The Role of Geography in Life Cycle Assessments of Grain Production

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Introduction

Climate change caused by global warming is a threat to the continuation of current human activities into the future[2,11]. Agricultural systems contribute to 26% of green house gas (GHG) emissions[27]. With projected rising populations, food supply chains will have increased demand to supply[27]. Food systems sustainability research aims to address concerns about environmental impacts of food supply chains.

Life cycle thinking is often used to assess the sustainability of food supply chains in an effort to identify environmental impact hotspots[15]. Life cycle assessment (LCA) is an ISO standardized framework to evaluate how the life cycle of a product contributes to impact categories (e.g. GHG, acidifying and eutrophying emissions, water, land and energy use)[15]. LCA is frequently applied to food product life cycles (e.g. grain, vegetable, meat, fish, beverage production)[15]. Stages of the food life cycle (e.g. production, processing, transportation, storage, sale, consumption, waste disposal) are analyzed with LCA[15]. Impacts are modeled to provide an estimate of how a food product and its production is contributing to environmental impacts[15].

With any model, there are limitations in its applicability and ability to evaluate uncertainty[23]. For LCA as it pertains to agriculture, there are limitations in methodological variation and geographical consideration[21, 23-24]. These become relevant when comparing LCAs of different products, as with the methodological limitations, comparisons become weaker[8,21, 23-24]. The role of geography in LCAs of grain production is being investigated in an effort to reduce uncertainty in conclusions drawn from LCAs of grain production.

If taxonomical restrictions of grain species are relaxed, is there a relationship between the climate of grain production and the emissions profile?

Objectives:

1. Explore the patterns in profiles of substage contribution to emissions across grain species.
2. Compare profiles within and between differing geographies.

Methods

Case study selection

- Inclusion and exclusion criteria decided
- Search term for Scopus created
- Case studies selected based on criteria

LCA Case study criteria[27]

- ○ <15 years old
- ○ 1kg functional unit
- ○ Quantifying GHGs in GWP using CO_2-eq
- ○ Production stage with appropriate substages
- ○ Attributional LCA
- ○ Conventional production

Data extraction

- Global warming potentials (GWP) extracted in kg CO_2-eq
- Contribution by substage to total GHG emissions/GWP (e.g. fertilization, fuel use, pesticides, herbicides, etc.)
- Data from common substages compiled so the case studies are comparable across methodological variations

Analysis

- Data visualization with proportionally stacked bar graphs
- Compare data within and across geographic and climatic regions

Literature Review

Life cycle assessments

- LCA is a method of completing a cradle to grave analysis to understand how a system's processes contribute to environmental phenomena[15,29]
- Can identify system hotspots, and the production stage is often largest emitter in agriculture[15,29]
- To do so, the inputs and outputs of the system are analyzed and then their contribution to impact categories (e.g. global warming potential, eutrophying emissions, acidifying emissions, pollution, land use, etc.) are measured
- Inputs into the production stage of agriculture include fertilizer, fuel, pesticides, herbicides, electricity, etc.

Synthetic analyses

- Use results of LCAs to draw high-level conclusions about food systems[7,8]
- Conclusions inform policy decisions[27]

System models are limited

- Models are limited in ability to capture whole system[13,21,24,34]
- Limitations due to methodological variation, data availability, and capturing all environmental factors[13,21,24,34]
- Result in differences between each LCA study, should be accounted for in synthetic analyses

Problem proposed

- Controlled for production method (conventional only) in grain systems to minimize between-system variability
- Analyzing the contribution of source emissions to total production stage GHG emissions in terms of Global Warming Potential (GWP)
- Explored patterns within and across geographical regions with a focus on variation due to production locale
- Species scope of all grains (e.g. wheat, rye, barley, oat, quinoa)

This allowed for the investigation of geography's influence on the contribution of different source emissions to total production stage GHG emissions from grain LCAs.

