

# The Exportation of Agricultural Water in California and other Arid Regions of the US



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## What I will go over

- Project background
- Scope and methodology
- Water and groundwater management implications



"Thee" drought image of decade →  
 (Lake Oroville in 2014)

Image source: Justin Sullivan Getty Images

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A less exciting, depleting groundwater basin →  
 (Kelso Valley, Kern County)

Image source: Nature All naturepic.com

## Project team

- Background in life cycle analysis (water, GHGs, energy, etc.)
- Team associated by the Berkeley Water Center



- Collaboration between geospatial, visualization, agriculture, and water supply expertise (and the neophytic enthusiasm of an undergrad)



## Context and Motivation

### Agriculture

- California generates more agricultural revenue than any U.S. state<sup>1</sup>
  - 40% of U.S. vegetable revenues, 20% of dairy, over 70% of fruits, tree nuts, and berries<sup>2</sup>
- California agriculture consumes 80% of the state's developed water use<sup>3</sup>
  - Which has been increasingly become dependent on groundwater



Image source: inhabitat.com

<sup>1</sup>USDA 2014, 2012 Census of Agriculture: Highlights <sup>2</sup>USDA 2015 2012 Census Highlights <sup>3</sup>California Department of Water Resources 2014 California Water Plan: Update 2013, Highlights <sup>4</sup>USBEA 2015 GDP by State

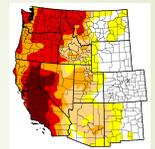
## Context and Motivation

### Climate

- Historically severe droughts since 2010:
  - Great plains: record low rainfall<sup>2</sup>
  - Washington, Oregon: record low snowpacks<sup>3</sup>
- Climate change expected to increase drought severity and duration<sup>4</sup>
- Increasing risk of multi-decadal droughts in Southwest and Central Plains<sup>4</sup>

Source: droughtmonitor.usda.gov

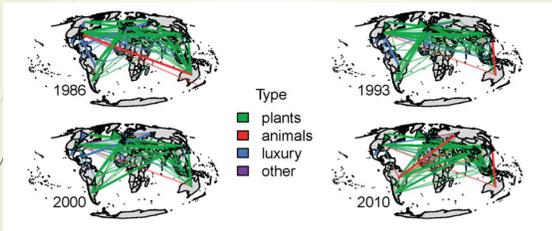
August 2015



June 2011

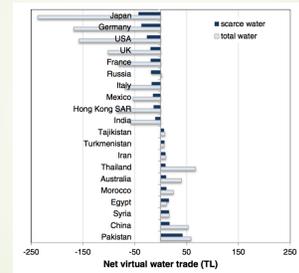
<sup>1</sup>Combs, S. (2012). The Impact of the 2011 Drought and Beyond. <sup>2</sup>Hoerling et al. (2014). Causes and Predictability of the 2012 Great Plains Drought. <sup>3</sup>Thompson, A. (2013). Pacific Northwest's "Wet Drought": Possible Sign of Future. <sup>4</sup>Cook et al. (2013). Unprecedented 21<sup>st</sup> Century Drought Risk in the American Southwest and Central Plains.

## Previous Work



Carr et al., 2013

## Previous Work



Lenzen et al. 2012

## Context and Motivation

Simple question:

How much water is leaving California in the form of agricultural and livestock products?

## Scope and Methodology – Water Use



- States included: California, Texas, Arizona, New Mexico, Nevada, Wyoming, South Dakota, Nebraska, Kansas, Oklahoma, and Colorado
- Part 1: modeling water intensity (L/kg) variations over time in California (1998-2012)
- Data: USDA Food and Ranch Irrigation Survey (FRIS) for irrigation quantities and yields for 9 crops

2012 CENSUS OF AGRICULTURE

Water Footprint NETWORK

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  - Data: USDA Food and Ranch Irrigation Survey (FRIS) for irrigation quantities and yields for 9 crops
- Part 2: modeling water demands for 2012 production for over 70 products
  - Applied to 11 states with recent "exceptional" droughts: CA, TX, AZ, NM, NV, WY, SD, NE, KS, OK, CO
  - USDA National Agricultural Statistics Service (NASS) for production data
  - Product water intensities: Part 1, Mekonnen and Hoekstra (2011, 2012), Kendall et al. (2015)

