$ for every reg $\times$ stage $\times$ comm
- Used as regularization weights in Step 2

Step 2: Cross-Entropy Calibration

Objective — minimize weighted deviation from Bayesian priors:

$$\min_{\{w_{\text{ret},c}, w_{\text{cons},c}\}} \sum_c [\lambda_{\text{ret},c} (w_{\text{ret},c} - \hat{\pi}_{\text{ret},c})^2 + \lambda_{\text{cons},c} (w_{\text{cons},c} - \hat{\pi}_{\text{cons},c})^2]$$

Aggregate intake constraint:

$$\sum_c \tilde{S}_c (1 - w_{\text{ret},c}) (1 - w_{\text{cons},c}) = I$$

Bounds: $0 \leq w_{\text{ret},c} \leq 1, \quad 0 \leq w_{\text{cons},c} \leq 1$

$\lambda_c = 1/\hat{\sigma}_c^2$: precision from Bayesian posterior.

High-precision commodities stay close to their priors.

Results

Identification Results: Who Is Flagged?

Income group	Countries	CYs	% of supply
Low	5	31	20.3%
Lower middle	13	28	10.3%
Upper middle	17	63	3.1%
Total	35	122	

Global aggregate: subsistence production $\approx$ 0.42% of FAO food supply.

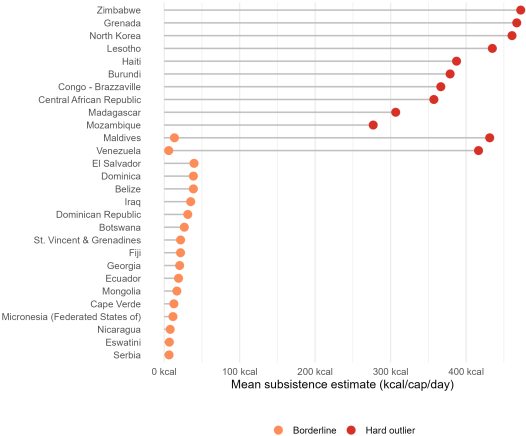
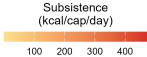
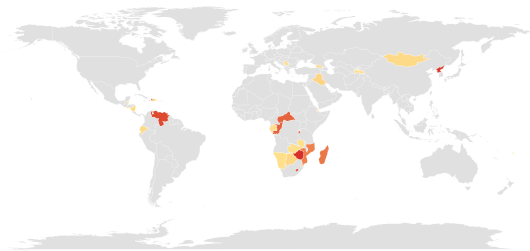
Waste rates corrected

	Before	After
Retail (mean)	3.8%	7.0%
Consumption (mean)	4.9%	7.7%

Identifying the supply gap *before* calibration removes an endogeneity that biased waste shares downward.

Subsistence Agriculture Estimates

Estimated subsistence agriculture — geographic distribution and top countries
Mean 2004–2019 | implied supply – FAO supply

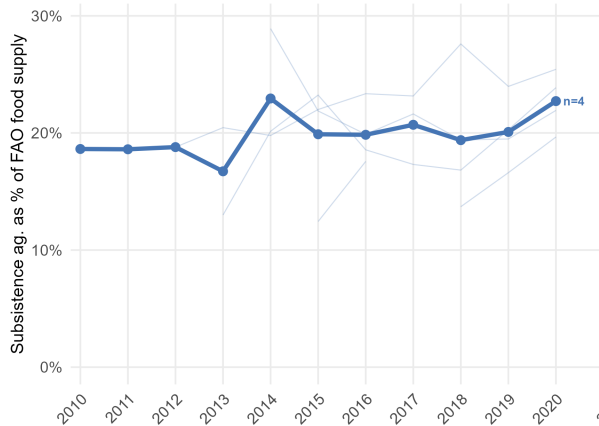


Subsistence Agriculture: Time Trend (2010–2020)

