Food Product Environmental Footprint Literature Summary:

Foreword

State of Oregon
DEQ Department of Environmental Quality

with support from
The Oregon Sustainability Board

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Background

Agricultural production and food product manufacturing are important industries in both Oregon and the U.S. In addition, food – when evaluated across its entire life cycle (production, packaging, transport, storage, use and disposal) contributes significantly to environmental challenges, and by extension, offers potential for improvement. For example, food contributes close to 15 percent of Oregon's consumption-based greenhouse gas emissions. On the supply side, many food producers are actively exploring methods of producing foods in less environmentally damaging ways. On the demand side, some customers (including retailers, food service companies, and large institutions) are particularly interested in supporting low-carbon and other low-impact foods through purchasing decisions. Interest in this topic is high, but information used to inform decisions is inconsistent and sometimes misused. For example, a belief that "local" food inherently has a lower carbon footprint creates the potential of marketing challenges to Pacific Northwest producers who rely on export markets; yet most life cycle analyses show that, in most cases, transportation of food contributes a surprisingly small amount to greenhouse gas emissions and other environmental impacts.

Research Need and Purpose

There has been extensive industry and academic research into the environmental footprints of foods, but much of the information is not easily accessible to small- and medium-sized businesses in the U.S., some can be found only in the academic literature, and much is written using scientific terminology that can be difficult to understand. In addition, different teams of researchers have studied the same food commodities and have come to different conclusions – at times because they rely on different assumptions and accounting frameworks. Results may appear to conflict with each other, but sometimes these conflicting results are due to differences in modeling approaches. Even highly motivated businesses may have difficulty in identifying, understanding, and then drawing meaningful conclusions from this technical literature.

Oregon's Department of Environmental Quality has commissioned literature reviews and nine resulting summary documents in order to highlight what is known about the environmental impacts of producing, processing, distributing and consuming a variety of foods. These summaries are based on a thorough review of publicly available life cycle assessment LCA studies that are written in English and published since 2005. Such LCA studies can help identify those parts of the food value chain with disproportionately high environmental burdens, allowing improvement efforts to focus where they are likely to have the greatest potential for change. These LCA reviews can also point to potential trade-offs between environmental indicators or abatement strategies. These summaries do not provide information that is specific to Oregon production, and foods produced in Oregon may have different environmental impacts than those produced elsewhere. Some of the food products studied are not produced in Oregon, but are imported and consumed in Oregon. Nevertheless, a review of existing literature may be useful to producers, sellers, and users of food products in Oregon, as well as other locations.

Research Goal

The goal of this project is to distill life cycle research currently available in the scientific literature and present it in an easy to use format to inform a variety of decisions. These include improving production practices, guiding procurement patterns, assessing packaging alternatives and distribution modes, and focusing future research.

The literature review and summaries may identify:

- Those activities in the life cycle that contribute significantly to environmental impacts (e.g., are most of the environmental impacts associated with fertilizer use, packaging, transportation, cold storage, or some other aspect of production or consumption?). This may aid in prioritization of voluntary environmental initiatives.
- Relative environmental impacts of different practices (e.g., how different production, transport, processing, or packaging methods compare). This may aid in the evaluation of alternatives.
- Limitations in the available literature. This may help users to avoid drawing conclusions that are incorrect, as well as to identify knowledge gaps that might benefit from further research.

The objective of this project is *not* to:

- Conduct original life cycle analyses;
- Evaluate production conditions specific to the Pacific Northwest;
- Compare Pacific Northwest foods against foods produced elsewhere;
- Compare different types of foods against each other;
- Inform, propose, or promulgate regulations.

Commodities Studied

This critical literature review evaluates beer, citrus, coffee, land-based aquaculture, pork, tomatoes, and wine. Two cross-cutting topics – the significance of transportation as a contributor to environmental impacts of foods and the tradeoffs between packaging and food waste – are also included.

Project Partners

The Oregon Department of Environmental Quality led this project, with support from the Oregon Sustainability Board. Additional funding was provided by Metro. The University of Michigan Center for Sustainable Systems conducted the project research under contract; Martin Heller was the primary author of the resultant literature summaries.