Results

- **Fertilizer** and **field emissions** consistently contribute significantly, averaging **47 and 45%**, respectively
- Only **36%** of the studies included **an analysis of field emissions** in their LCA
- It is **challenging** to **compare** within and across **climatic regions**
- Grain species **does or does not** affect the subsystem contribution

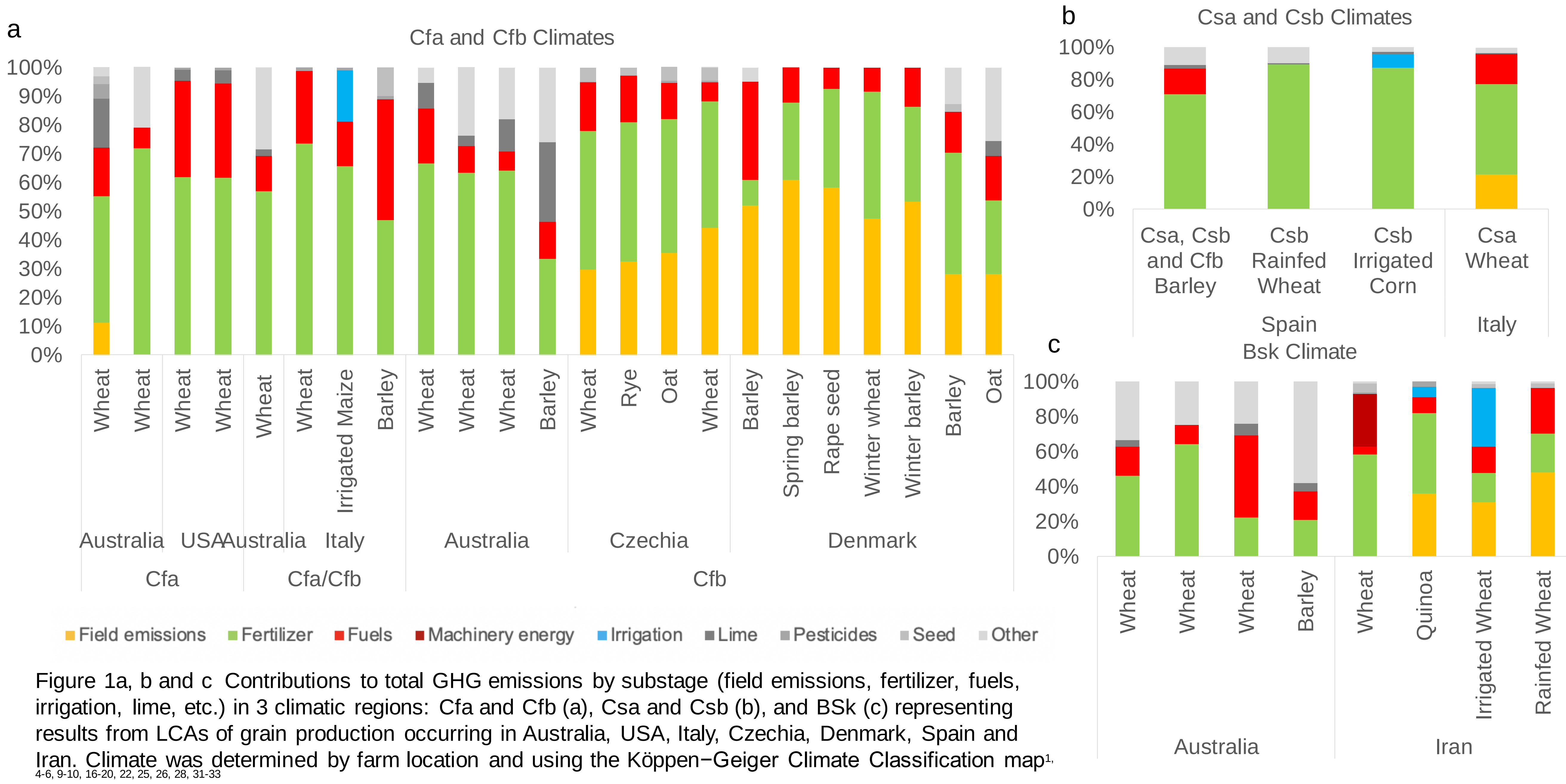
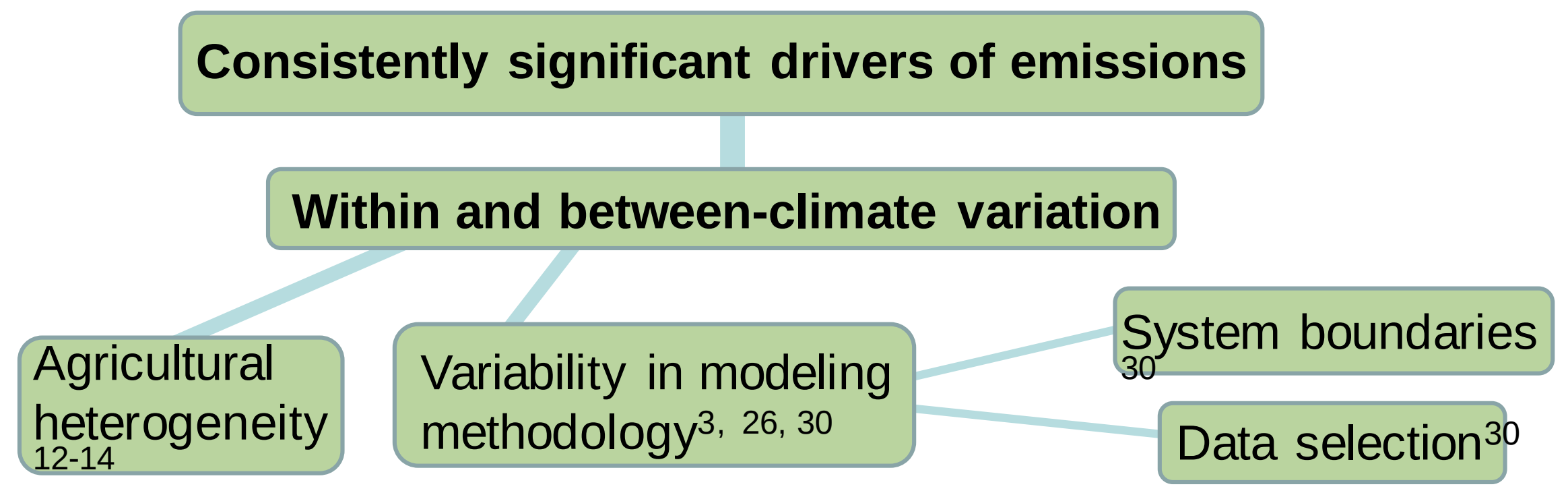