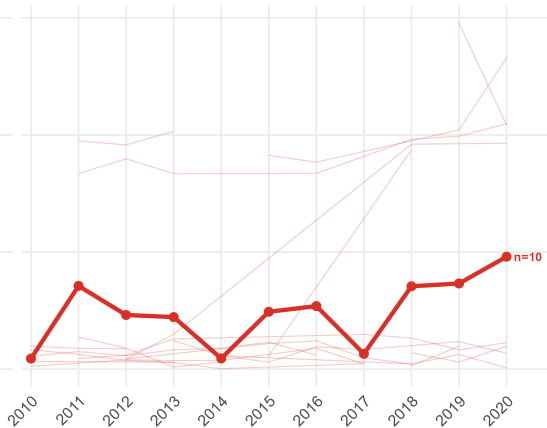
Subsistence agriculture estimates over time (flagged country-years only)

Thin lines => individual countries; thick line => income-group mean

Low Income



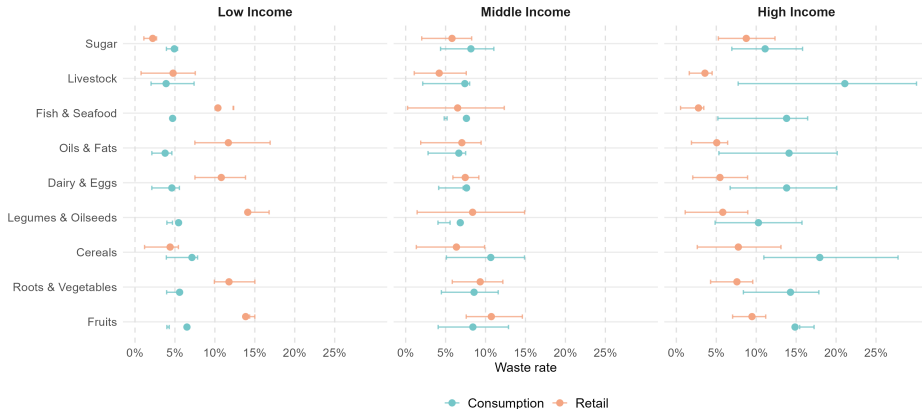
Middle Income



FLW Shares by Commodity, Stage, and Income Group

Estimated FLW shares by income group, commodity, and supply chain stage

Point = mean; bar = interquartile range (Q25–Q75) | 178 countries × 39 commodities × 2 stages × 11 years => 134,984 obs.

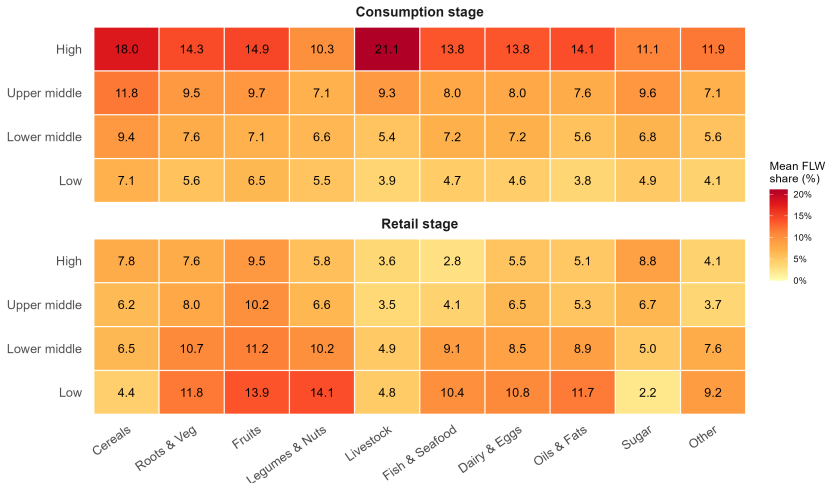


- Stage pattern differs by income
- Rich countries, wider spread
- Commodity ranking is stable

Estimated FLW Shares: Commodity and Stage Breakdown

Estimated FLW shares by income group, commodity, and supply chain stage

Mean across country-years 2010–2020



Conclusions & Next Steps

Conclusion

1 Food waste rates vary substantially by income and stage

Global average $\sim 19\%$ (FAO/UNEP 2024) masks large heterogeneity: high-income countries waste more at *consumption*; low-income countries lose more at *retail*.

2 Contribution 1: disaggregated food waste database + method

Food waste rates by commodity $\times$ country $\times$ year $\times$ stage panel (178 countries, 2010–2020), built via a Bayesian + cross-entropy disaggregation framework.

