ENVIRONMENT IMPACT OF FOOD PRODUCTION ANALYSIS DOCUMENTATION

GOAL

To assess the environmental impact of food production at both macro and micro levels and propose data-driven insights to mitigate the negative effects of food production on the environment.

A. ANALYSIS QUESTIONS (Based on Dataset)

1. Which foods contribute the most to greenhouse gas (CO_2 equivalent) emissions, and at which stages (land use, farm, processing, transport, packaging, retail)?
2. Which foods have the highest water footprint, and how does this correlate with their carbon footprint?
3. What is the relationship between food types and land use change emissions? Are there foods that disproportionately impact land resources?
4. At which stage of the food lifecycle (farm, processing, transport, packaging, retail) do emissions peak for most food products?
5. Can we rank foods from "most sustainable" to "least sustainable" based on combined emissions, water, and land use?
6. How do animal-based products compare to plant-based products in terms of overall environmental footprint?

B. DATA PREPARATION

Before Preparation

- 1 Dataset (43 records, 23 parameters)
- Most columns had null values.

Cleaning

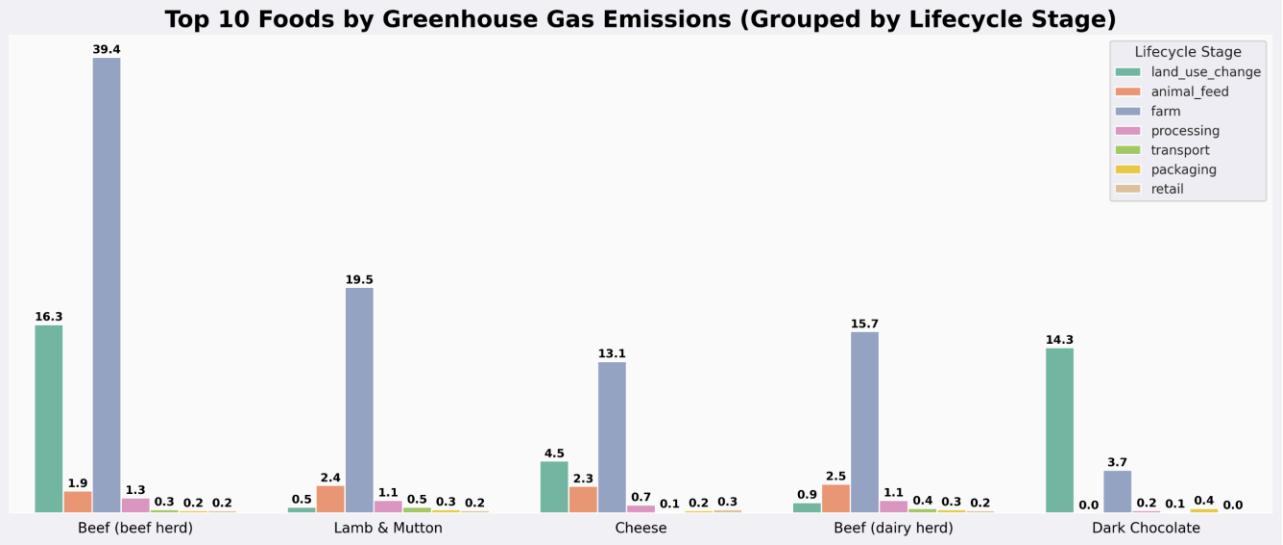
1. Conventionalized column names by replacing spaces with underscores "_".
2. Filled null values with median or mean depending on skewness of column values.
   Where there was high skewness, median was used, and where there was low skewness, mean was used.
3. Rounded all float values to 2 decimal places.

Dataset After Preparation

- 43 records, 23 parameters

C. ANALYSIS, VISUALIZATIONS & INSIGHTS

1. Which foods contribute the most to greenhouse gas (CO_2 equivalent) emissions, and at which stages (land use, farm, processing, transport, packaging, retail)?

