Computing Challenges in Food-Energy-Water Nexus
: A Perspective

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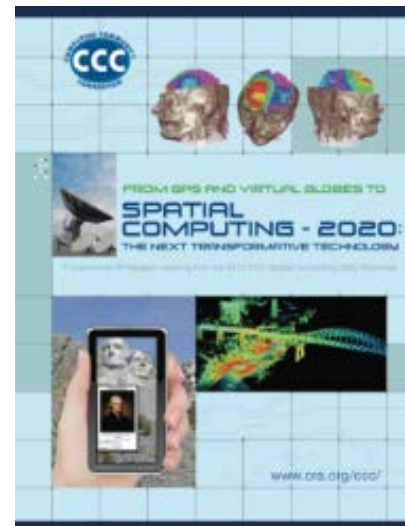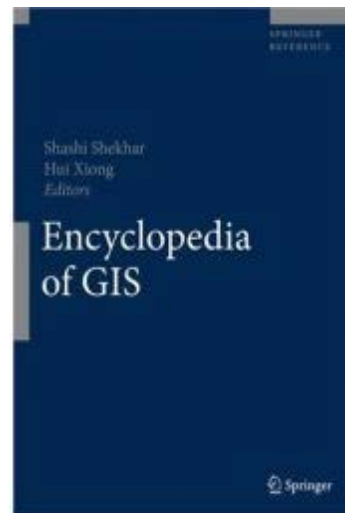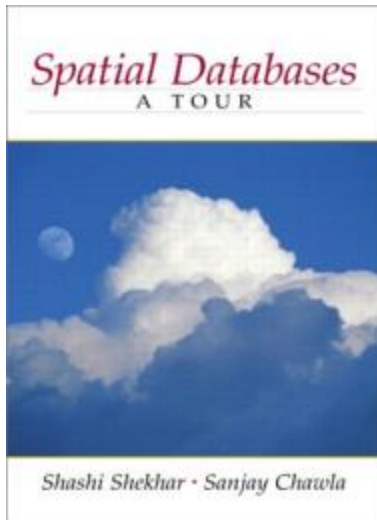
Outline

- FEW Nexus
  - Context
  - History

- Role of Computing
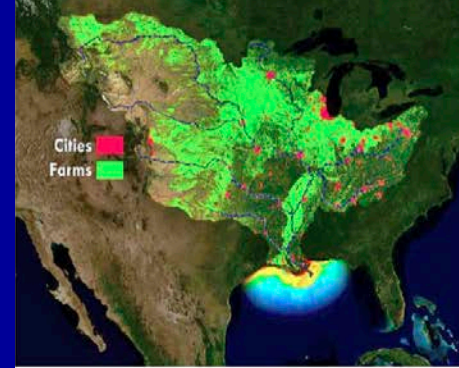
- Computing Challenges in FEW Nexus

- Next

U.N. Sustainable Development Goals 2030

includes Food (2), Energy (7), Water (6), Climate Action (13), …

Downside of Piece-meal Approach

- Piece-meal policies => unanticipated problems
  - Ex. Fertilizers affect Water quality (e.g., Great Lakes, Mississippi River)
 - Ex. Bio-fuel subsidy => Rise in food prices (2008)

Courtesy: Wikipedia

- Crucial to understand interactions across Water, Food, Energy Systems
  - National priority
    - Reports: USDOD/NIC, NSF, USDA USDOE, USGS, …
    - Research Initiatives: NSF/USDA, USDOE
  - Global priority with initiatives from U.N. University and many countries

Interactions among Food, Energy, Water Systems

- Piecemeal decisions in one affect the other

- **Efficiency** or abundance in one reduces scarcity in others!

- **Chokepoint:** Scarcity in one constraints growth in others!

