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Linking USGS Water Use Data to Detailed Industries for Environmental Input-Output Modeling of the U.S. Food System

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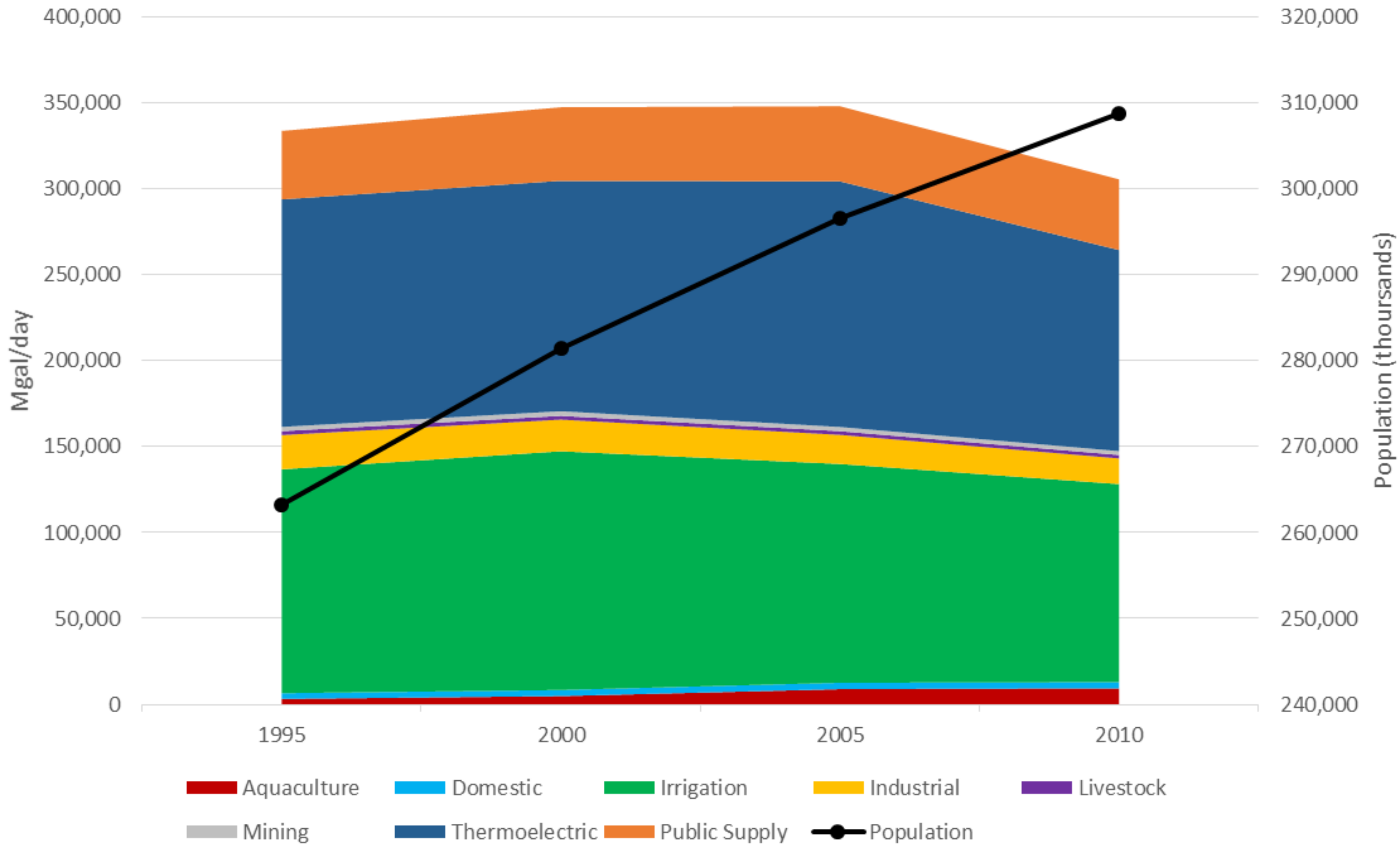
Motivation for studying water