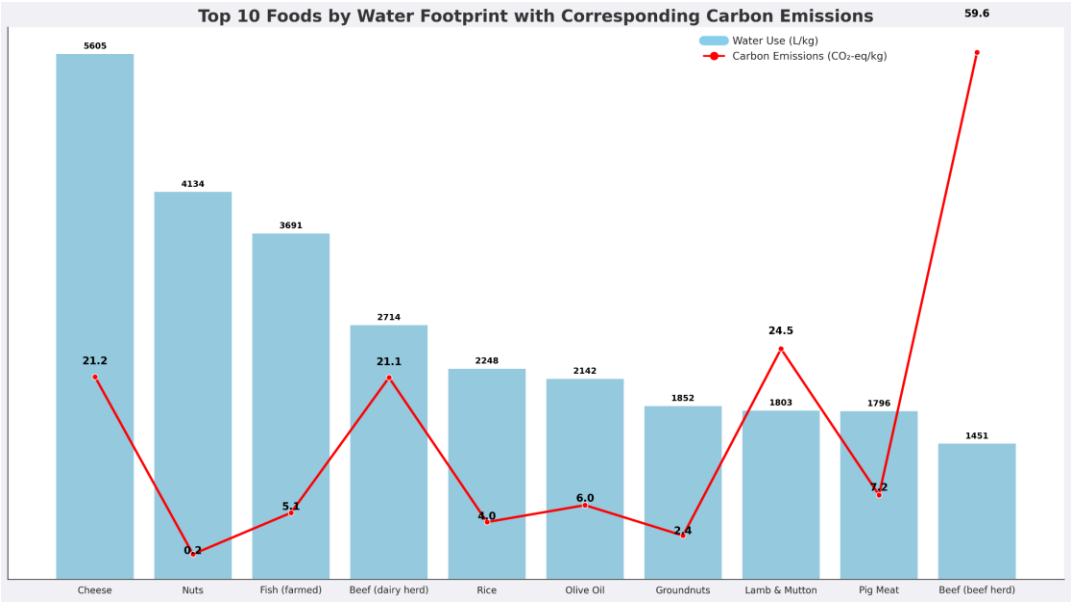


- Beef (beef herd) has the highest total greenhouse gas emissions per kg, with farm-stage emissions dominating, followed by significant land use change.
- Lamb & Mutton, Cheese, and Beef (dairy herd) also exhibit high emissions, primarily driven by farm-stage activities.
- Dark Chocolate stands out due to a high contribution from land use change despite lower farm emissions.
- Emissions from processing, transport, packaging, and retail are comparatively minimal across all top foods.

Key Takeaway

- Greenhouse gas emissions are overwhelmingly driven by farm-stage activities and land use change, especially for livestock-based foods.
- Targeting agricultural practices and land management offers the greatest potential for reducing emissions.