- **Stressors:**
  - Population Growth
  - Climate Climate
  - Rising Economy
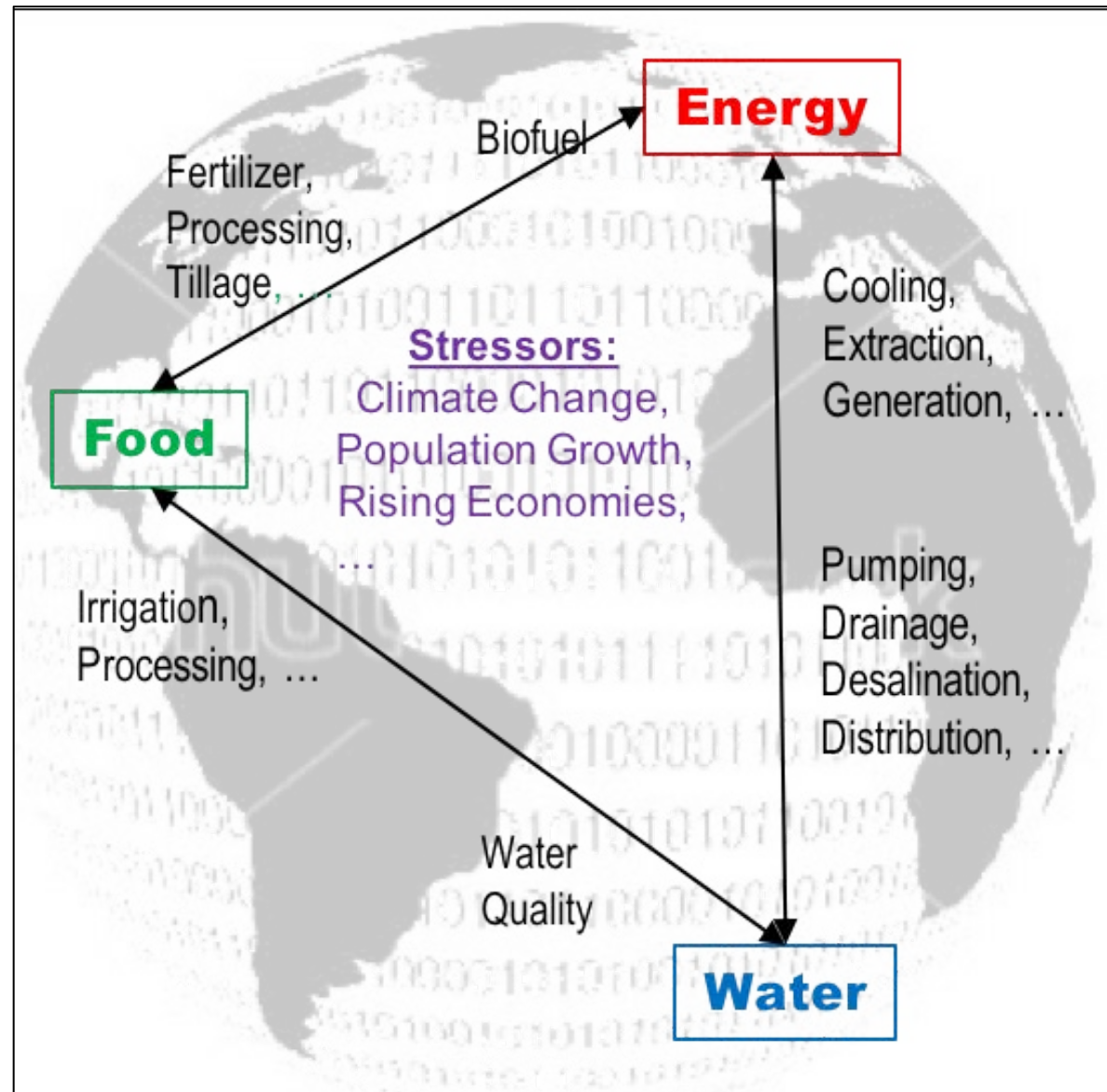
Outline

- FEW Nexus

- Role of Computing
  - Precision Agriculture
  - Crop Monitoring

- Computing Challenges in FEW Nexus

- Next

Deconstructing
Precision Agriculture

#AgInnovates2015

Wednesday, March 4, 2015
Reception | 5:00 to 7:00 pm

House Agriculture Committee Room,
1300 Longworth House Office Building,
Washington, DC

Think Moon landing.

Think Internet.

Think iPhone and Google.

Think bigger.

Come hear U.S. farmers, leading agriculture technology companies, and scientists tell how they work together to fuel U.S. innovation and the economy to solve this global challenge.

The event will exhibit three essential technologies of precision agriculture that originated from a broad spectrum of federally funded science: Guidance Systems and GPS, Data & Mapping with GIS, and Sensors & Robotics.