- Water is a finite natural resource and primary input in the U.S. food system.
- Water faces stress due to:
  - Climate change
  - Population growth
  - Dietary changes

Water withdrawals 1995-2010

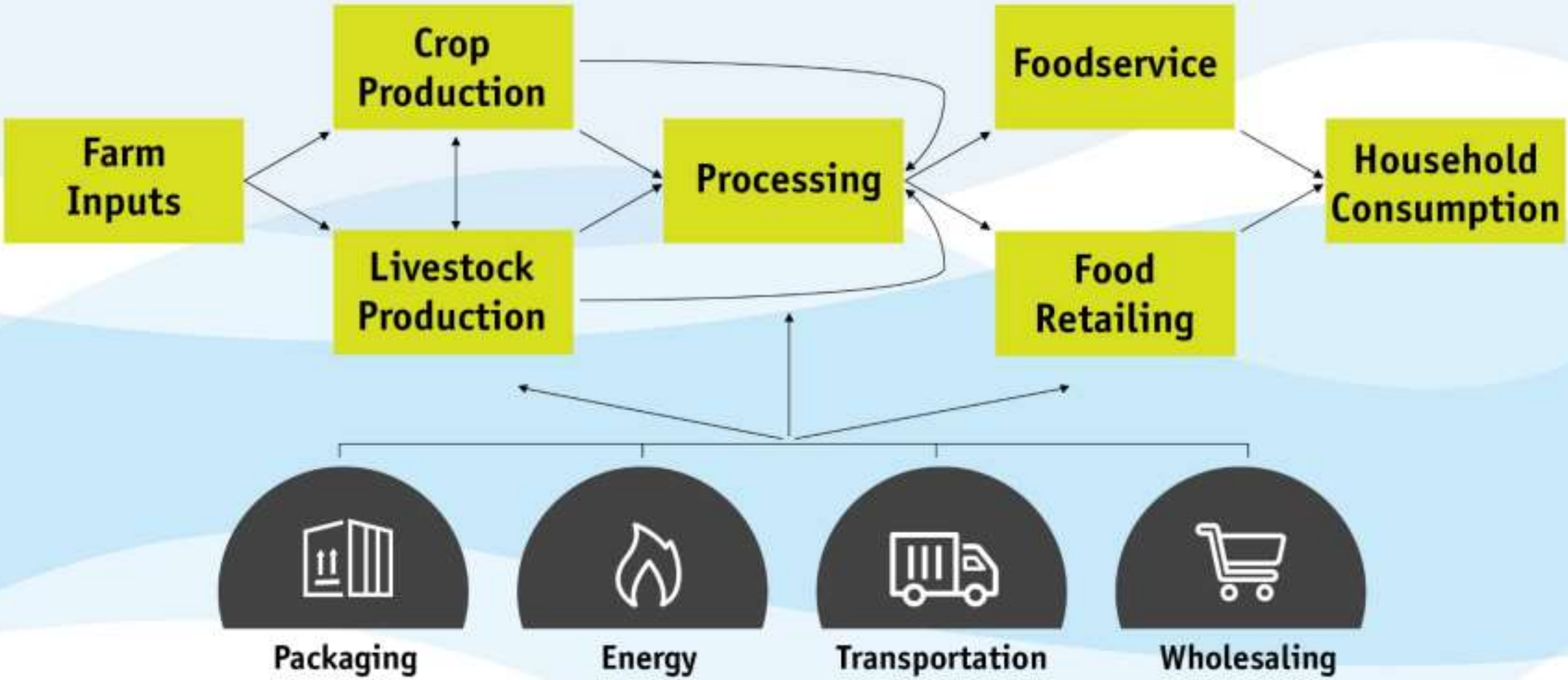


Source: Authors' calculations based on USGS data

Motivation for linking data sources

- Environmental input-output (EIO) model
  - Allows for measurement of direct and indirect water
  - Used widely in the literature for resource assessment
- Answer interesting policy questions within an economic systems framework
  - Rehkamp and Canning (2018) study water use in the U.S. food system using EIO
  - We are now expanding to a multi-year analysis

