Developing a Data-Driven Model to Quantify Farm-Specific Greenhouse Gas Emissions for Open-Field Tomato Production on a Global Scale

W.Y. Lam[1], M. Kulak[2], I. Butnar[2], S. Sim[2], L. Tambjerg[2], M. Douziech[1], R. van Zelm[1] & M.A.J. Huijbregts[1]

[1]Radboud University, Institute for Water and Wetland Research, Department of Environmental Science, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands

[2]Safety and Environmental Assurance Centre, Unilever, Sharnbrook, Bedford MK44 1LQ, United Kingdom

1. Introduction

- ~ 36.9 million metric tonnes of **tomatoes** are produced per year for processing into paste, sauce, canned tomatoes and other tomato-based products from 2012 to 2015.[1]
- Globally the most important **vegetable crop** at a production volume of 163 million metric tonnes in 2013 according to FAOSTAT.[2]

Goal

- Quantify the **greenhouse gas (GHG) footprint** of open-field tomato crop cultivation worldwide and the **variability** therein using farm-specific data.
- Build a data-driven model to quantify farm-specific GHG footprint on a global scale.

2. Methodology

- Data from 463 farms spanning fourteen countries were collected from farmers as part of a supply chain monitoring system of Unilever.
- Greenhouse gas footprinting was performed on each farm using a functional unit of **1 tonne of fresh tomatoes** (Figure 1).

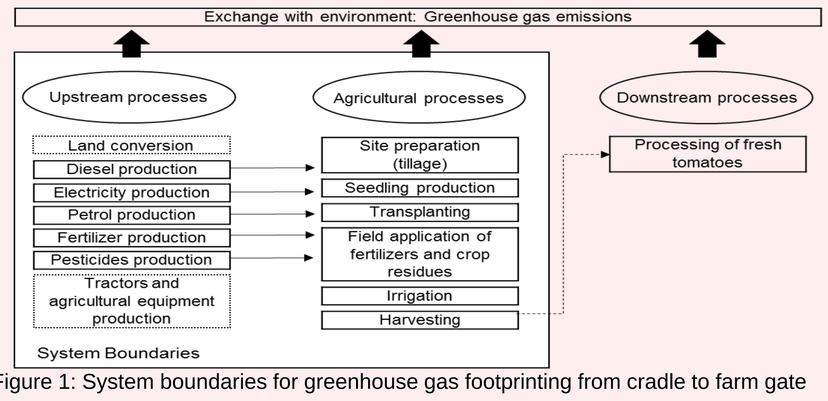

Figure 1: System boundaries for greenhouse gas footprinting from cradle to farm gate

Table 1: Drivers of variability for greenhouse gas footprints from cradle to farm gate accounted in this study

Drivers of GHG footprint	Variability
Nitrous oxide (N_2O) emissions from fertilizer application	Technological: amount and type of fertilizer applied
Fossil emissions	Technological: machine use and material inputs
Yield	Spatial: soil composition, climate, i.e. temperature and rainfall Technological: farm management practices and technologies (e.g. material inputs and machinery)

3. Results and Discussions

- The median and production-weighted mean GHG footprint is 62 and 56 respectively, compared to literature values of 86 to 130 kg CO_2-eq. per tonne of tomatoes[3,4,5].

Within-country variability	Between-country variability
• Percentage difference between the 5th to 95th percentile for all countries ranges from 110 % for Egypt to 880 % for Portugal.	• The median GHG footprint of India is about 5.3 times that of Chile (120 vs 23 kg CO_2-eq. per tonne of tomatoes). • Relative importance of different input parameters varies between countries.

- Typically fertilizer production is the largest contributor to the GHG footprint of tomatoes: 44 % of median GHG footprint and 30 % to the 5th to 95th percentile variability of GHG footprints.
- Regression of GHG footprints with **nitrogen fertilizer input** and **yield** shows relationships that can be used to build an empirical model to predict farm-specific GHG footprints of tomato crops based on limited data available.

Figure 2: Box and whisker plot (5th, 25th, 50th, 75th and 95th percentile) of the total GHG emissions of open-field tomato production for countries with more than 10 farms in the sample. For these countries, a breakdown of relative contributions of the different sources of emissions was done as in Figure 3b.

