21st Century Water Security and Implications for Animal Agriculture

Cumulative freshwater losses in California (left), the Middle East (center) and NW India (right) from GRACE, 2002-2014

Famiglietti, 2011
Voss et al., 2013
Rodell et al., 2009

Jay Famiglietti
Department of Earth System Science, University of California, Irvine, USA
NASA Jet Propulsion Laboratory, California Institute of Technology, USA
True confessions of a hydrologic scientist...

I wanted to be a veterinarian
Overview

• Who am I and why do I care?

• Some key examples of the importance of water to animal agriculture

• What our research and the best science is telling us about freshwater availability, water cycle change and global change

• How will the industry respond in the future?
Who am I and why do I care?

- I am a hydrologist, a professor and a research scientist

- My students and I have been working for 3 decades on
  - Using satellites to track how freshwater availability is changing around the world
  - Developing advanced computer models to predict how it may change in the future
  - Communicating our findings to elected officials, water managers, industry and the general public

- I care because the findings are eye-opening and not really fully appreciated; and water management has a long way to go to adjust
Importance of water to animal agriculture

- Water to grow feed
- Water for processing and packaging
- Water associated with energy needs
- Climate change and changing hydrologic extremes of flooding and drought
- Animal waste and water quality issues
NASA Gravity Recovery and Climate Experiment (GRACE)

- Launched in 2002
- Functions like a ‘scale in the sky’ that can weigh the monthly increases or decreases in water storage in large (>200,000 km²) regions with an accuracy of 1.5 cm
NASA GRACE Follow-On (GRACE-FO)
Launch on schedule for August 2017
Similar resolution as GRACE
Estimating water storage changes with GRACE

- The difference between two GRACE global gravity fields yields a time-variable component.
- The main contributors to time variations in the gravity field are changes in water storage in the ocean, the atmosphere and on land.
- Why? Because water is REALLY HEAVY!
- Consequently, the GRACE time-variable signal on land is dominated by changes in terrestrial water storage, i.e. GRACE monitors changes in all of the water stored on land, the change in total water storage (all of the snow, surface waters, soil moisture and groundwater), at monthly and longer timescales.
- Given the extremely high precision of GRACE, the resulting errors are ~1.5 cm for monthly storage anomalies at the 150,000 km² scale (~2.25 km³)
GRACE observations of Terrestrial Water Storage changes in California

2002 05 09

Animation by NASA GSFC and JPL
Change in total water storage in the Sacramento-San Joaquin River basins from GRACE 2002-2014

Time series and images computed from NASA JPL Mascons solutions by Felix Landerer
Characterizing California drought with GRACE and Total Water Storage Deficit

Actual monthly water storage variations

‘Normal’ range of monthly water storage variations

Differences from ‘normal’ dry conditions

peak Total Water Storage Deficit is 42 km³ in 2014
Importance of groundwater worldwide

- Groundwater accounts for as much as 33% of water withdrawals worldwide
- Over 2 billion people rely on groundwater as their primary water source
- Half or more of irrigation water is supplied by groundwater
- Groundwater provides the key ‘strategic reserve’ for water supply during prolonged periods of drought

Ironically, groundwater is poorly managed and monitored in many regions around the world, so that global water security is at far greater risk than is currently acknowledged.
Estimating groundwater storage changes with GRACE

\[ \Delta S_{\text{Total}} = \Delta S_{\text{Snow}} + \Delta S_{\text{Surface Water}} + \Delta S_{\text{Soil Moisture}} + \Delta S_{\text{Groundwater}} \]

\[ \Delta S_{\text{Groundwater}} = \Delta S_{\text{Total}} - \Delta S_{\text{Snow}} - \Delta S_{\text{Surface Water}} - \Delta S_{\text{Soil Moisture}} \]

Remove this \((\Delta S_{\text{Snow}} + \Delta S_{\text{Surface Water}} + \Delta S_{\text{Soil Moisture}})\) from \(\Delta S_{\text{Total}}\)...