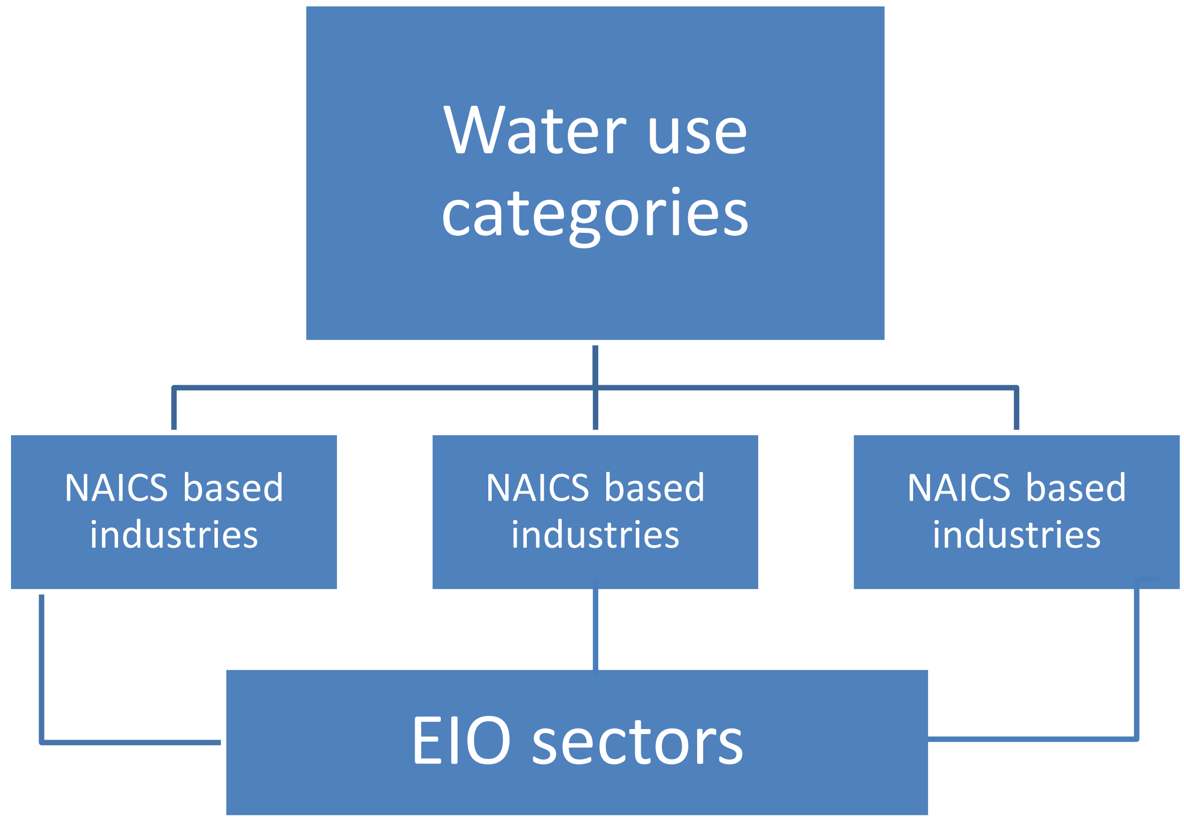
Water is used along all stages of the supply chain