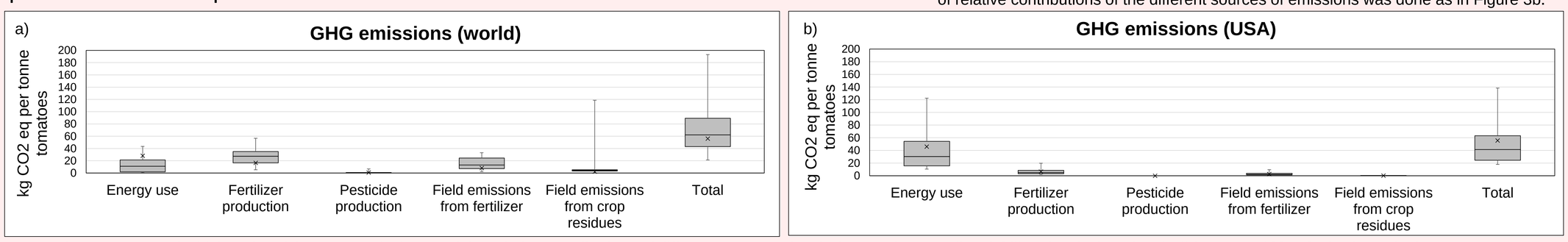

Figure 3: Box and whisker plot of the GHG emissions and the relative contributions of different sources of emissions to the overall variability of emissions for a) all farms; and b) only the farms in the USA

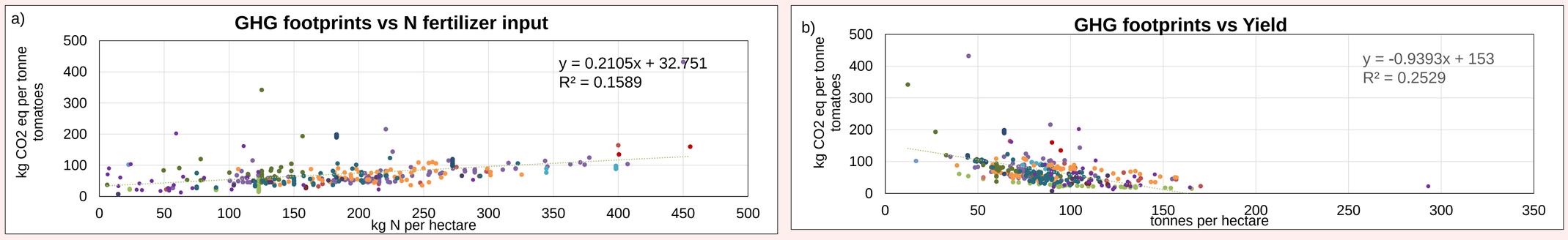

Figure 4: Scatter plot of the GHG footprints vs a) nitrogen fertilizer input b) yield of the farms.

4. Conclusion and Looking Forward

- The relative contribution of sources of emissions to the total GHG footprint provides insights for actions to reduce GHG emissions within supply chains, e.g. through facilitating optimization of management practices at the farm level.
- Future work will include further statistical analysis and regression of GHG footprints with more input parameters, i.e. electricity use, irrigation volume, etc.

References

1. WPTC (2016) World Production Estimate of Tomatoes for Processing. Accessed through WPTC website on 19th April 2016.
2. FAOSTAT (2015) Food and Agriculture Organization of the United Nations Statistics Division. Retrieved from: http://faostat3.fao.org/home/E on 12 February 2016.
3. Theurl, M.C, Haberl, H., Erb, K., Lindenthal, T. (2013) Contrasted greenhouse gas emissions from local versus long-range tomato production. Agronomy for Sustainable Development Volume 34, Issue 3, pp 593-602.
4. Manfredi, M., Vignali, G. (2014) Life cycle assessment of a packaged tomato puree: a comparison of environmental impacts produced by different life cycle phases. Journal of Cleaner Production 73, 275-284.
5. Karakaya, A. & Özilgen, M. (2011) Energy utilization and carbon dioxide emission in the fresh, paste, whole-peeled, diced and juiced tomato production processes. Energy 36, 5101-5110.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 641459

Unilever

Radboud University