3 Contribution 2: Subsistence agriculture

35 countries, 122 country-years with implied off-books production up to 20% of FAO supply in low-income countries.

4 Policy implications

Rich countries: reduce plate waste. Poor countries: invest in cold-chain, packaging, and infrastructure to cut retail losses.

Next Steps

- **Subsistence agriculture disaggregation** — break down implied off-books production by commodity to understand what subsistence households produce and consume
- **Poverty reassessment** — augment FAO supply for the 35 flagged countries; re-estimate poverty headcounts using corrected food availability data
- **Policy simulations in GTAP** — use calibrated w_{ret} , w_{cons} to explore differential food waste reduction policies across income groups and supply chain stages

Thank you!

Jing Liu

Department of Agricultural Economics, Purdue University

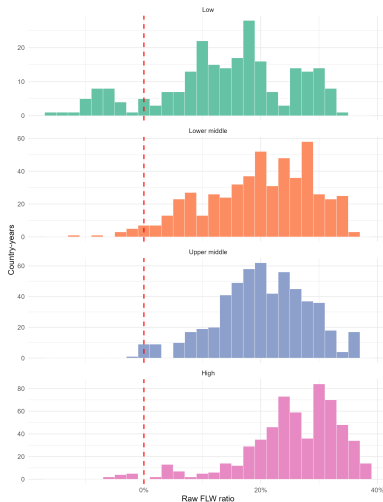
`liu207@purdue.edu`

Supplementary Slides

Distribution of Raw FLW Ratio by Income Group

Distribution of raw FLW ratio by income group

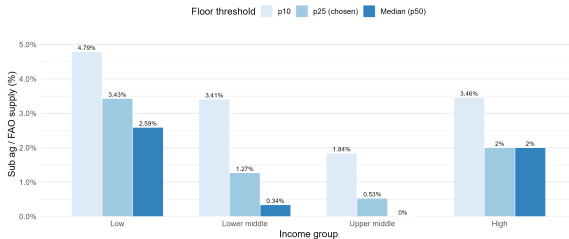
$FLW_raw = (FAO\ supply - Springmann\ intake) / FAO\ supply$ | Red = zero



Threshold Sensitivity

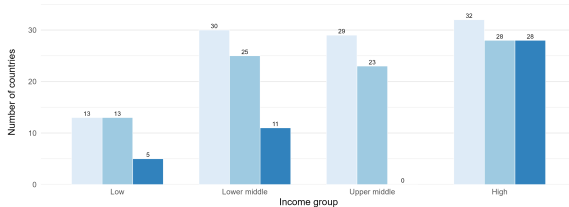
Subsistence agriculture as share of FAO supply

Floor threshold: p10 vs p25 (chosen) vs income-group median | 2010–2020 panel



Number of countries with positive subsistence estimate

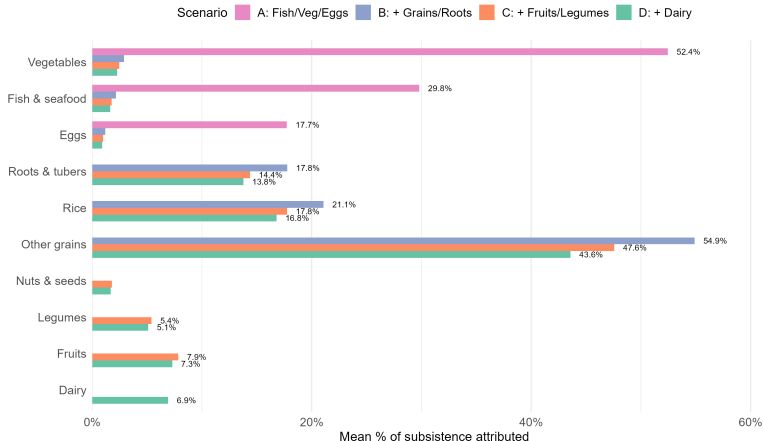
By income group and floor threshold



Food Group Attribution Under Alternative Scenarios

Share of subsistence attributed to each food group by scenario

Weights from flagged-country supply shares only | Groups sum to 100% per scenario per country



Four scenarios

A Fish, vegetables, eggs

B A + Grains, roots

C B + Fruits, legumes

D C + Dairy

Weights derived from
flagged-country supply
composition.