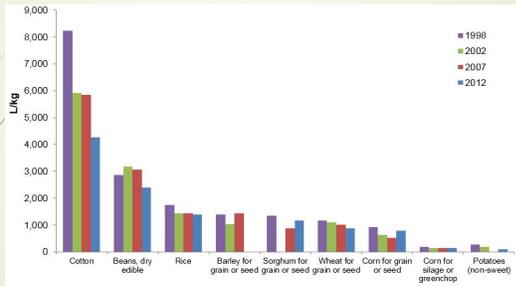
2012 CENSUS OF AGRICULTURE

Water Footprint NETWORK

## Water Intensities

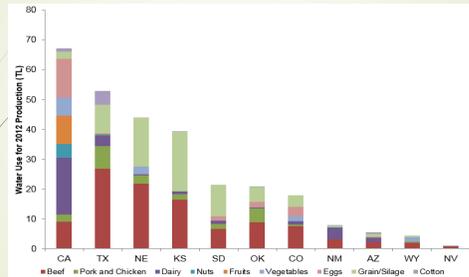
Product grouped in commodity	Source	Water Intensity (L/kg)
<b>Cereal Grains</b>		
Wheat	USDA, CA Average <sup>2</sup>	1,171
Oats	CA Average <sup>4</sup>	2,515
Barley	CA Average <sup>4</sup>	1,356
Sorghum	USDA, CA Average <sup>2</sup>	1,171
Corn for grain	USDA, CA Average <sup>2</sup>	789
<b>Meat</b>		
Cattle and calves	US Average <sup>3</sup>	9,553
Hogs and pigs	US Average <sup>3</sup>	4,747
Sheep and lambs	US Average <sup>3</sup>	9,000
Poultry	US Average <sup>3</sup>	4,325
<b>Animal feed and animal derived products</b>		
Corn for silage or greenchop	USDA, CA Average <sup>2</sup>	150
Eggs	US Average <sup>3</sup>	1,336
<b>Agricultural Products</b>		
Dry beans	USDA, CA Average <sup>2</sup>	2,394
Cotton	USDA, CA Average <sup>2</sup>	4,263
Rice	USDA, CA Average <sup>2</sup>	1,973
Sunflower seeds	CA Average <sup>4</sup>	4,274
Sugarcane for sugar	CA Average <sup>4</sup>	1,694

## Applied Water in CA: Temporal Variations



## State-wise Water Demand by Product Type

## State-wise Water Use by Product Type

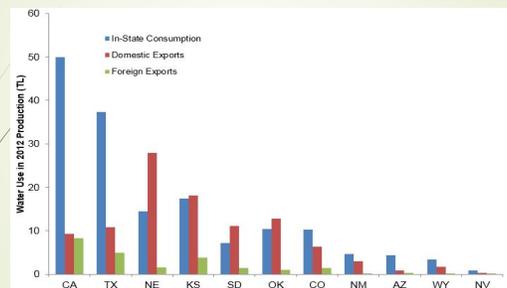


## Scope and Methodology – Tying Water Use and Trade

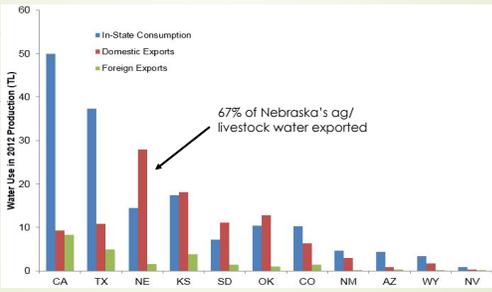
## Scope and Methodology – Tying Water Use and Trade

- Using 2012 US Census Bureau Commodity Flow Survey:
  - Created aggregated water intensities for agricultural categories (e.g. cereal grains, agricultural products\*, meat, etc.)
  - Determined in-state consumption, domestic and foreign exports of agricultural categories for each of the 11 states
  - Combined consumption data with aggregated water intensities
- For California, analyzed regional data for domestic exports
- \*Disclaimer: Census Bureau gave us a **very coarse** estimate of where agricultural products were going!