To isolate this \((\Delta S_{\text{Groundwater}})\)
Sacramento River Basin
San Joaquin River Basin
Tulare Lake Basin

California’s Central Valley
• One of the most productive agricultural regions in the world
• Produces more than 250 different crops worth $17 billion per year (2002), or 8% of the food produced in the U.S. by value
• Accounts for 1/6 of irrigated land in the U.S.
• Supplies 1/5 of the demand for groundwater in the U.S.
• Is the second most pumped aquifer in the U.S.
• Groundwater depletion and subsidence have been documented there for decades (e.g. Faunt, 2009)

Groundwater depletion in California’s Central Valley, October, 2003 - March, 2009
Estimating groundwater storage changes in California’s Central Valley with GRACE

\[ \Delta S_{\text{Groundwater}} = \Delta S_{\text{Total}} - \Delta S_{\text{Snow}} - \Delta S_{\text{Surface Water}} - \Delta S_{\text{Soil Moisture}} \]
Estimating groundwater storage changes in California’s Central Valley with GRACE
California’s system of aqueducts for surface water redistribution
Cumulative groundwater depletion in California’s Central Valley from USGS and GRACE
Estimating groundwater storage changes with GRACE

Colorado River Basin (2005-2013)

Castle et al., 2014
Water storage changes in the United States from GRACE (2002-2014)

Trend map courtesy of Felix Landerer, NASA JPL
Famiglietti et al., 2011
~3 km³/yr

Voss et al., 2013
~13 km³/yr

Rodell et al., 2009
~18 km³/yr

Bourzac, 2013; after Rodell et al., 2009; Famiglietti et al. 2011; Voss et al., 2013
Animation credit
Jay Famiglietti,
Jason Craig, Eric de Jong, Felix Landerer, JT Reager, Mike Stetson, NASA JPL
Trends in Freshwater Availability from the NASA GRACE Mission 2002-2014

- Antarctic ice sheet melting
- Patagonia glaciers melting
- Alaska glaciers melting
- Greenland ice sheet melting
- Southeastern U.S. drought
- Central Valley groundwater depletion
- Northwest Australia groundwater depletion
- Orinoco and Amazon floods
- Upper Midwest U.S. flooding
- High Plains Aquifer groundwater depletion
- Caspian/Aral Seas shrinking
- Western Africa floods
- India/Bangladesh groundwater depletion
- Indian monsoon
- High latitude precipitation increase
- North China Plain groundwater depletion
- North Africa groundwater depletion
- Mekong drought
- Brazil drought
- NW Australia groundwater depletion
- High Plains aquifer groundwater depletion
- Okavango floods
- Ukraine drought
- Brazil drought
- Peru glaciers melting
- Central Valley groundwater depletion
- Guarani Aquifer groundwater depletion
- Central Valley groundwater depletion
- Patagonia glaciers melting
- Antarctic ice sheet melting
Trends in Freshwater Availability from the NASA GRACE Mission, 2002-2014
Trends in Freshwater Availability from the NASA GRACE Mission, 2002-2014

October 29, 2014, Nature Climate Change

COMMENTARY:
The global groundwater crisis

J. S. Famiglietti

Groundwater depletion the world over poses a far greater threat to global water security than is currently acknowledged.

Groundwater — the water stored beneath Earth's surface in soil and porous rock aquifers — accounts for as much as 33% of total water withdrawals worldwide. Over two billion people rely on groundwater as their primary water source, while half or more of the irrigation water used to grow the world's food is supplied from underground sources.

Groundwater also acts as the key strategic reserve in times of drought, in particular during prolonged events such as those in progress across the western United States (Fig. 1), northeastern Brazil and Australia. Like money in the bank, groundwater sustains societies through the lean times of little incoming rain and snow. Hence, without a sustainable groundwater reserve, global water security is at far greater risk than is currently recognized.
How should the industry respond/is it responding

- Message #1: The water cycle and water availability are changing. Water availability will become progressively more strained, while increasing extremes like flooding and drought threaten both animal exposure and supply chains.

- Message #2: Everybody loves food so don’t feel like you’re a target. We need to change the conversation from urban vs ag; farmer vs fish; economic growth vs environment, to ‘how much water does society want to allocate to produce food,’ or to “how can we produce the best/most using the least amount of water.”

- Message #3: Clearly animal agriculture uses tons of water and generates considerable waste disposal problems. No need to shy away from that because we need to eat and grow food. Rather, take ownership, clearly articulate the issues, and become industry leaders and stewards: “How can we raise the best product while having the smallest environmental impact.”
Resources for communication (links at http://jayfamiglietti.com)

@JayFamiglietti

http://newswatch.nationalgeographic.com/author/jfamigli/

Last Call at the Oasis

Can We End the Global Water Crisis, http://youtube.com

The Global Groundwater Crisis, Oct 29, 2014

November 16, 2014, ‘Depleting the Water’