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Category-Level Product Environmental Footprints of Foods

Recommendations for Further Evaluation

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STATEMENT OF WORK:
Task 2. **First draft of recommendations:** Contractor will prepare a separate document containing its recommendations for which food types (commodities) to study in further detail. For the purpose of this contract, "commodity" is defined not only as a farm-level output but rather as a distinct type of food product. For example, "fluid milk" (for use in making food products or final consumption in fluid form) is a commodity, while "yogurt", "ice cream" and "cheese" are separate commodities. Contractor may propose more food types than budget allows, and contractor may rank or group commodities (for example "high priority", "medium priority", and "not recommended"). At a minimum, ten commodities will be recommended as "high priority" with at least four additional commodities identified as contingencies. Recommendations will be based on the quality of environmental information available (based on the results of Task 1), giving preference to high volume products produced or purchased in the states of Oregon and Washington, while also taking into account the organizational structure of the agricultural and food industry as well as interest by institutional buyers.

1. Introduction

Climate, soils and topography make food production in the states of Oregon and Washington a valuable and diverse economic sector. Tables 1 & 3, below, indicate the top ranking agricultural commodities in Oregon and Washington, respectively. In addition, Oregon and Washington rank as top U.S. producers of a number of unique crops, as seen in Tables 2 & 4, making their production practices relevant not only locally but to national and international consumers as well.

Food production contributes significantly to environmental concerns, and by extension, offers potential for significant improvement. Production of the food consumed in the U.S. accounts for on the order of 10% of the country's *total* greenhouse gas emissions[1]. Food contributes close to 14% of Oregon's consumption-based greenhouse gas emissions. These impacts include not only the agricultural production of food, but also contributions from processing, distribution, storage and consumption. Making reductions in the environmental footprint of supplying food, however, requires an understanding of the sources of current impacts, along with guidance as to where improvement efforts should focus for maximal effectiveness.

The objective of this project is to highlight those attributes and characteristics of individual food commodities that are meaningful predictors of reduced environmental impact. This will be done through a series of summary reports capturing what is known about the environmental impacts of a particular food commodity, based largely on review of the LCA literature, but drawing from other scientific fields as well. The purpose of the current document is to recommend the specific commodities to focus on for further evaluation.

[1] Heller, M. C. and G. A. Keoleian (2014). "Greenhouse Gas Emission Estimates of U.S. Dietary Choices and Food Loss." Journal of Industrial Ecology **19**(3): 391-401.

Table 1. Oregon's top 20 Agricultural Commodities: 2014[2] (gray shaded commodities will not be considered in this phase of the project)

Rank	Commodity	Value - Dollar
1	Cattle & calves	922,031,000
2	Greenhouse & nursery	829,909,000
3	Hay	703,080,000
4	Milk	656,635,000
5	Grass seed	449,018,000
6	Wheat	302,056,000
7	Potatoes	164,703,000
8	Hazelnuts	129,600,000
9	Pears	127,392,000
10	Grapes for wine	118,320,000
11	Onions	106,334,000
12	Christmas Trees	103,777,000
13	Blueberries	102,325,000
14	Cherries	82,709,000
15	Eggs	65,781,000
16	Mint, for oil	51,433,000
17	Blackberries	50,133,000
18	Crab	47,980,000
19	Sweet Corn	45,121,000
20	Apples	42,240,000

Table 2. National Ranking of Oregon Agricultural Production: 2014[2] (gray shaded commodities will not be considered in this phase of the project)

Commodity	Ranking among states	Percent of US production
Blackberries	1	100%
Boysenberries	1	100%
Hazelnuts	1	100%
Raspberries, black	1	100%
Ryegrass seed	1	92%
Orchardgrass seed	1	94%
Crimson clover	1	85%
Fescue seed	1	61%
Sugarbeets for seed	1	47%
Red clover seed	1	75%
Potted florist azeleas	1	59%
Onions, storage	1	22%
Christmas trees	1	17%
Peppermint	2	32%
Sweet cherries	2	16%
Hops	2	12%
Dungeness crab	3	27%
Pears	3	26%
Kentucky bluegrass seed	3	20%
Austrian winter peas	3	16%
Nursery stock	3	11%
Snap beans, processing	3	5%
Raspberries, red	3	2%
Strawberries	3	1%
Garlic	3	<1%
Blueberries	4	15%
Green peas	4	11%
Mink	4	8%
Cranberries	4	6%
Wine grapes	4	1%