2. Which foods have the highest water footprint, and how does this correlate with their carbon footprint?

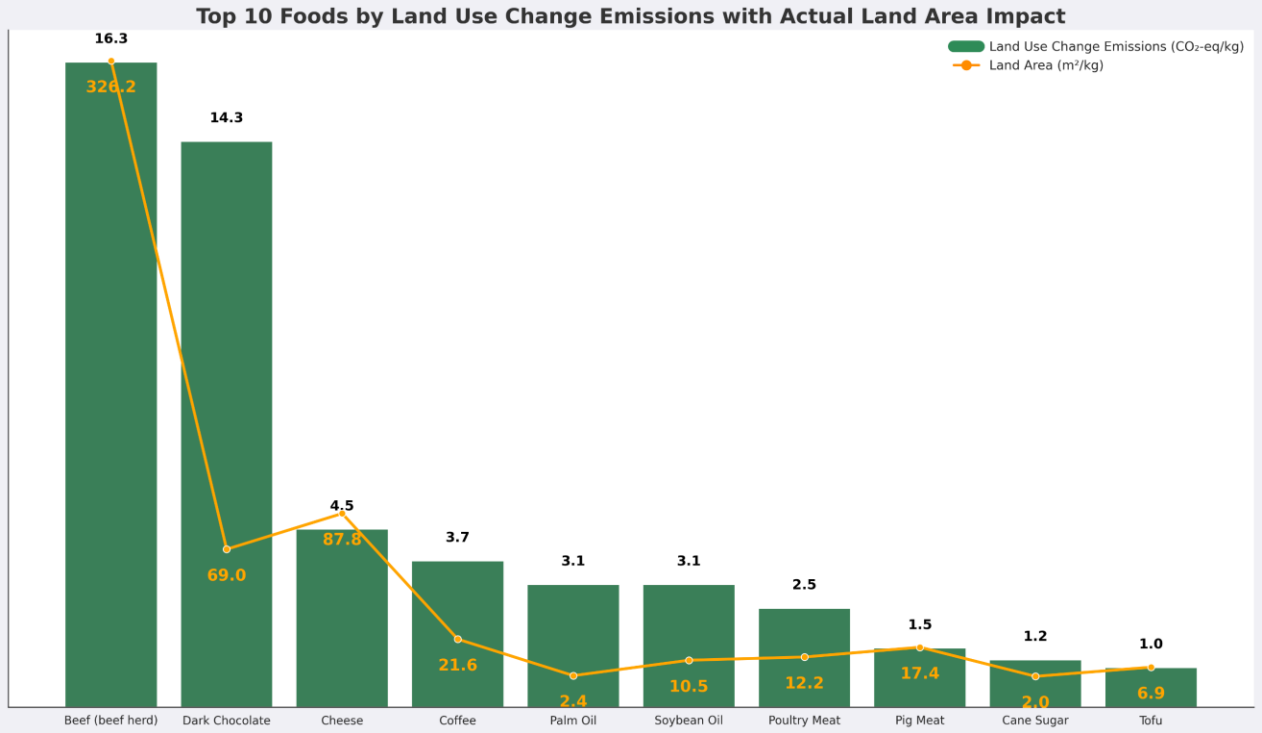


- The analysis shows Cheese has the highest water footprint, using over 5,600 L/kg, followed by Nuts and Farmed Fish at 4,134 and 3,691 L/kg, respectively.
- Meanwhile, Beef (beef herd) has a comparatively low water footprint (1,451 L/kg) but the highest carbon emissions at 59.6 kg CO_2-eq/kg.
- Plant-based foods like Groundnuts and Rice are water-intensive but emit significantly less carbon, showing trade-offs between water and emissions.
- The moderate correlation of 0.33 confirms that water use and carbon emissions are not strongly aligned.

Key Takeaway

- Water footprint and carbon emissions show only a moderate correlation (0.33), meaning one metric alone doesn't capture full environmental impact.
- Beef remains the highest emissions driver, while Cheese and Nuts dominate water use, emphasizing multi-factor sustainability assessments.

3. What is the relationship between food types and land use change emissions? Are there foods that disproportionately impact land resources?