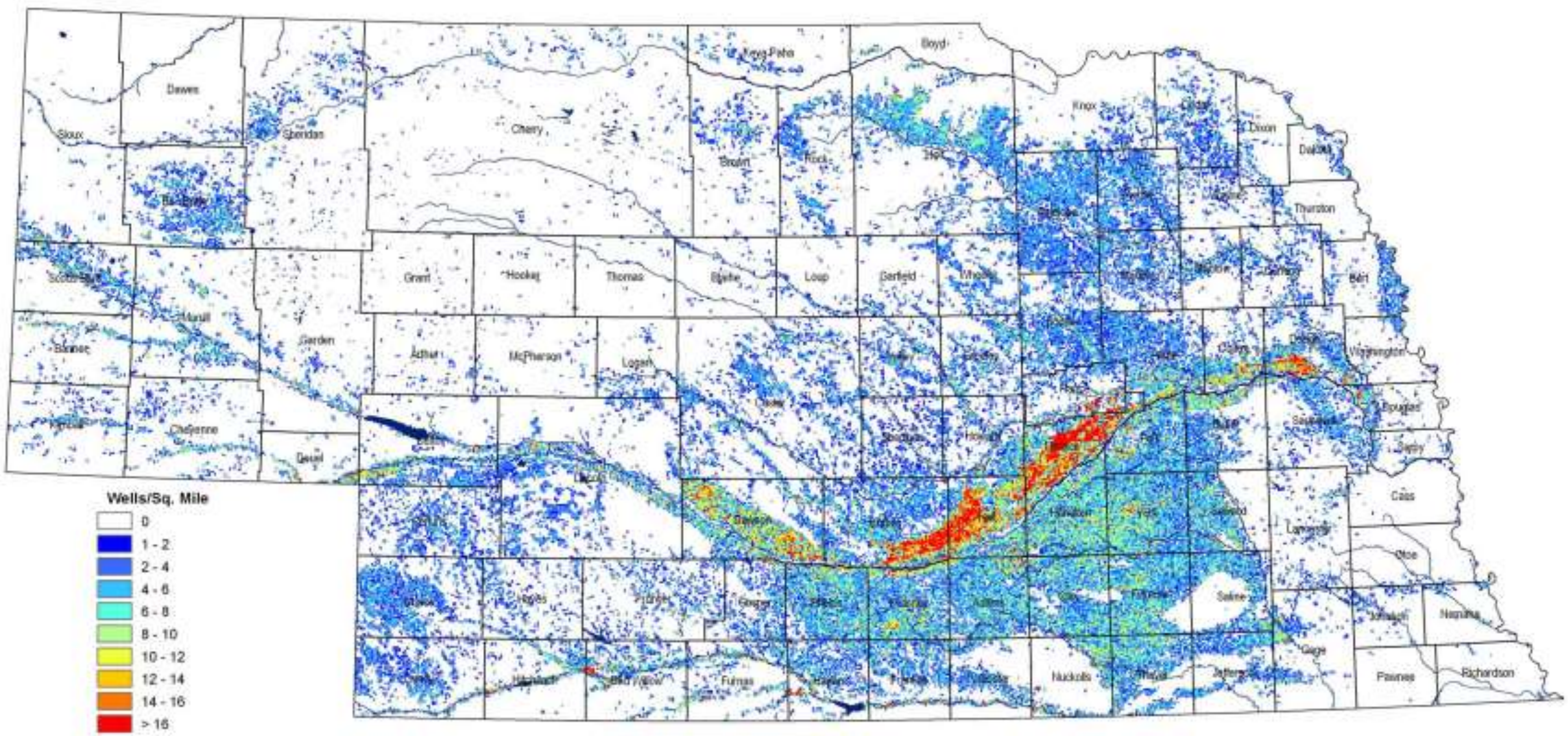
Source: Lori Fields, USDA-ERS

Objective

- Link 8 broad water use categories from USGS to 344 narrower sectors in the EIO model



Density of Registered Irrigation Wells in Nebraska
August 2007



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Mark Burbach, Water Levels Coordinator, CSD

Source: University of Nebraska (2018)