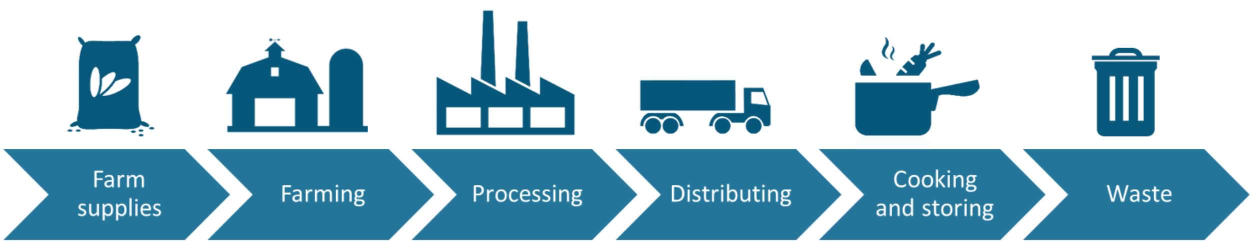
Research Learning

The Food Product Environmental Footprint literature summaries provide a systematic review of available LCA literature, focusing on the prevailing production practices for the chosen commodities, based on the current state of research for the selected food items/topics. They highlight life cycle impacts in terms of global warming potential expressed in kilogram of carbon dioxide equivalents (kilogram CO2 equivalents), and additional environmental impacts where included in the literature. The research also highlights information gaps and identifies areas for future research, and possible opportunities for improving local production, purchasing tactics, and delivery of products to market.

Life Cycle Assessment of Food

The life cycle of food (Figure 1) is quite complex and intricately bound to the local ecosystem where the food item is produced, while at the same time receiving production inputs from many global industrial sectors. The resulting final products are sold far and wide across the planet. The implication of such a complex system, where production may be separated by large distances from consumers, is that many consumers – or other stakeholders in the food product chain – do not have a clear sense of the inputs and processes required to provide their food. As the old adage goes, "out of sight, out of mind." In addition, impacts associated with food production may be disproportionately borne by producing regions and communities, while the 'fruits' are enjoyed elsewhere. LCA can offer perspective into these complex and far-reaching systems, allowing a broader understanding of their overall environmental impacts.

FIGURE 1. Generic life cycle of food production and distribution



Life Cycle Assessment is a methodological approach that has evolved from initial efforts in the early 1970s to a widely accepted tool in use today. LCA is used to assess the potential environmental impacts of product systems and services, accounting for the emissions and resource used throughout a product's life cycle. While LCA has been defined and standardized through international guidelines, there remains great flexibility in the method, thus permitting application to a wide range of questions about diverse product and service systems. The basic LCA framework is an iterative procedure involving:

- Definition of the goal and scope of the study – what are we studying, how are we studying it, why, and for whom?;
- Life cycle inventory analysis − data collection and calculation procedures to quantify relevant inputs and outputs (energy, raw materials, co-products, waste, emissions to air, water, and soil) across each unit process within the system boundary;
- Life cycle impact assessment – associating inventory data with specific environmental impact categories and modeling the relevance of those impacts; and
- Interpretation of outcomes.

Agricultural and food product systems have offered both an ideal and challenging application of LCA methods due to their complexity and their close interlink between nature and the "managed" system. Research applying LCA to food has increased almost exponentially since the mid-1990s, and many methodological challenges have been addressed. Still, agriculture and food production is inherently dispersed and heterogeneous in comparison to other industrial production systems, making the collection of truly representative data extremely difficult. As a result, most food LCAs are case studies representing select sets of geographical regions and production practices. Many of these studies make comparisons between production practices or other relevant parameters. These intra-study comparisons can be considered more reliable than comparisons between studies, as methodological choices within a given study can influence outcomes. Thus, the meta-analysis style comparisons made in Oregon's Product Environmental Footprint literature summaries should be considered as general guidance rather than an absolute representation of differences in environmental performance.

