Carbon Footprint of Five California Orchard Crops

The following is a summary of a Life Cycle Assessment (LCA) produced by the Agricultural Sustainability Institute (ASI) at UC Davis for five important California orchard crops: almonds, peaches, pistachios, prunes, and walnuts. This project is one of several LCA models that ASI developed to analyze carbon and energy footprints and evaluate the greenhouse gas (GHG) emissions associated with the production of various foods.[1,2,3]

Life Cycle Perspective

Rather than evaluating only the environmental impacts of on-farm activities (such as fuel consumption by tractors, energy to pump water, etc.), LCA models examine environmental impacts throughout a product's entire life-cycle, accounting for all inputs necessary for producing, using, and disposing of a product. For more information on the characteristics and applications of LCA studies, see the related factsheet, "Life Cycle Assessment: A Tool for Assessing the Environmental Footprint of Farm Crops."[4]

In this study, ASI researchers calculated the GHG emissions, energy use and on-farm water use linked to the production of the five orchard crops, and considered the following stages of production:

1. Orchard establishment (e.g., soil preparation, planting)
2. Orchard management, including pruning, irrigation, tree replacement, pest control, and fertilizer use (including its production and transport)
3. Orchard removal and disposal
4. Post-harvest processing and handling
5. Transportation along the entire life cycle

LCA models can be used to compare the impacts of different scenarios. This model evaluated the impacts of different sets of orchard management practices in order to inform orchard industry decision makers about the best options for mitigating GHG emissions.

Findings

While the LCA found key sources of GHGs at every production stage, transportation of inputs and products to and from the farm had the smallest energy cost. The largest GHG and energy footprint was associated with the orchard management phase of production, indicating that focusing on farm management alternatives offers the greatest potential for lowering GHG emissions.

Across all five orchard systems, either irrigation or nutrient management (including fertilizer production and application) accounted for the greatest life cycle GHG emissions. Nutrient management accounted for up to 40% of emissions, while irrigation accounted for up to 20%, depending on the crop. This indicates that increasing nitrogen use efficiency and improving irrigation efficiency could significantly reduce emissions.

Open burning of orchard waste is a major emitter of methane, a potent GHG. Alternative disposal methods for prunings and removed trees, such as chipping the trees

What Growers Can Do To Decrease the Carbon Footprint of Orchards

According to this LCA model, the three most important practices that can decrease GHG emissions in orchard systems, in order of importance, are:

- Chip orchard waste (tree prunings, removed trees) and use for electricity production or apply as a soil amendment instead of burning
- Reduce synthetic nitrogen fertilizer use through the adoption of precision management techniques
- Improve irrigation energy efficiency through the use of drip or micro-sprinklers and solar pumps

and incorporating the biomass back into the soil or using it as mulch, can dramatically decrease GHG emissions. Another option is converting orchard waste to bioenergy, which can offset 20% to almost 60% of GHG emissions generated during the entire orchard lifespan, depending on variables such as the carbon content of the fossil fuel source being replaced.

photo credit: USDA

Study Implications

For evaluating scenarios — The LCA model can be used to evaluate various scenarios and inform management decisions. For example, it shows the rate of biomass accumulation and carbon storage is most rapid as trees mature and typically levels off before the end of the orchard's productive lifespan. This indicates that managing orchard lifespan for both yield and optimal carbon sequestration can increase soil and climate benefits.

The LCA model could also be used to evaluate the combined savings possible when irrigation and nutrient management are optimized. Delivering fertilizers (either synthetic or organic) via drip irrigation systems can improve the precision and timing of fertilizer applications, and therefore minimize both fertilizer and water use.

For policy development — The findings of this LCA study could be influential in either the development of protocols guiding the terms of carbon trading, or by identifying public investment opportunities to support management practices with the greatest climate benefits. California has implemented a cap-and-trade program that creates both a carbon market and a public source of revenue—the Greenhouse Gas Reduction Fund—that provides incentives for GHG-reducing activities. Also, the USDA Natural Resources Conservation Service is identifying which conservation practices have the greatest climate benefits and may prioritize some farm bill funds for this purpose. In addition, this LCA could inform future regulation that should take into account both GHG emissions from orchards and also their potential for carbon sequestration.

For food companies — Several efforts underway by food companies to develop environmental stewardship standards present additional possibilities for the application of LCA results. The Sustainability Consortium, for example, considers LCA to be the "gold standard" methodology for assessing environmental sustainability for commodity sourcing.

For researchers — One example of research needs identified by this model is the assessment of soil carbon sequestration in organic orchard systems. The LCA model found that substituting organic soil amendments such as manure and/or cover crops can reduce GHGs associated with energy-intensive synthetic fertilizer manufacturing if the organic inputs are transported relatively short distances. In many cropping systems, organic methods have also been shown to increase soil carbon sequestration, however there is insufficient research on organic orchards.

For clean energy development — The LCA demonstrates substantial reductions in net GHG emissions when old and diseased trees are used to produce renewable energy (replacing fossil fuel energy sources) rather than burned in the fields. It also finds that improvements in the efficiency of power plants is the single most effective way to reduce GHGs in the entire life cycle. Improvements in California's biomass power generation capacity and efficiency can offer substantial climate benefits in a landscape filled with tree crops that age out on a rotating basis. The benefits of using orchard biomass to produce clean energy must be weighed against the co-benefits of integrating chipped trees and prunings back into orchards as soil amendments or mulch, which increases soil organic matter and thereby improves water penetration and retention, fertility and resilience to floods and drought.

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[1] Greenhouse Gas and Energy Footprint of California Almond Production. http://asi.ucdavis.edu/sarep/sfr/almond-study

[2] Honey Carbon Footprint. http://asi.ucdavis.edu/sarep/sfr/lifecycleassessments/honey

[3] Life Cycle-Based Comparisons of Energy Use, Greenhouse Gas Emissions and Water Use of California versus Michigan Processed Tomato Products and California versus Southeastern Paddy Rice. http://asi.ucdavis.edu/sarep/sfr/tomato-study

[4] Available at http://asi.ucdavis.edu/sarep

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