Allocation metrics

- **Aquaculture** → Disaggregation not necessary
- **Industrial** → Employment data from County Business Patterns
- **Irrigation** → Irrigated acreage in county from Census of Agriculture multiplied by state irrigation rate by crop from FRIS
- **Livestock** → Livestock inventory from Census of Agriculture and water use coefficients by livestock from USGS
- **Mining** → Employment data from County Business Patterns
- **Public Supply** → Public water outlays from IO model
- **Thermo electric** → Disaggregation not necessary

Note: Net public supply is allocated and domestic water withdrawals allocated to households

Irrigation allocation

$$WW_{irrigation,g,n} = \underbrace{WW_{irrigation,g}}_{\text{Source data from USGS}} \text{ x } \underbrace{\frac{[Acres_{g,n} \; x \; IrrRate_{g,n}]}{\sum_{g,n}[Acres_{g,n} \; x \; IrrRate_{g,n}]}}_{\text{Share of n based on allocation metric}}$$

Source data from USGS

Share of n based on allocation metric

where WW is water withdrawals
g is geographical index
n is commodity index
Acres is irrigated acres harvested (Census of Agriculture)
IrrRate is irrigation rate (Farm and Ranch Irrigation Survey)

Livestock allocation

$$WW_{livestock,g,n} = WW_{livestock,g} \text{ x } \frac{[Inv_{g,n} \ x \ WUC_n]}{\sum_{g,n}[Inv_{g,n} \ x \ WUC_n]}$$

Source data from USGS

Share of n based on allocation metric

where WW is water withdrawals
g is geographical index
n is commodity index
Inv is livestock inventory (Census of Agriculture)
WUC is water use coefficient (USGS)

Constrained maximum-likelihood estimation for data suppressions

1) $\min_{x^1_{n,g,r}} \sum_n \sum_g \sum_r \left(\frac{x^1_{n,g,r} - x^0_{n,g,r}}{v^0_{n,g,r}} \right)^2$

subject to

2) $\sum_{nc \in np} x^1_{nc,g,r} = x^1_{np,g,r}, \quad \forall\, np \in n, g, r$

Commodity constraint
peaches < non-citrus fruit

3) $\sum_{gc \in gp} x^1_{n,gc,r} = x^1_{n,gp,r}, \quad \forall\, gp \in g, n, r$

Geography constraint
county < state

4) $\sum_{rc \in rp} x^1_{n,g,rc} = x^1_{n,g,rp}, \quad \forall\, rp \in r, n, g$

Row constraint
bearing age acres < total

5) $x^1_{n,g,r} = x^0_{n,g,r} \;\forall\, v^0_{n,g,r} = 0$

Zero variance of published statistic

Source: Canning (2013)

Livestock example

- Use geographical and commodity constraints
- Also inform the model by number of farms by inventory range