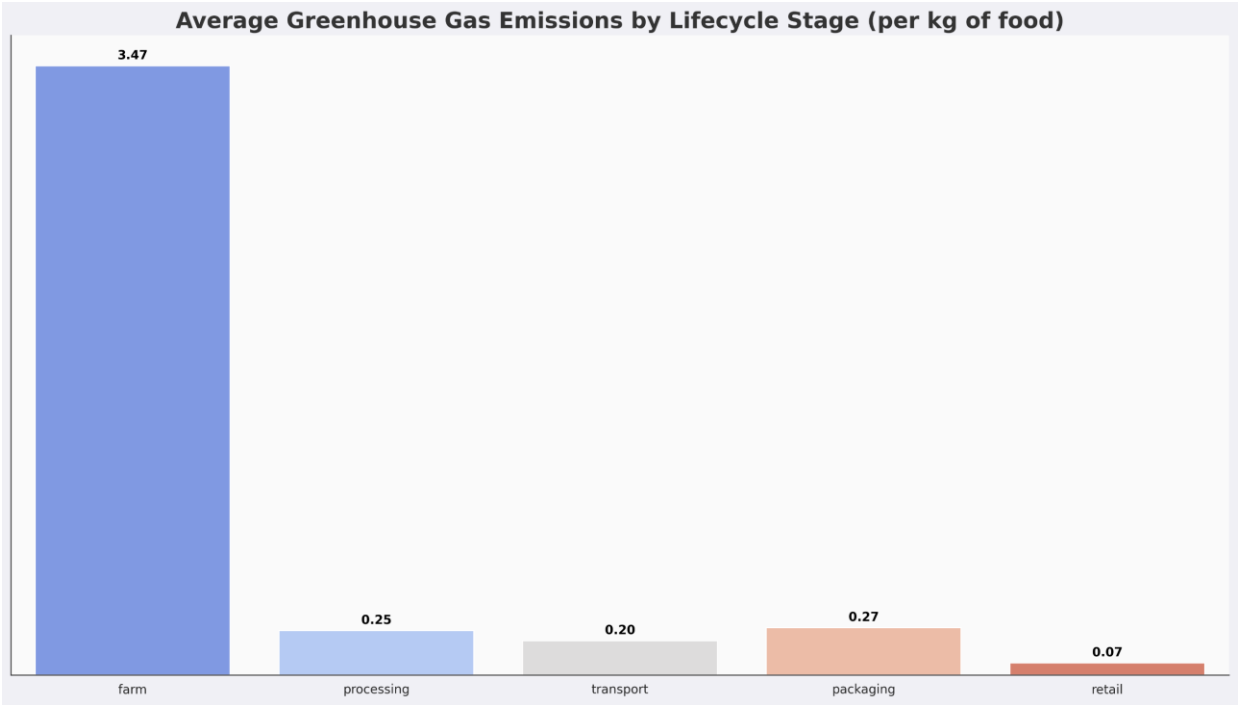


- The analysis shows that beef (herd) and dark chocolate have the highest land use change emissions, with beef also demanding an exceptionally large land footprint of 321.2 m²/kg.
- Foods such as cheese, coffee, and oils (palm and soybean) follow but with relatively lower emissions and land intensity.
- Plant-based products like tofu and cane sugar demonstrate minimal land use change emissions, paired with small land requirements.
- The overall correlation of 0.54 suggests that foods with higher land use change emissions also tend to occupy disproportionately larger land areas.

Key Takeaway

- Beef and dark chocolate exert disproportionately high land use emissions, making them critical targets for sustainable interventions.
- Shifting consumption towards plant-based, low-footprint foods can significantly reduce pressure on land resources.

4. At which stage of the food lifecycle (farm, processing, transport, packaging, retail) do emissions peak for most food products?