Figure 1a, b and c Contributions to total GHG emissions by substage (field emissions, fertilizer, fuels, irrigation, lime, etc.) in 3 climatic regions: Cfa and Cfb (a), Csa and Csb (b), and BSk (c) representing results from LCAs of grain production occurring in Australia, USA, Italy, Czechia, Denmark, Spain and Iran. Climate was determined by farm location and using the Köppen−Geiger Climate Classification map[1, 4-6, 9-10, 16-20, 22, 25, 26, 28, 31-33]

Discussion

After **relaxing grain taxonomies** and **comparing the emissions profiles** of grain production within and between **climatic regions** (Figure 1), there are some **consistently significant drivers of emissions** (e.g. fertilizer use and field emissions), but the **heterogeneity of agricultural systems** and the **variation of LCA methodology** makes for high between-system **variability** and **low comparability**[3, 12,-14, 30].



Consistently significant drivers of emissions

Within and between-climate variation

Agricultural heterogeneity[12-14]

Variability in modeling methodology[3, 26, 30]

System boundaries[30]

Data selection[30]

Conclusions & Acknowledgements

- Models such as LCAs remain imperfect, yet they do produce some conclusions
- Developments required in the consideration of field emissions in agricultural LCAs
- Ideally, we would be able to focus LCAs locally while allowing global comparison
- Aggregate work must address the agricultural and methodological variability

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