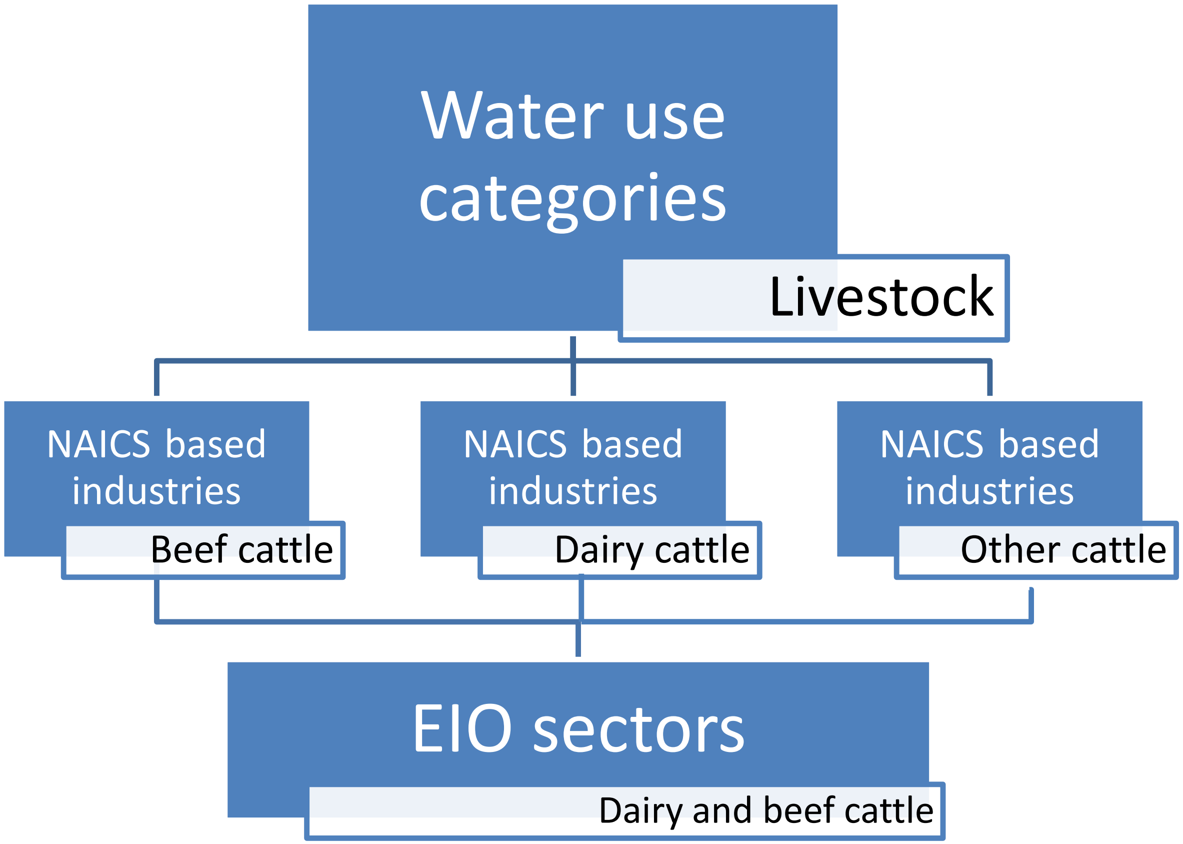
Table 11. **Cattle and Calves - Inventory and Sales: 2007 and 2002** - Con.

[For meaning of abbreviations and symbols, see introductory text]

Item		Brown	Carlton	Carver	Cass	Chippewa
INVENTORY						
Milk cows	farms, 2007	69	31	120	18	1
	2002	97	38	168	28	8
	number, 2007	5,461	1,294	9,250	1,218	(D)
	2002	6,647	1,891	11,992	1,533	653
2007 farms by inventory:						
1 to 9	farms	2	8	4	3	-
	number	(D)	29	(D)	3	-
10 to 19	farms	-	5	1	2	-
	number	-	(D)	(D)	(D)	-
20 to 49	farms	23	10	36	8	1
	number	837	347	1,254	283	(D)
50 to 99	farms	26	4	51	2	-
	number	1,765	238	3,515	(D)	-
100 to 199	farms	15	3	23	1	-
	number	2,073	312	3,077	(D)	-
200 to 499	farms	3	1	5	2	-
	number	(D)	(D)	1,375	(D)	-
500 or more	farms	-	-	-	-	-
	number	-	-	-	-	-

Source: Census of Agriculture (2007)