Moderator

Raj Khosla, Professor of Precision Agriculture at Colorado State Univ.

Farmers

David Hula, of Renwood Farms in Jamestown, Virginia

Rod Weimer, of Fagerberg Produce in Eaton, Colorado

Del Unger, of Del Unger Farms near Carlisle, Indiana

Speakers

Mark Harrington, Vice President of Trimble

Carl J. Williams, Chief of the Quantum Measurement Division at NIST

Bill Raun, Professor at Oklahoma State Univ.

Marvin Stone, Emeritus Professor at Oklahoma State Univ.

J. Alex Thomasson, Professor at Texas A&M Univ.

Dave Gebhardt, Director of Data and Technology at Land O'Lakes/WinField

Shashi Shekhar, Professor at the Univ. of Minnesota

RSVP
http://bit.ly/1CoOYoa

Hosted by
the Congressional Soils Caucus

In partnership with

Agricultural Retailers Association
American Society of Plant Biologists
American Physical Society
American Society of Agronomy
Association of Equipment Manufacturers
Coalition for the Advancement of Precision Agriculture
Computing Research Association
CropLife America
Crop Science Society of America
PrecisionAg Institute
Soil Science Society of America
Task Force on American Innovation
Texas A&M AgriLife
Trimble
WinField

This is about feeding the world.

Precision Agriculture

- Reduce fertilizer run-offs, water use

- Improves yield

- Computing is critical
  - Cyber-Physical Systems
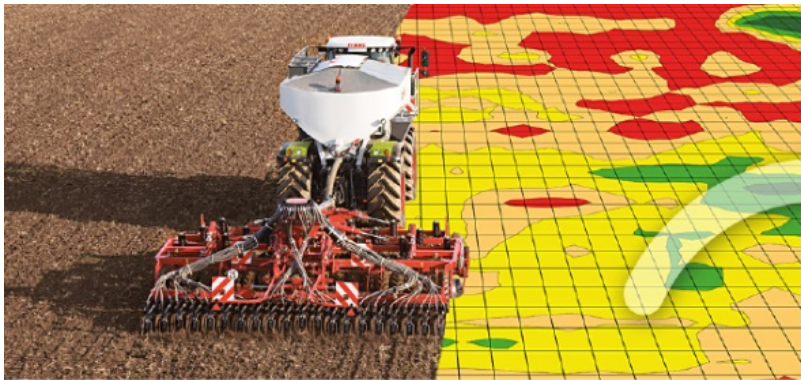 - Data & Data Science Elements

Yield Monitors	Direct & Remote Sensing	Precision Navigation	Variable Rate Technology