[2] Oregon Department of Agriculture, "Oregon Agriculture Facts and Figures", July, 2015. http://www.oregon.gov/ODA/shared/Documents/Publications/Administration/ORAgFactsFigures.pdf.

Table 3. Washington's top 10 Agricultural Commodities: 2013[3] (gray shaded commodities will not be considered in this phase of the project)

Rank	Commodity	Value - Dollars
1	Apples	2,189,095,000
2	Milk	1,298,880,000
3	Wheat	1,014,032,000
4	Potatoes	792,000,000
5	Cattle and calves	706,447,000
6	Hay	675,050,000
7	Cherries	385,198,000
8	Grapes	278,640,000
9	Pears	225,392,000
10	Hops	202,101,000

Table 4. National Ranking of Washington Agricultural Production: 2013[3] (gray shaded commodities will not be considered in this phase of the project)

Commodity	Ranking among states	percent of US production
Red raspberries	1	93
Hops	1	79
Spearmint oil	1	73
Wrinkled seed peas	1	60
Apples	1	57
Sweet cherries	1	51
Pears	1	50
Grapes, concord	1	37
Carrots, processing	1	37
Green peas, processing	1	34
Peppermint oil	1	31
Sweet corn, Processing	2	25
Potatoes	2	24
Onions	2	21
Apricots	2	11
Nectarines	2	8
Grapes, all	2	5
Asparagus	3	25
Lentils	3	19
Grapes, Niagra	3	19
Prunes and plums	3	18
Blueberries	3	15
Dry edible peas	3	12
Tart cherries	3	6
Barley	4	7
Wheat	4	7
Cranberries	5	2
Strawberries	5	0
Dry edible beans	6	9
Peaches, freestone	7	2
Milk	10	3

[3] USDA NASS, "Value of Washington's 2013 Agricultural Production Surpasses Ten Billion Dollars," January 26, 2015. http://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Current_News_Release/2015/VOP_2014.pdf

2. Selection criteria

We have attempted to combine our review of existing LCA literature with an appreciation of food production in Oregon and Washington to recommend ten commodities for further research and development of summary reports. Criteria accounted for in the recommendations include:

- Selection of food commodities produced in large volume in OR and/or WA
- Selection of commodities for which production in OR and/or WA represent a large fraction of total U.S. production
- Selection of foods for which the environmental impact of their production in OR and WA is significant, based on estimated greenhouse gas emissions associated with on-farm production.
- Selection of food commodities for which the available LCA literature is of sufficient quantity and quality to offer sound guidance.
- Assurance that a diverse selection of food types be included in order to represent a range of product life cycles in the final summary documents. For example, including both apples (a hard fruit) and raspberries (a soft fruit) may be warranted as they represent very different handling, storage and distribution product chains and may therefore provide lessons transferrable to other foods of their type.

As the scope of this project is limited to *foods*, agricultural crops that are not typically food for humans, such as grass and clover seed, (shaded gray in in Tables 1-4) were not considered. Beef is not recommended for further evaluation in the current phase of this project based in part on high variability in production methods and associated environmental impacts, and the fact that a large portion of the life cycle of cattle born in OR or WA occurs elsewhere. In addition, for cattle that graze on rangelands (a common production practice in Oregon), the impacts of grazing on soil carbon can vary significantly and soil carbon impacts lack clear standards for accounting.

Table 5 summarizes information on important food crops in OR and WA agriculture, including an estimate of the greenhouse gas emissions that their production contributes in each state, and a summary of the available LCA literature. Foods in Table 5 are ranked based on a subjective evaluation of the above-mentioned criteria; the first ten foods listed are recommended for further evaluation, but others may be options if interest develops.