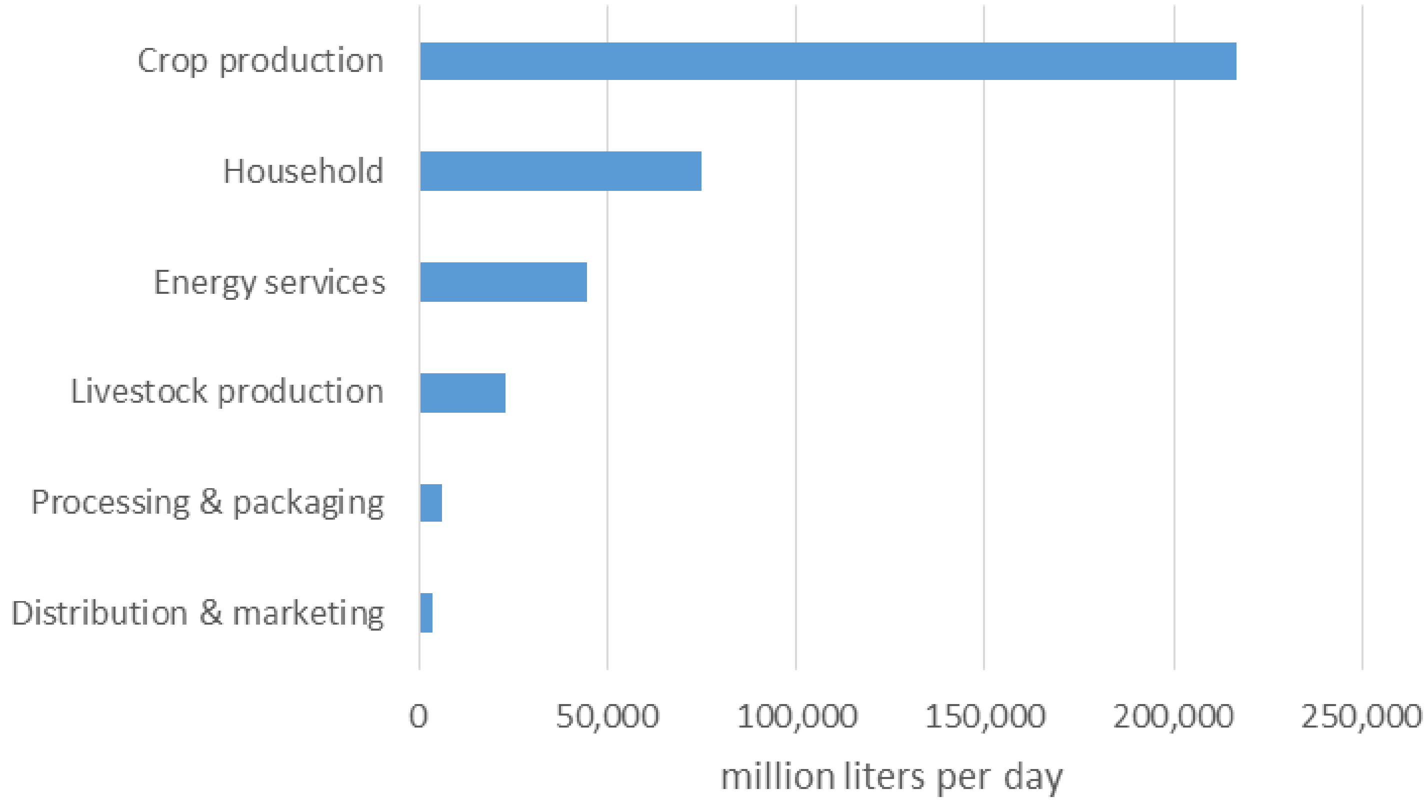
Linking water to industries



Also aggregate up geographically for EIO analysis.