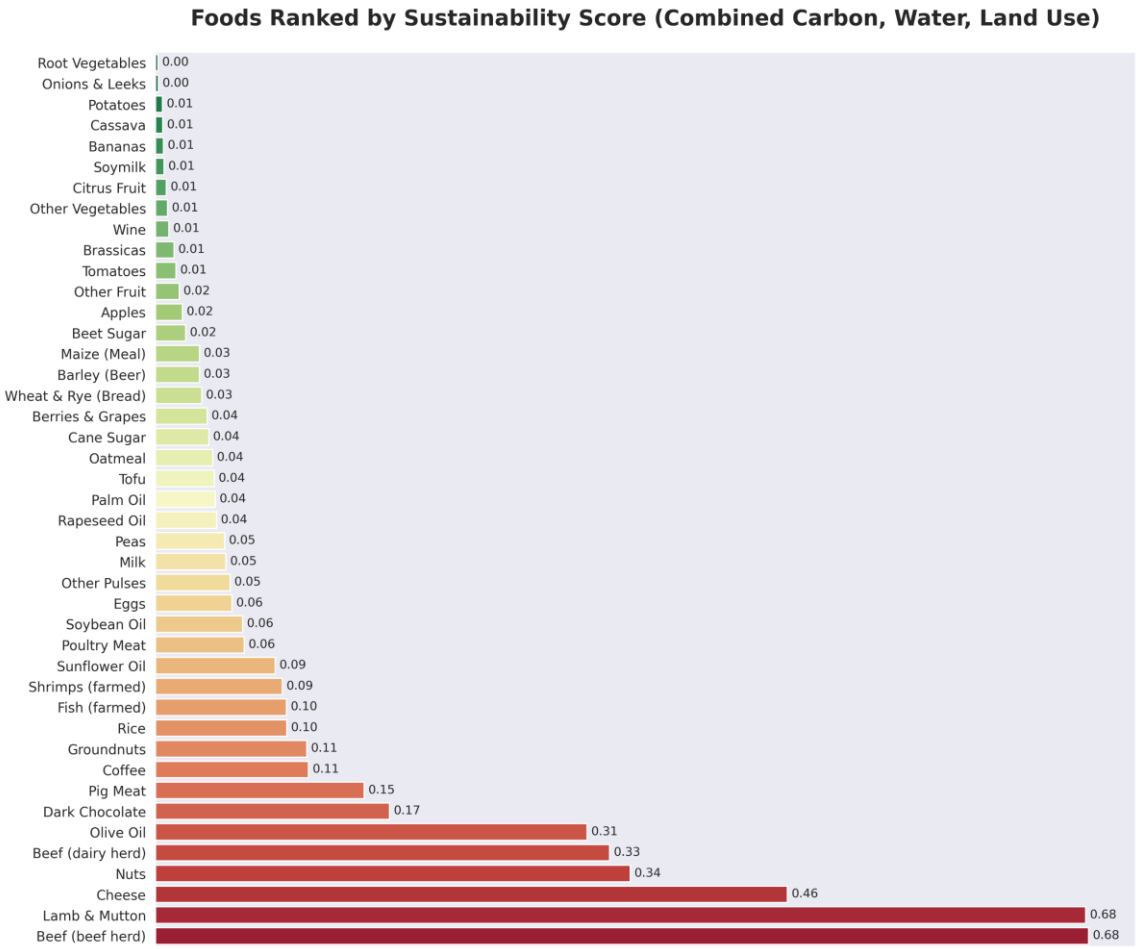


- The Farm stage is by far the dominant source of greenhouse gas emissions, averaging 3.47 kg CO_2-eq per kg of food, which overshadows all other lifecycle stages.
- Processing (0.25 kg) and packaging (0.27 kg) have modest but comparable emissions, while transport (0.20 kg) and retail (0.07 kg) contribute minimally.
- This trend reflects the high emissions from agricultural activities, including fertilizer use, livestock methane, and field management practices.
- The visualization clearly demonstrates that emission reduction efforts should prioritize on-farm practices, as downstream stages add relatively minor contributions.

Key Takeaway

- Over 80% of food-related emissions occur at the farm stage, making it the critical focus for sustainability interventions.
- Downstream stages like transport, packaging, and retail have minimal overall impact compared to agriculture.