The success of this project is dependent on providing information to businesses and organizations that may find it useful in directing change. Often the ease by which change can be made is dependent on the organizational structure of an industry. Therefore, **we welcome input from stakeholders on the organizational structure within the Pacific Northwest of the recommended food industries, as well as suggestions of commodities not included here that may be of particular interest to institutional buyers and/or food processors**.

Table 5. Recommended foods for further evaluation and categorical footprint assessments, including importance to OR and WA and quality of LCA data. The first 10 foods are recommended.

		Oregon Production				Washington Prodcution			
	food	2014 production (lbs)[a]	$ value (2014)[a]	ranking in $ value	estimated annual GHGE (at farm gate)[b] kg CO_2eq	2014 production (lbs)[c]	$ value (2014)[c]	ranking in $ value	estimated annual GHGE (at farm gate)[b] kg CO_2eq
1	dairy (farm milk)	2,555,000,000	656,635,000	4	1,263,232,000	6,584,000,000	1,626,248,000	2	3,255,233,000
2	wheat	2,666,640,000	302,056,000	6	374,966,000	6,507,600,000	719,270,000	3	915,057,000
3	apples	155,000,000	43,269,000	20	17,577,000	7,300,000,000	1,895,887,000	1	827,806,000
4	potatoes	2,256,200,000	178,240,000	7	368,422,000	10,147,500,000	771,210,000	4	1,657,018,000
5	eggs	94,914,000	65,781,000	15	146,808,000	254,583,000	176,805,000	15	393,777,000
6	wine grapes	116,000,000	118,320,000	10	24,204,000	454,000,000	251,970,000	8	94,728,000
7	pears	432,000,000	127,392,000	9	48,204,000	832,000,000	233,824,000	9	92,838,000
8	hazelnuts	72,000,000	129,600,000	8	16,982,000				-
9	raspberries	8,650,000	17,159,000	37	800,000	72,990,000	57,921,000	24	6,754,000
10	aquaculture (food fish)	N/A	1,536,587		-	N/A	83,570,349	17	-
11	aquaculture (mollusks)	N/A	10,554,532		-	N/A	149,319,676		-
12	strawberries	15,500,000	13,125,000	40	3,797,000	9,900,000	11,093,000	33	2,425,000
13	onions	1,423,800,000	106,334,000	11	251,872,000	1,300,000,000	106,444,000	11	147,418,000
14	blueberries	87,300,000	102,325,000	13	18,611,000	94,600,000	112,638,000	19	20,168,000
15	cherries, sweet	115,800,000	82,709,000	14	28,364,000	474,000,000	502,370,000	7	116,102,000
16	green peas (for processing)	82,860,000	10,466,000	39	20,296,000	236,880,000	29,433,000	25	58,021,000
17	Carrots (for processing)	N/A	N/A			(D)	(D)		
18	snap beans (for processing)	69700000	13,940,000		47,423,000	N/A	N/A		
19	garlic	1,200,000	1,080,000		354,000	N/A	N/A		
20	sweet corn, (for processing)	440,960,000	27,841,000	19	-	1,385,200,000	74,693,000	13	-

[a] http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=OREGON and NASS QuickStats database: http://quickstats.nass.usda.gov/

[b] Annual farm gate greenhouse gas emissions estimated based on average emission factors from Food LCA Literature Review database and 2014 state production values.

[c] http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=WASHINGTON and NASS QuickStats database: http://quickstats.nass.usda.gov/

Table 5, continued. Recommended foods for further evaluation and categorical footprint assessments, including importance to OR and WA and quality of LCA data. The first 10 foods are recommended.