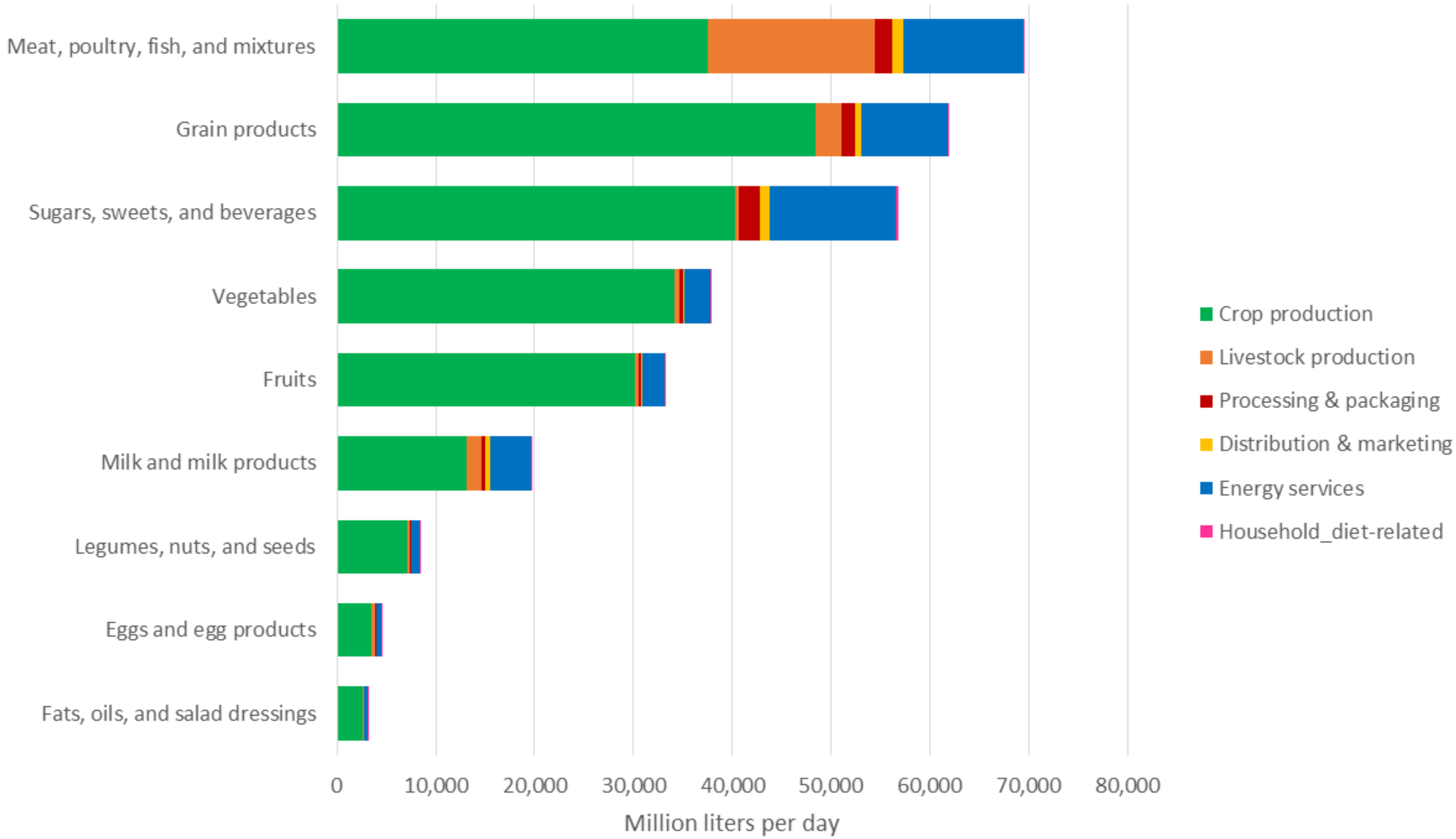
U.S. food system uses 28% of total water withdrawals, 2005

369 billion liters of water = 148 million Olympic-sized swimming pools



Source: Rehkamp & Canning (2018)

Meats in current American diet use the most water



Source: Rehkamp & Canning (2018)

Thank You!

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202-694-5584

References

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- Rehkamp, S. and Canning, P. 2018. "Measuring Embodied Blue Water in American Diets: An EIO Supply Chain Approach," *Ecological Economics, Vol 147: May. pp.179-188*
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