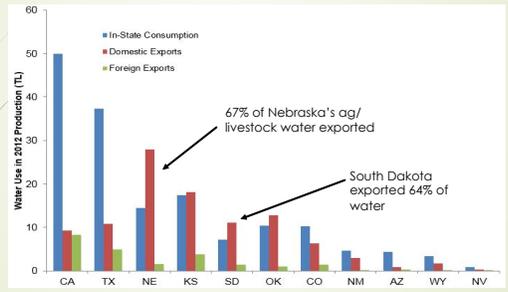
## Water Exports by State, a first pass



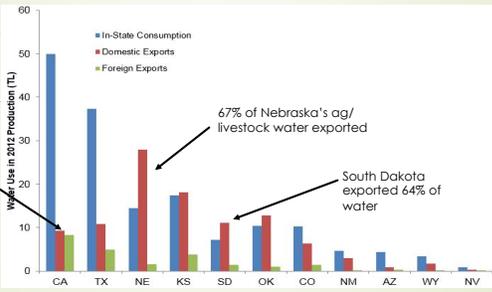
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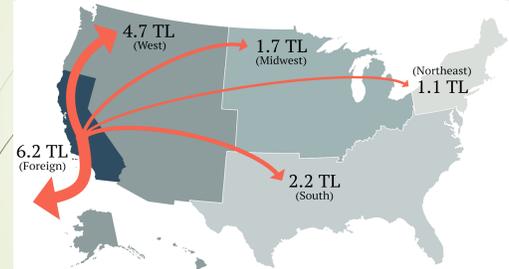
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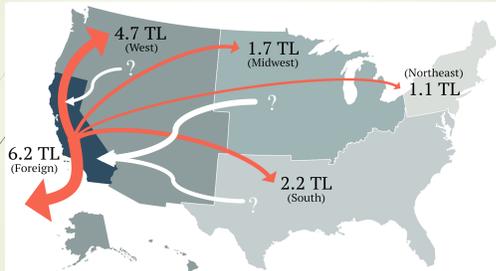
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## Destinations of California Exported Water



## An obvious counterpart: What is being imported?



We haven't gotten there yet...

## Agricultural Water Sources

- California agricultural water users are heavily reliant on in-state water transmission projects and groundwater
- In-state transmission highly energy intensive: accounting for 2-3% of total state electricity consumption<sup>1</sup>
- Farmers doubled use of groundwater to replace shortages in recent drought?

## Agricultural Water Sources

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- In-state transmission highly energy intensive: accounting for 2-3% of total state electricity consumption<sup>1</sup>
- Farmers doubled use of groundwater to replace shortages in recent drought<sup>2</sup>
- Groundwater supplies 60% of Texas's total water consumption
  - 80% of this groundwater goes to agriculture<sup>3</sup>
  - These sources expected to decline 30% over next 30 years<sup>3</sup>
- Kansas withdrawing water 50-100x faster than recharge rate<sup>4</sup>
- These regions are responsible for over 50% of groundwater overdrafts since 1900<sup>5</sup>

<sup>1</sup>NRECA 2004 Energy Down the Drain: The Hidden Costs of California's Water Supply <sup>2</sup>Howitt R E et al 2015 Economic Analysis of the 2015 Drought for California Agriculture <sup>3</sup>Texas Water Development Board 2012 Water for Texas, 2012 State Water Plan <sup>4</sup>Kansas Water Office 2014 Kansas Water Plan, Section 2.3 Statewide Water Assessment - Water Supply <sup>5</sup>Scanlon B R et al 2012 Groundwater depletion and sustainability of irrigation in the US High Plains and Central Valley

## Takeaways

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- There exists data gaps and uncertainties within trade data and water use data
- BMPs??



Thank you!

Thoughts, questions, comments?