		LCA data quality and quantity				
	food	rating of LCA data	# entries in DB	# studies	U.S. Studies?	NOTES
1	dairy (farm milk)	hi	81	21	Yes	some comparisons of conventional & organic. Numerous alternative production methods represented
2	wheat	hi	19	7	Yes	Organic vs. conventional comparisons, crop rotation comparisons
3	apples	hi	25	12	Yes	numerous comparisons between conventional & organic. One study explores local cold storage vs. imports from southern hemisphere (in UK context)
4	potatoes	hi	16	7	No	conventional & organic comparisons
5	eggs	hi	30	9	Yes	comparisons of production styles
6	wine grapes	med	11	4	yes	comparisons between conventional & organic.; all focused on grape production (do not include impacts of wine making)
7	pears	low	8	5	no	comparisons of conventional & organic production in China; studies consider impacts up to point of retail
8	hazelnuts	low	9	2	no	
9	raspberries	low	5	3	no	UK study explores seasonality& local vs. import
10	aquaculture (food fish)	med	27	8	no	comparisons of production systems (recirculation, flow-through, etc)
11	aquaculture (mollusks)	low	4	2	no	
12	strawberries	med	11	7	Yes	comparisons of conventional & organic, greenhouse & open field, local & import
13	onions	very low	1	1	no	no detailed info on production impacts
14	blueberries	low	4	2	Yes	compares conventional & organic
15	cherries, sweet	low	3	1	no	considers local vs. imported
16	green peas (for processing)	low	3	1	no	considers local vs. imported
17	Carrots (for processing)	low	5	2	no	
18	snap beans (for processing)	low	4	1	no	considers local vs. imported
19	garlic	low	3	1	no	considers local vs. imported
20	sweet corn, (for processing)	very low	0		no	

3. Recommended foods for further evaluation and development of Categorical Footprint Summaries

The following paragraphs provide a brief justification for the top ten recommended commodities.

Dairy

Dairy is an important economic commodity in both Oregon and Washington, and because of the relatively large carbon footprint of dairy production, it also represents a significant fraction of the total greenhouse gas emissions in these states (2% in OR[4], 3.5% in WA[5]). Dairy production has also been extensively studied with LCA, including a comprehensive, geo-spatially explicit U.S. study sponsored by Dairy Management Inc. We were a part of the research team for this national study and have intimate familiarity with the study and its results. Combined with other milk LCA literature, this will offer a robust summary statement about the environmental impact of dairy production in OR and WA. In addition, we have previously studied the environmental trade-off between energy and water use in sourcing feed crops[6] and can apply insights from that work to dairy in the Pacific Northwest. Note that we are currently recommending that the focus be on farm-gate milk, as the bulk of the environmental impacts for processed dairy products (cheese, yogurt, etc.) originate on-farm. However, if the interest arises, specific consumer-level dairy products could be considered independently. According to USDA QuickStats, there are 20 dairy processing plants in OR, and 10 in WA, providing some indication of the structure of dairy processing in the region.

Wheat

Wheat is also a very important crop economically in both Oregon and Washington. The region produces primarily soft white wheat, used in pastries, cakes, pretzels, cookies and Asian noodles, but also includes hard red winter and spring wheats. With more than 85% of Oregon-grown wheat being exported, wheat is the #1 product exported through the Port of Portland. A large number of LCA studies on wheat exist in the literature. In addition, wheat is one of seven commodities currently represented in the USDA's LCA Digital Commons[7], with inventories derived from USDA ag census and other data available specifically for OR and WA production over multiple years.

Apples

Washington is the leading producer of apples in the U.S., with apples being the state's highest value agricultural commodity. Apple production is also important in Oregon. Long-term storage in controlled temperature and atmosphere facilities is common with apples, and often in market competition with fruit imported out-of-season from southern

[4] Based on Oregon 2014 Total Emissions of 60.1 million MT CO2 eq. (http://www.oregon.gov/deq/AQ/Pages/Greenhouse-Gas-Inventory-Report.aspx#inventory)

[5] Based on Washington 2012 Total Gross Emissions of 92.0 million MT CO_2 eq. (http://www.ecy.wa.gov/climatechange/docs/2012GHGtable.pdf)

[6] Heller, M. C. and G. A. Keoleian (2011). "Exploring a Water/Energy Trade-off in Regional Sourcing of Livestock Feed Crops." Environmental Science & Technology **45**(24): 10619-10626.