5. Can we rank foods from “most sustainable” to “least sustainable” based on combined emissions, water, and land use?

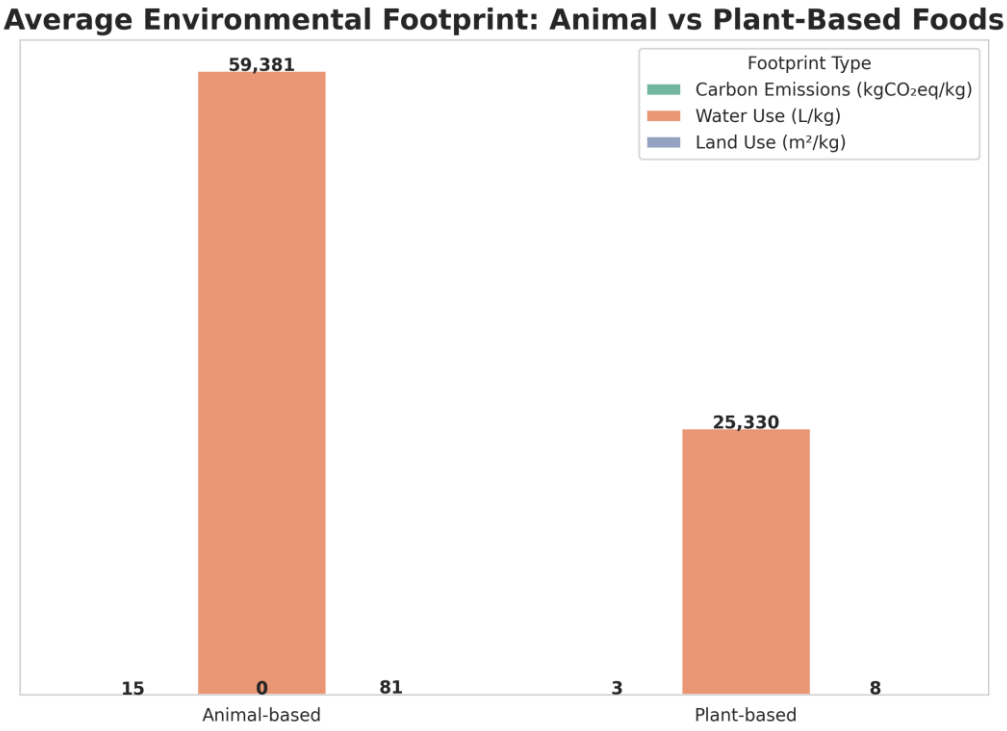


- Plant-based staples like root vegetables, onions, potatoes, cassava, and bananas dominate the top of the sustainability ranking, with scores near 0.00–0.01, reflecting minimal combined environmental impact.
- Mid-tier foods include grains, pulses, and plant oils, which show moderate land and water usage but relatively low carbon emissions.
- Animal-based products, particularly beef (beef herd, dairy herd), lamb & mutton, and cheese, are the least sustainable, with scores above 0.45, driven by high land requirements and methane emissions.
- The wide gradient from green to red visually emphasizes the sharp sustainability gap between plant-based vs. animal-derived foods.

Key Takeaway

- Plant-based foods are consistently more sustainable, showing minimal carbon, water, and land impact.
- Beef, lamb, and dairy products are environmental hotspots, offering the biggest opportunity for footprint reduction.

6. How do animal-based products compare to plant-based products in terms of overall environmental footprint?



- Animal-based foods show a significantly higher average environmental footprint (~59,476) compared to plant-based foods (~25,341).
- This trend reflects higher emissions, water consumption, and land requirements for livestock production.
- Plant-based foods generally cluster on the lower end of the footprint scale, indicating better sustainability.
- The gap suggests production inefficiencies and resource intensity in animal-based food systems.

Key Takeaways

- Animal-based foods have more than double the environmental footprint of plant-based foods.
- Shifting towards plant-based diets can meaningfully reduce overall resource use and emissions.

D. GENERAL INSIGHTS & CONCLUSIONS

1. Livestock production dominates environmental impact: Animal-based products—particularly beef, lamb, and dairy—are the leading contributors to greenhouse gas emissions, land use change, and overall environmental footprint, often far surpassing plant-based alternatives.
2. Farm-stage activities are the primary emissions hotspot: Over 80% of total emissions occur during the farm stage, underscoring that interventions at the production level will have the greatest impact.
3. Trade-offs exist between environmental metrics: Foods like cheese and nuts have high water footprints but relatively lower emissions, showing that sustainability assessments must consider multiple factors (carbon, water, land) rather than a single metric.

4. Plant-based foods consistently show sustainability advantages: Most plant-based staples (root vegetables, grains, pulses) have lower combined environmental footprints, with minimal land and water requirements.
5. A small number of foods drive a disproportionate share of impact: High-footprint items such as beef and chocolate present opportunities for targeted policy and consumer behavior interventions to achieve significant environmental gains.
6. Production system inefficiencies amplify impacts: The large disparity between animal and plant-based products highlights resource inefficiencies in livestock production, such as feed conversion ratios, methane emissions, and land clearing.

E. RECOMMENDATIONS

1. Promote plant-based diets and alternative proteins: Encourage dietary shifts towards plant-based staples, pulses, and innovative protein sources (e.g., lab-grown meat, legumes) to reduce environmental footprint.
2. Focus on farm-level emissions reduction: Implement precision agriculture, methane-reducing feed additives, better manure management, and regenerative farming practices to tackle emissions at their primary source.
3. Target high-impact foods for intervention: Prioritize reducing consumption and production of beef, lamb, dairy, and other disproportionately impactful foods through education, labeling, and pricing strategies.
4. Encourage water-efficient farming: Promote drip irrigation, drought-resistant crop varieties, and better water governance to reduce water footprint for high-use foods like nuts and cheese.
5. Protect and restore land ecosystems: Limit deforestation, incentivize sustainable land management, and invest in reforestation to address land use change emissions.
6. Invest in food system innovation: Support research into sustainable farming technologies, carbon capture in agriculture, and climate-smart livestock systems to balance food security with environmental protection.
7. Consumer awareness and policy alignment: Combine clear product labeling, awareness campaigns, and sustainability standards to drive informed choices and systemic change.

Github link for full project:
https://github.com/dspselorm/Evironmental_Impact_of_Food_Production_Analysis