LIFE CYCLE ASSESSMENT: A TOOL FOR QUANTIFYING THE ENVIRONMENTAL IMPACTS OF PLUM AND PRUNE PRODUCTION

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OBJECTIVE

Life Cycle Assessment (LCA) is a comprehensive approach for assessing the environmental impacts and resources used throughout the full life cycle of a system or a product, such as an orchard crop. LCAs typically account for the energy and environmental impacts of all stages of a product's life cycle, such as acquisition of raw materials, the production process, handling of waste byproducts, and more. To date, this life cycle model of plum/prune production considers the quantity of irrigation water used specific to orchard location, energy and fuel required for pumping water, energy required to produce, transport, and apply fertilizers and pesticides, energy needed for harvest, transport, and post-harvest processing including drying.

By characterizing, quantifying, and interpreting the environmental flows from "cradle-to-grave," LCAs can play an important role in assessing the greenhouse gas (GHG) and pollutant emissions associated with agricultural products, which tend to be more dependent on regionally specific conditions and factors than industrial products. Importantly, LCAs can also identify "hot-spots" - opportunities along the production chain for reducing energy consumption and pollutant/ GHG emissions. The LCA approach can also identify and quantify potential GHG and pollutant reductions that occur in the production process. This plum/prune model also includes estimates of carbon sequestration in orchard floor soils as well as avoided emissions from fossil-fuel based energy production from the use of orchard waste biomass as an electricity feedstock.

The life cycle perspective is also useful in avoiding problem shifting from one phase of the life cycle to another or from one environmental issue to another. For example, the use of synthetic nitrogen fertilizer accounts for a relatively modest portion of the total GHG emissions of field production for many crops when only considering on-farm operations and soil emissions of nitrous oxide (caused by adding nitrogen to the soil). However, when the energy-intensive manufacturing of the fertilizer is included as a stage in the analysis, the portion of GHG emissions attributable to synthetic nitrogen use can increase by 30-150%, typically making it one of the largest sources of total GHG emissions in the carbon footprint of many crops, and warranting much more attention in GHG reduction efforts.

Greenhouse gas tracking or "carbon footprint" LCAs have applications for growers, food manufacturers, and retailers interested in reducing the GHG emissions of their products. Growers might use LCA models to estimate total emissions and understand where their greatest emissions are occurring, as well as to estimate the effects of different farming practices. They may also be used in the future to help focus publicly funded GHG emissions reductions incentive programs such as farm bill conservation programs or California's cap-and-trade Greenhouse Gas Reduction Fund, or to demonstrate eligibility for market-based carbon offsets as these programs become available. Manufacturers, retailers, and commodity organizations can use LCAs on a farm-level or industry-wide basis for marketing, labeling, or certification purposes.

PROCEDURE

Data on plum and prune production were collected from a variety of sources. UC Davis Economic Cost/ Return Studies as well as some grower interviews provided generalized data on typical practices, equipment, and agrochemical inputs; the USDA NASS Cropscape dataset provided prune and plum orchard location in the Central Valley; the California DWR provided data on surface water delivery infrastructure and groundwater depth; an orchard clearing company provided data on biomass removal; GaBi and EcoInvent provided life cycle-based data on resource use and pollutant emissions for various inputs and manufacturing processes; the CDFA provided yield and market share (of dried vs fresh plum) data; and the California Biomass Collaborative provided data on soil carbon accumulation in orchards and California biomass power plant locations and characteristics. Data on post-harvest processing and other external or contracted operations (nursery production, transportation, pollination, etc) were obtained from published literature, questionnaires, and interviews.

The above data were used to develop an LCA model of plum and prune production in ArcGIS and Microsoft Excel. This model sums the life cycle emission and energy use data for all inputs and processes occurring in plum/prune production, treating each production year, from orchard establishment through maturity, separately. Results are calculated on the basis of several functional units: per acre of orchard, per kilogram of fruit, and per nutritional calorie.