[7] https://www.lcacommons.gov/discovery/search

hemisphere growing regions. This is a particularly interesting trade-off to examine with LCA, and two identified studies examine the seasonality of local vs. imported apples in a European context. Apple processing (into juices, sauce, etc.) is also important to the apple industry in the Pacific Northwest, and while LCA studies on these final products specifically is lacking, we are investigating other means of estimating processing impacts in order to offer perspective on their relative importance.

Potatoes

Potatoes are Oregon's 7th highest value crop; potatoes rank #4 in Washington. Because of the large volume of production, the potato industry also represents a noticeable portion of each state's greenhouse gas emissions: an estimated 0.6% of total state emissions in OR, and 1.8% in WA. Potatoes are annual vegetables, so their production typology differs from the perennial fruits and nuts included among recommended commodities. Some of the LCAs of potatoes consider processed end forms and find significant increases (above farm-gate impacts) in carbon footprint: peeled potatoes 50-60% greater, mashed potatoes 2-2.8 times greater, potato chips 3-4 times greater. Refinement of this type of information may provide insights to hotspots in potato processing, in addition to considerations of the production phase.

Eggs

While perhaps not considered an iconic Pacific Northwest food, egg production is nonetheless a strong agricultural commodity, ranking 15th in dollar value in both OR and WA. Egg production practices vary widely, with a number of choices available in the marketplace (organic, conventional, cage free, free range, etc). Many of these options have been compared in LCA studies (albeit in a European context), offering insights into differences in environmental impact. In general, feed production accounts for the largest share of impacts in egg production, so feed conversion efficiencies lead to reduced overall emissions. But these efficiencies need to be considered in light of the environmental costs of feed sourcing as impacts of feed production can vary significantly. Likewise, feed sourcing in the arid west is of particular interest due to irrigation needs for feed crop production; energy/water trade-offs in feed sourcing, mentioned previously, also apply here.

Wine grapes

Wine grapes are a distinctive product of the Pacific Northwest that contributes significantly to the agricultural economy of the region. Viticulture presents a unique set of perennial cultivation practices with distinct differences from orchard crops. Grape production in California's wine growing regions has been analyzed with LCA, and insights gained in those studies may be translatable to OR and WA wine grape regions.

Pears

Pear production ranks 9th in terms of value of agricultural commodities in both OR and WA, with WA being the top US producer at 50% of the US pear crop, and OR ranking 3rd among states with 26% of US production. In 2005, the Oregon legislature named the pear the state fruit. LCA studies of pear production in Switzerland Portugal, Italy, and China have been identified. From an environmental impact perspective, pear cultivation, storage,

processing, and distribution is likely similar to apples; this should be considered in making the final commodity selection.

Hazelnuts

Oregon produces virtually the entire U.S. hazelnut crop, with the U.S. ranking third in global production. The largest hazelnut processor in North America is located in OR. To date, we have identified only two LCA studies that consider hazelnuts: one in an Italian context and the other in Iran. The Italian study considers different final forms (hazelnut paste, spreadable cream, chocolate covered) and includes estimates of energy demand for various processing steps. In addition, we have identified a hazelnut enterprise budget for the Willamette Valley developed by Oregon State University[8] which should allow a scan-level estimate of the environmental impacts of OR hazelnut production.

Raspberries (cane berries)

Cane berry production, including red and black raspberries, blackberries, and boysenberries, is very important in the Pacific Northwest. Oregon is the lead U.S. producer of blackberries, boysenberries and black raspberries, growing nearly all of the country's commercial crop. Washington is the top producer of red raspberries, with OR ranking 3rd among states. These small, soft fruits have short shelf lives as fresh berries, thus requiring expeditious distribution channels that make their life cycles considerably different than pome fruits such as apples and pears. Because of their high perishability, processing methods (freezing, canning, preserves) are important to the overall product chain. We have found only a few LCA studies focused on raspberries; however, we anticipate (and will confirm) that production methods among cane berries are similar enough that combining cane berries into a single environmental footprint summary will be appropriate. Information from raspberry LCAs will be combined with data on energy use of freezing and processing soft fruits and evidence-based approaches to testing 'local food' claims to offer environmental impact information of value to the berry industry.