Global Positioning Systems

Geographic Information Systems

Support (Farm-level) Decisions and (Insurance) Policy

Support (Global) Decisions and Policy Making
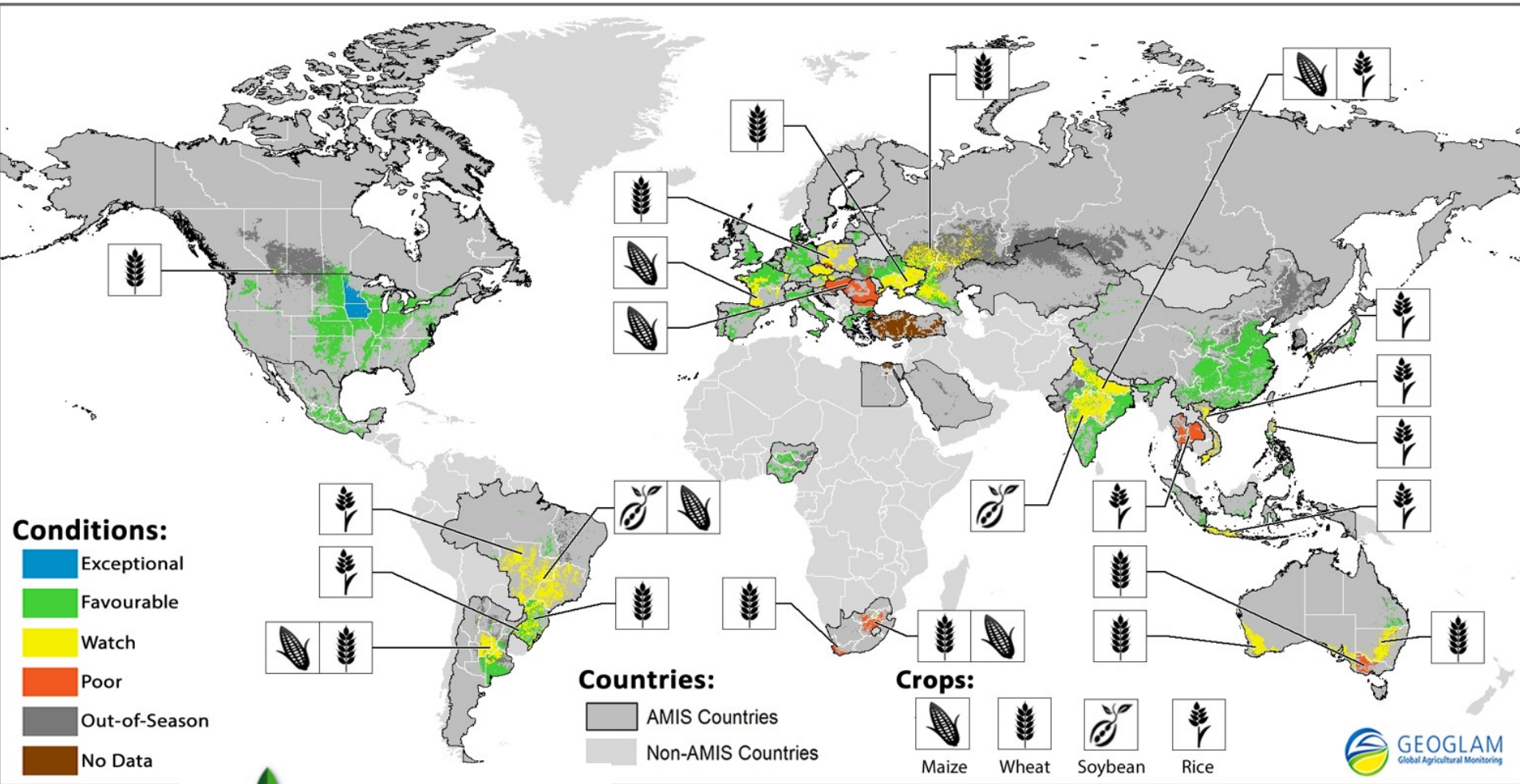
Monitor resources & trends to detect risks

Communicate with public and stakeholders

Aral Sea Shrinkage (1978-2014)
Due to Cotton Farms

Alerts

Nexus Dashboard

State

Trends
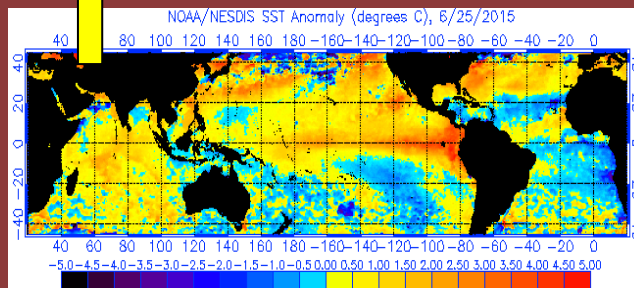
Sea-Surface Temperature Anomaly
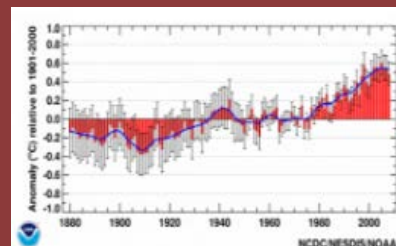
Global Temperature
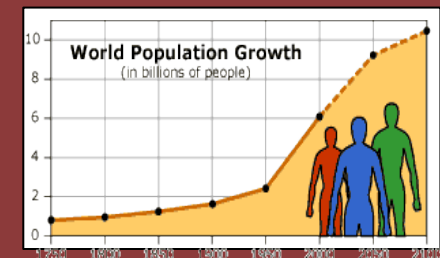
Global Population

Outline

- FEW Nexus

- Role of Computing

- Computing Challenges in FEW Nexus
  – NSF INFEWS Data Science Workshop (Oct. 2015)
  – Data and Data Science Gaps

- Next

New grants foster research on food, energy and water: a linked system

Amid population growth, drought and increased urbanization, understanding food, energy and water availability is increasingly important