RESULTS AND CONCLUSIONS

Model results to date indicate that on-site emissions and energy use are dominated by fuel combustion during harvest operations, and that off-site emissions and energy use are dominated by natural gas combustion in drying operations (Fig. 1). Post-harvest drying and processing accounts for greater emissions annually than all other orchard inputs and operations put together (Fig 2). When considered from nursery tree production through harvest on a per acre basis, plum/prune production environmental impacts compare favorably to other major California orchard crops. However, post-harvest drying drives the impacts of production significantly higher than other orchard crops. In the charts below, GHG impacts are shown because A) this impact category relates directly to financial implications for the plum industry via California carbon markets, and B) most other air pollutant emissions are roughly similar in pattern (but not magnitude) in industrial processes.

Quantification of temporary carbon storage in standing biomass of plum/prune orchards and estimates of soil carbon accumulation indicate some potential for offset of these GHG impacts. Accounting for these environmental benefits of prune and plum production is necessary for accurate assessment of the GHG footprint of the industry, especially inasmuch as it relates to the requirements of the state carbon cap-and-trade program, under which GHG offset is currently valued at $12.79 per metric tonne of carbon dioxide equivalent.

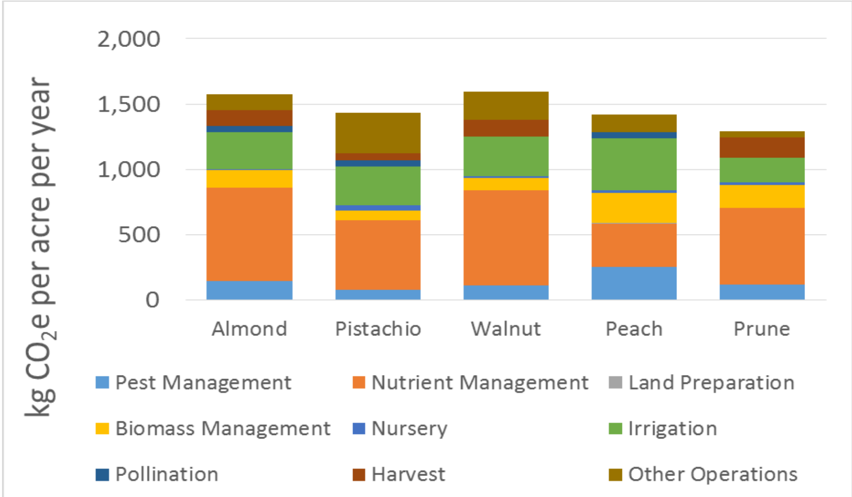

Figure 1. "Nursery to orchard gate" environmental impacts of major California tree crops as GWP_{100} greenhouse gas emissions (kilograms carbon dioxide equivalent over a 100 year timeframe). Impacts are labeled by management category, NOT including post-harvest processing.

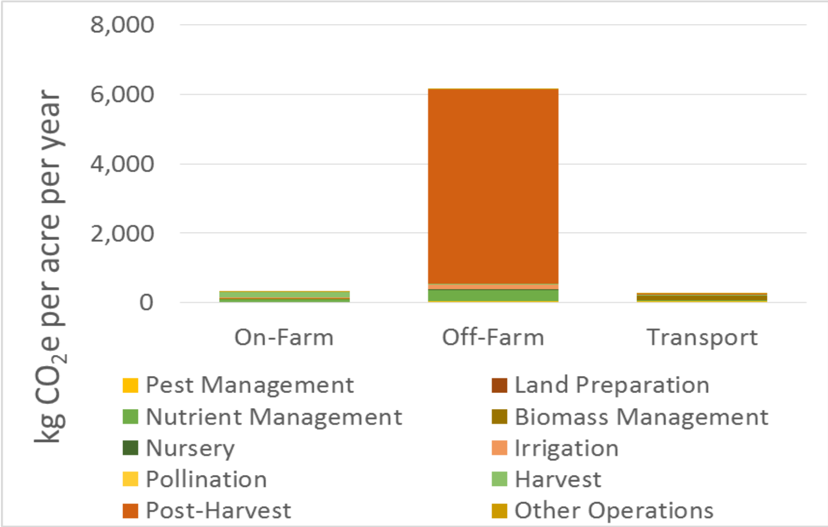

Figure 2. "Nursery to post-harvest facility gate" environmental impacts of prune production under drip irrigation as GWP_{100} greenhouse gas emissions (kilograms carbon dioxide equivalent over a 100 year timeframe). Impacts are labeled by management category (including post-harvest processing and drying) and production stage (on farm, off farm, or transport).

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