Distribution, Retail, and Consumption

The downstream stages of distribution, retail, and consumer-level processes such as household refrigeration and cooking can be important contributors to overall environmental performance for some foods. Depending on the scope of the questions being asked in a given LCA study, however, these stages may not be included in the analysis. For example, a study may be interested in exploring differences in environmental impact between conventional and organic production, and therefore focus on the on-farm activities. In addition, downstream stages are highly dependent on regional distribution networks and individual consumer behaviors; and they are challenging to model in a generic sense. Therefore, studies that do consider these downstream stages can give us a general sense of their relative importance, but it must be recognized that this is dependent on behaviors across the distribution chain and in individual households.

Literature Review Limitations

Geography

Each of the Food Product Environmental Footprint summaries represent the breadth of publicly available data (in English) for that specific food product or topic. Many of the underlying studies refer to specific analyses for a given geographic location. The geographies represented in LCA studies range across the globe, but are focused in Western Europe. Where available, examples of U.S. specific cases are included, however U.S.-specific studies were in the minority. It is therefore important to acknowledge that while the analyses provide a view into the life cycle environmental impacts of the products and processes, they may not directly reflect U.S. production conditions. For example, a study may reflect a packaging format (re-used glass bottles, for instance) that is common in Europe but not typically found in the U.S. Further, the researchers found no studies specific to Oregon production conditions. Regardless, the literature does offer a directional perspective as to the burdens associated with prevailing production and distribution patterns.

Comparisons between Food Products

This collection of food product or topic summaries as a whole is an attempt by the Oregon DEQ to research current literature and examine the usefulness of a meta-analysis approach for understanding environmental burdens associated with the production and distribution for a sampling of products consumed in Oregon. Each of the nine topic summaries were approached as independent literature reviews. This means that the content of each summary is specific to that food product or topic and each summary should be read as a stand-alone treatise. Comparison between topics and food products is not an appropriate use of these summaries because they are not presented on a common functional basis, the system boundaries – what's included in the analyses – vary, and for the most part, the products are not interchangeable. Generalizations across other food production systems should also be avoided.

Impact Categories

In general, the LCA literature for food tends to focus on greenhouse gas emissions, or carbon footprint, as a central measurement to represent the relative sustainability of the production system. Often, this is driven by data availability or uncertainties inherent in other impact categories. In some cases, food LCAs also address additional impact categories such as energy, water, or eutrophying emissions. Many other impacts are affected by food production, including additional impacts to soil, water, and air. Food commodities that are produced in one place and consumed in distant places carry with them embodied environmental burdens that may not be apparent in the place of consumption. These burdens include changes to land use and waterways, and demand for, and pressures on, natural resources. Potential impacts to water include acidification, turbidity, nutrient build-up leading to eutrophication, and eco-toxicity. Effects on air include changes to the global ozone layer, and smog and particulates in the air leading to respiratory illnesses and toxicity in humans. Long-term damage to soils is a growing concern worldwide as intensive agricultural practices, with their heavy reliance on petrochemicals, are exhibiting signs of weakening fragile soil ecology. A focus on limited impacts in the Food Product Environmental Footprint summaries does not reflect particular environmental priorities, but instead reflects the coverage provided in existing literature. Thus, the conclusions drawn must be taken in this context, acknowledging that there may be trade-offs with environmental categories not represented.

The Food Product Environmental Footprint summaries tend to focus on greenhouse gas emissions as an environmental indicator, but a variety of other environmental burdens also need our attention. This is particularly relevant as we consider food consumption: many of the foods consumed in Oregon are produced elsewhere. This means the food we consume results in environmental impacts that are borne by distant localities, often outside the United States.

Optimizing food production and consumption based solely on greenhouse gas burdens could result in shifting of burdens to other impact categories that have more direct impacts at or near the point of production. When looked at solely through the lens of carbon impacts, other impacts that may affect vulnerable communities and regions are left out of the equation. In addition, social equity issues are often a critical part of agricultural production, particularly for foods produced in developing countries for consumption in developed economies, and are also not represented. This means that making choices based solely on carbon footprint of products has the potential of leading to unintended consequences. At the same time, greenhouse gas considerations should not be ignored, and some information − even if still incomplete − is generally better than less information.