Conserving Water - Producing Energy - Sustaining Food
NSF Awards: Interactions of Food Systems with Water and Energy Systems
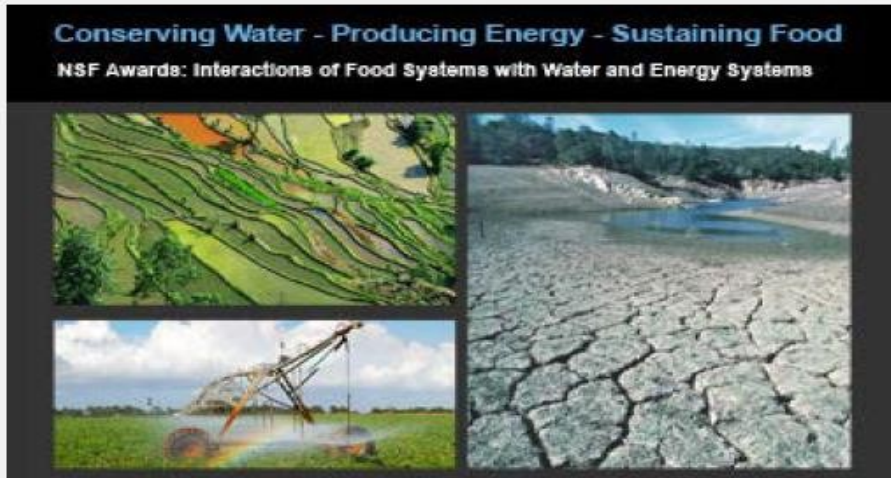
How food, water and energy systems interact: a photo gallery.
Credit and Larger Version

August 14, 2015

In a world where a growing number of people lack food, water and sources of energy, providing these resources has become a challenge.

To find new answers, the National Science Foundation (NSF) has funded 17 grants, totaling $1.2 million, to support workshops on the interactions of food, energy and water, or FEW. Additionally,

- **17+ NSF Workshop grants**
  - Planned across the country
  - Facilitate partnerships across disciplines, sectors
  - Define fundamental sc. & eng. research needs & questions

- **Two workshop with CISE PIs**
  - Technology & Information Fusion
  - Data Science

NSF INFEWS Data Science Workshop

- **Goals**
  – Develop visions, Identify gaps
  – Develop a research agenda

- **At** USDA NIFA, Oct. 5th-6th, 2015

- **Co-organizers:** Shekhar, Mulla, Schmoldt

- **URL:** www.spatial.cs.umn.edu/few

- **Draft report available for comments:**

  http://www.spatial.cs.umn.edu/few/few_report_draft.pdf

- **55 Participants** (Data-driven FEW & Data Sciences)

Gov.	Aca.	Industry
26	24	5

Food	Energy	Water	DataSc.
14	10	11	20

Multi-disciplinary Multi-sectoral Participation

Data Science	Names
Data Collection, Remote Sensing	Peggy Agouris David Corman (NSF) Thomas G. Dietterich Paul Gader Raju Vatsavai
Data Exploration, Management, Dissemination	Chandra Krintz Dieter Pfoser Hanan Samet Tom Shapland (Farmlink) Goce Trajcevski
Data Extrapolation …	Chid Apte (IBM) Vasant Honavar (CCC) Zico Kolter Vipin Kumar Sanjay Ranka …

FEW	Names
Food	Parag Chitnis (USDA) Jason Hill Rattan Lal L. K. Matukumalli (USDA) Rachel Melnick Rabi Mohtar Sonny Ramaswamy (USDA) Susan Jean Riha Paul Tanger Luis Tupas (USDA)
Energy	Noel M.Bakhtian (USDOE) Robie Lewis (USDOE) Bob Vallario (USDOE) Tamara Zelikova
Water	Richard Alexander (USGS) Brad Doorn (NASA) Alan Hecht (EPA)
Cross-cutting, Social Sc., …	Inna Kouper Zachary Hayden Moira Zellner Ariela Zycherman (NSF)

Outcomes: F-E-W Nexus Data Gaps

- Water: Need US water census
  - Equivalent of Ag. Census and US-EIA

- Other Data Needs:
  - Energy, Food– consumption & FEW Interaction data
  - A FEW nexus data community (BD FEW Spoke)