Aquaculture

Both Oregon and Washington have historically important aquaculture industries with significant growth potential. Oregon Department of Agriculture has acknowledged this growth potential and has pledged to continue to support development and expansion of an aquaculture industry in Oregon[9]. While demand for seafood products continues to grow, aquaculture faces numerous hurdles, not the least of which being misinformation and exaggerated fear of unfounded dangers of aquaculture[10]. LCA studies of aquaculture practices have been conducted in regions across the globe, with many studies making

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[8] Julian, James W., Clark F. Seavert, and Jeff L. Olsen. *Orchard economics: The costs and returns of establishing and producing hazelnuts in the Willamette Valley*. Corvallis, Or.: Extension Service, Oregon State University, 2008. http://hdl.handle.net/1957/17438.

[9] Industry Report from the State Board of Agriculture, January, 2015. http://www.oregon.gov/ODA/shared/Documents/Publications/Administration/BoardReport.pdf.

[10] Developing Additional Investment in Aqua Farming in Oregon: a roadmap for sustainable development. Oregon Department of Agriculture RFP #2014-05. March, 2015. http://www.oregon.gov/ODA/shared/Documents/Publications/MarketAccess/AquacultureInvestment.pdf

direct comparisons between alternative production practices[11]. A categorical footprint summary of aquaculture may be valuable to the developing industry in the Pacific Northwest in overcoming popular misconceptions. While we have divided aquaculture into "food fish" and "mollusks" in Table 5, it may be desirable to combine these production systems into a single footprint summary. Note that while commercial wildcatch fisheries have also been analyzed via LCA, it seems these are regionally dependent (e.g., how far ships must travel from port) and we have been unable to identify LCA studies of Pacific Northwest fisheries. It is our impression that the environmental performance of aquaculture practices is less location dependent and therefor lessons gleaned from LCA studies can be applied to current or future production in the Pacific Northwest.

Other foods in Table 5

Table 5 lists an additional ten foods that are relevant and important to agriculture in OR and WA, but in most cases the available LCA literature is quite limited. Onions are an interesting example: Oregon is the nation's top onion producer, while Washington ranks number 2. While the value of these onion crops falls farther down the "top commodities" list in each state, because of the high production volume, we estimate that the greenhouse gas emissions associated with this production is quite significant. However, there is very little LCA research that analyzes onion production. Similarly, there is a notable vegetable processing industry in OR and WA: green peas, carrots, snap beans and sweet corn all rank as high volume processed crops. When taken individually, there is limited LCA data on production of these crops. We anticipate there being limited differences in environmental impact at farm gate between these crops, however, and a combined categorical footprint summary with generalized information on the relative importance of processing and distribution to the overall life cycle may be a valuable addition.

Foods not emblematic of PNW agriculture

The above recommendations lean heavily on foods that are *produced* in large quantities in the Pacific Northwest. Based on interest from food buyers and processors, it may be desirable to further evaluate foods that are *not* produced in large quantities in OR or WA. The following list indicates foods for which the quantity and quality of LCA literature is high. While other foods may be possible, they would require examination on a case-by-case basis.

- Citrus fruits
- Orange juice
- Bananas
- Tomatoes
- Chicken
- Pork

[11] Cao, L., J.S. Diana, G.A. Keoleian, "Role of life cycle assessment in sustainable aquaculture" *Reviews in Aquaculture* (2013) 5(2): 61-71.

4. Conclusions

Recommendations of food commodities for further evaluation and development of categorical footprint summaries were made based on five criteria. The first five of the ten recommended foods score high in regional production value, quantity and quality of LCA data, and estimated environmental impact. The remaining recommended foods demonstrate trade-offs in criteria. They were selected to represent a diversity of food types in the final collection of footprint summaries. These recommendations serve as a basis for stakeholder input and determination of a final list for next steps.

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