The research findings provided in the nine topic summaries offer opportunities to consider production practices, distribution modes, and packaging solutions for business and purchasing decisions, but only for the specific items covered in this study. Given the limitations of the existing literature, this body of work also offers insights into further research needs that would evaluate some of the other damage categories not represented in current scientific literature.

Glossary of Terms

Life Cycle Assessment (LCA) is the internationally accepted and standardized methodology that defines a systematic set of procedures for "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle." A cradle-to-grave system boundary considers the life cycle stages of a product from raw material extraction through to the disposal at the end of life of the product. A cradle-to-gate system boundary considers the life cycle from raw material extraction through an intermediate life cycle stage (e.g. grape production).

Product Carbon Footprints (CF) are a subset of LCA that focus only on the climate change or the global warming potential impact category. A product carbon footprint, reported in CO_2-equivalents (CO_2eq), is a measure of greenhouse gas emissions (GHGE) over a product's life cycle. Greenhouse gases of particular relevance to food and agriculture include carbon dioxide, methane, nitrous oxide, and fluorinated hydrocarbons used as refrigerants. These gases differ in their warming effect, and are characterized relative to the warming effect of carbon dioxide. Thus, over the 100-year period following release to the atmosphere, methane has a Global Warming Potential of 30 kilograms CO_2 eq (28 for biogenic methane) and nitrous oxide 265 kilograms CO_2 eq, according to the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report.

Carbon dioxide equivalent (CO_2 eq): The universal unit of measurement to indicate the global warming potential (GWP) of each greenhouse gas, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate releasing (or avoiding releasing) different greenhouse gases against a common base.

Eutrophication originates mainly from nitrogen and phosphorus in sewage outlets, manures and fertilizers that find their way to waterbodies. Nutrients that run off, leach or otherwise enter waterways accelerate the growth of algae and other vegetation in water. Degradation of this excess organic material consumes oxygen, resulting in oxygen deficiency and fish kills (dead zones). Eutrophication potential quantifies nutrient enrichment by the release of substances in water or into the soil, and is commonly expressed in PO_4 equivalents.

Acidification originates from the emissions of sulfur dioxide and oxides of nitrogen, which react with water vapor in the atmosphere and form acids that precipitate to the earth's surface (acid rain). Acidification potential measures the contribution of an emission substance to acidification, typically expressed in SO_2 equivalents.

Water use: Water resources are also essential for agricultural production, and irrigation with surface and ground water (termed "blue water" in water use jargon) makes agriculture possible in more arid regions. Geographical location influences the amount of blue water required to produce a given crop. The impact of that water use on the local environment and other potential users, however, also varies with location: using water in water stressed regions is more impactful than using water in regions with ample supply. Generalization of water use from one production region to another is difficult and unadvisable. Water use in LCA is often reported simply as an inventory (liters), but consensus is building as to how best to incorporate the impact of water use in an LCA framework.

Human toxicity potential, **eco-toxicity** potential: A toxicological effect is an adverse change in the structure or function of a species as a result of exposure to a chemical. Characterization factors for various chemicals are developed based on multimedia chemical fate models, exposure correlations, and chemical risk screenings. Toxicity potentials are characterized by high uncertainties due to the complex fate, exposure and toxicological modeling required.

95% Confidence interval is a statistical parameter that acts as a good estimate of the uncertainty of a sample of data. In the case of estimating a product's carbon footprint, we don't actually know the "true" mean value. When averaging estimates from a number of studies, there is obviously uncertainty; not only do LCA methods introduce uncertainty, but there is expected variability depending on the specifics of the modeled system (soil, climate, electricity grid mix, etc.). A 95% confidence interval means that if 100 samples were taken and a confidence interval were computed for each sampling, we would expect 95 out of 100 of the intervals to contain the "true" mean value.