- Data Integration Challenges
  - Varied data collection (e.g., aquifer withdrawal meter in TX & CA)
  - Heterogeneous data format (e.g., raster climate data, vector population)
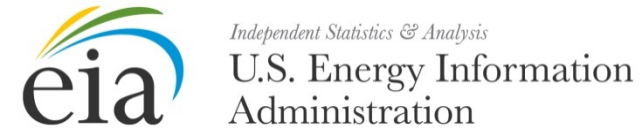
Outcomes: Data Science Gaps

1. Methods to help stakeholders reach consensus on FEW issues
   - Social science methods: scenario-based discussion, design exercises, etc.
   - Computational tools: visualization, explainable/interpretable models, interactive simulation and optimization

2. Spatio-temporal modeling
   - Dealing with data collected multiple spatial, temporal scales,
   - missing values

3. Fusion of multiple model types
   - Data-driven, process-driven, economic, etc.

4. Lifecycle thinking for the FEW Nexus
   - modeling human behavior, understanding indirect effects of perturbations, supply chains, opportunity costs, agent-based modeling

5. Data uncertainty, incompleteness, bias
   - provenance, conflict of interest, capturing and visualizing uncertainty

Gap Example: Spatial Fragmentation in Optimization

Landscape geodesign
- stakeholder collaboration (designs F, G, H, I)
- linear programming (designs A, B, C, D, and E)
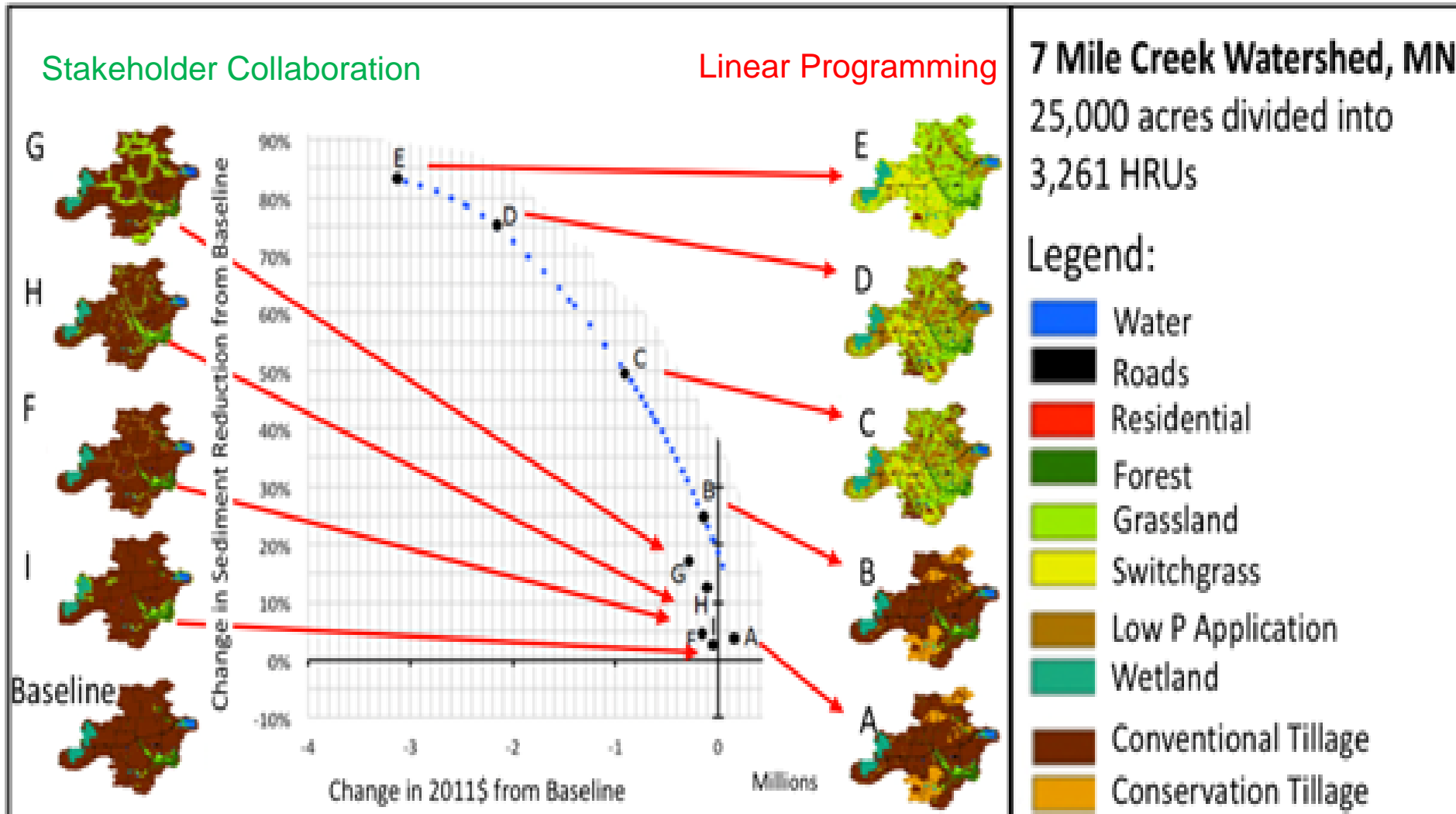
Outline

- F-E-W Nexus

- Role of Computing

- Computing Challenges

- Related Events
  - Dec. 2015: NSF INFEWS Solicitation
  - Jan. 2016 : NCSE
  - Mar. 2016: Midwest Big Data Hub – FEW Spoke
  - Mar. 2016: Whitehouse Water Summit
  - Aug. 2016: ACM SIGKDD Workshop on FEW
  - Dec. 2016: AGU session proposal

Innovations at the Nexus of Food, Energy and Water Systems (INFEWS)

PROGRAM SOLICITATION
NSF 16-524

National Science Foundation
Directorate for Geosciences
Directorate for Engineering
Directorate for Computer & Information Science & Engineering
Directorate for Mathematical & Physical Sciences
Directorate for Social, Behavioral & Economic Sciences
Directorate for Education & Human Resources
Office of International Science and Engineering
Office of Integrative Activities

National Institute of Food and Agriculture

Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):

March 22, 2016

IMPORTANT INFORMATION AND REVISION NOTES

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised NSF Proposal & Award Policies & Procedures Guide (PAPPG) (NSF 16-1), which is effective for proposals submitted, or due, on or after January 25, 2016. Please be advised that proposers who opt to submit prior to January 25, 2016, must also follow the guidelines contained in NSF 16-1.

Anticipated Funding Amount: $50,000,000

With $9,000,000 to $15,000,000 for Track 2, Visualization and Decision Support for Cyber-Human-Physical Systems at the FEW Nexus;

INFEWS Goals

Four Tracks

1. Significantly **advance our understanding** of the food-energy-water system through quantitative and computational **modeling**, including support for relevant cyberinfrastructure;

2. Develop real-time, cyber-enabled interfaces that improve **understanding of the behavior** of FEW systems and increase **decision support** capability;

3. Enable research that will lead to **innovative** system and technological **solutions** to critical FEW problems; and

4. Grow the scientific **workforce** capable of studying and managing the FEW system, through **education** and other **professional development** opportunities.

The Food-Energy-Water Nexus

16th National Conference and Global Forum on Science, Policy and the Environment
January 19-21, 2016
Hyatt Regency Crystal City at the
Washington, DC National Airport

- Highlights:
  - Participation from NSF, USDA, USDOE, NOAA, USGS, NASA, USFS, etc.
  - Many sessions related to NSF INFEWS
  - Ex. S-E2: Towards a F-E-W nexus data science community

NSF Director Córdova (right) with former NSF Director Rita Colwell, who received a lifetime achievement award from National Council for Science & Environment (NCSE).

Community Building: NSF MBDH FEW Spoke
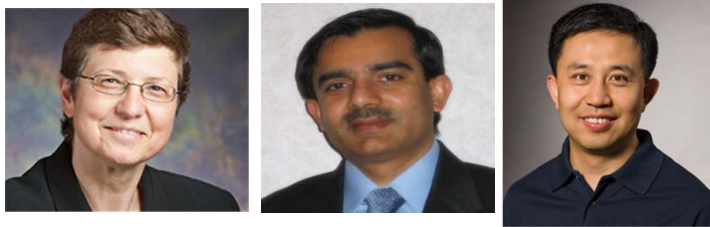
Lead: Klara Nahrstedt
Assisted by Shashi Shekhar, Shaowen Wang
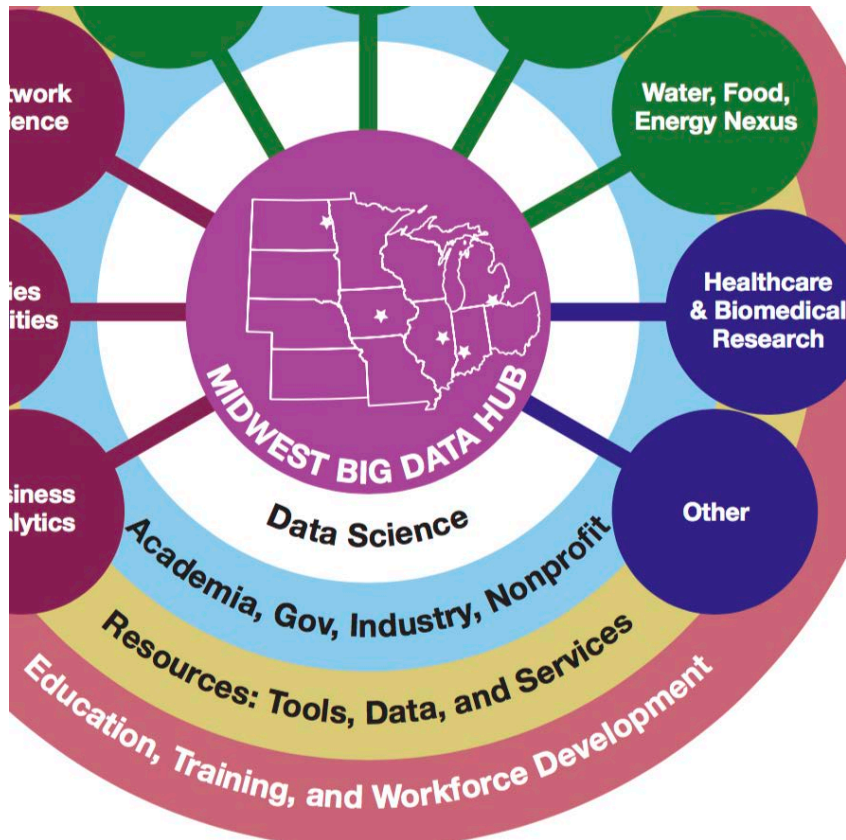
Over 40 partners

Multi-disciplinary
- Food: AgMIP/GABBS (Purdue)
- Energy: NWU Inst … Ren. Energy
- Water: Env. Eng. (UIUC, IU), Water Center at UMN & NWU,
- UMN Institute on Env., MN Population Center
- NCSA CyberGIS

Multi-sector
- Academic: TAMU, NCSU, U Glasgow, …
- Industry: IBM, Climate Corp.
- Govt.: Chicago Water Distr., NCAR, USGS, …
- NGO: Nature Conservancy
- International: U Glasgow, Govt. of Canada

KDD 2016 Workshop on Data Science for Food, Energy and Water

ACM SIGKDD Conference on Knowledge Discovery and Data Mining
August 13 - 17, 2016 | San Francisco, California

Details @ https://sites.google.com/site/2016dsfew/home

NSF MBDH Travel Support for Early Career Researchers

May 27th	Paper submissions due
June 13th	Acceptance notification
July 20th	Camera-ready papers due
August 14th	Workshop date

White House Water Summit: March 22, 2016

Commitments to Action on Building a Sustainable Water Future

The New York Times   MARCH 17, 2016

Water Is Broken. Data Can Fix It.

NSF Multi-year Cross-Directorate Initiative

News: **https://foodenergywater.wordpress.com/**

Research:

- Innovations for F, E, W Nexus (INFEWS)

Education:

- NRT solicitation - INFEWS as a priority

Infrastructure & Community Building:

- Big Data Hub, Big Data Spoke

EPSCoR

FOOD ENERGY WATER

NSF INNOVATIONS AT THE NEXUS OF FOOD + ENERGY + WATER SYSTEMS

FUNDING • EVENTS • ABOUT • WHAT'S NEW WITH FEW

INFEWS Data Science Workshop Draft report available for comments:
http://www.spatial.cs.umn.edu/few/few_report_draft.pdf