TRANSFORMING AGRICULTURE WITH INTELLIGENT INFRASTRUCTURE

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Session: *Transforming Cities, Transportation, and Agriculture With Intelligent Infrastructure*

AAAS 2018*: Advancing Science Discovery to Application*

Acknowledgements: *R. Chandra (Microsoft), C. Krintz (U.C.S.B.), K. Van der Waal & P. Pardey (University of Minnesota), Midwest Big Data Hub, Computing Community Consortium.*

Details: S. Shekhar et al., **Intelligent Infrastructure for Smart Agriculture:** An Integrated Food, Energy and Water System, Computing Community Consortium whitepaper; arXiv preprint arXiv:1705.01993, 2017.

UNIVERSITY OF MINNESOTA
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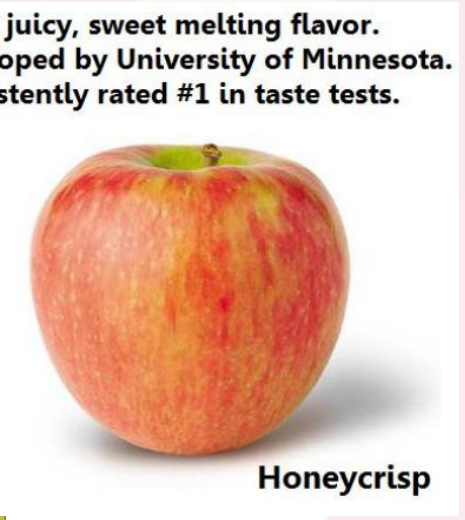
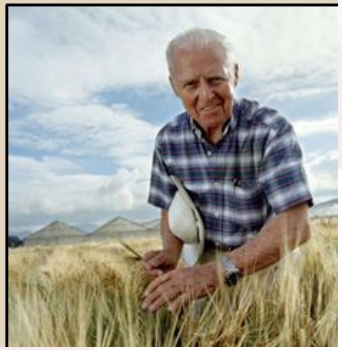
AGRICULTURE & UNIV. OF MINNESOTA

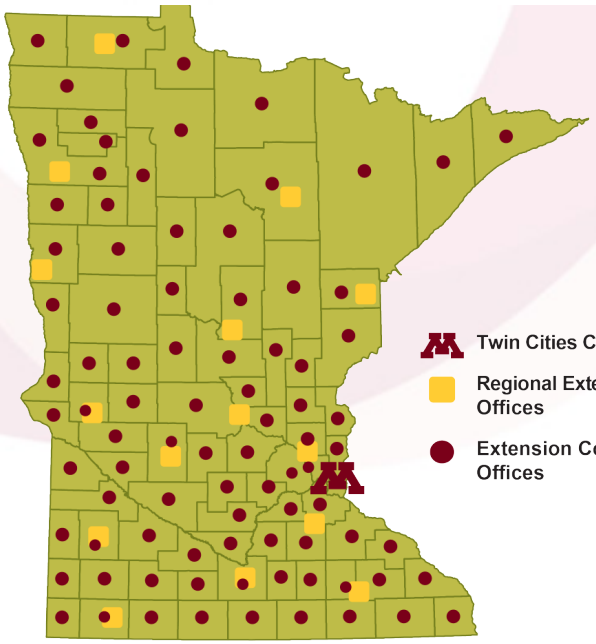
- Land Grant Mission
- Contributions
  - Honeycrisp Apple: Research you can bite into
  - People : Norman Borlaug



Norman Borlaug

- *Known as "The father of the Green Revolution"*
- *Nobel Peace Prize Winner*
- ***University of Minnesota** Graduate*
- *Created varieties of high yield, disease resistant wheat crops*
- ***Result:** boost the production of wheat around the world.*





Agriculture Today	Success Stories	Transformative Opportunities	Discovery to Application	Next

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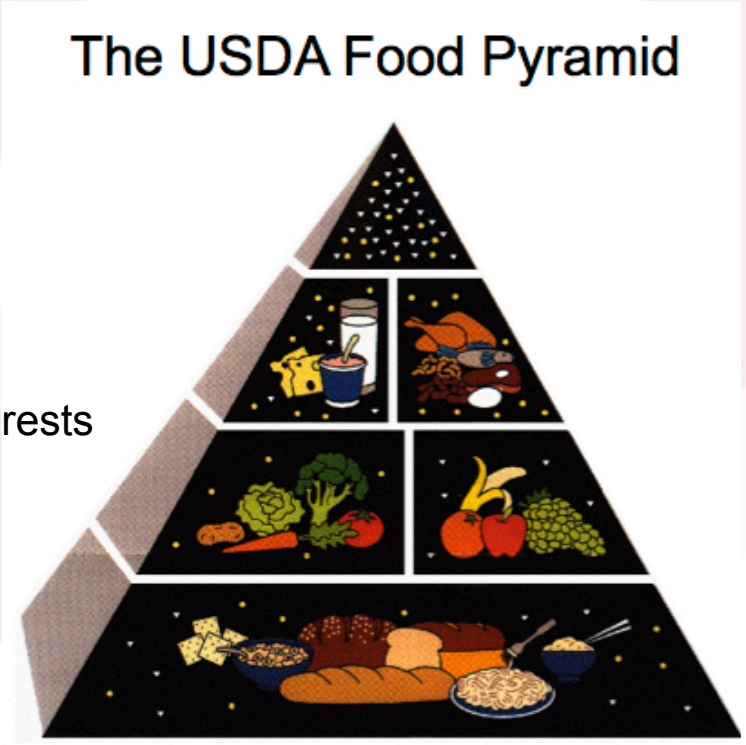
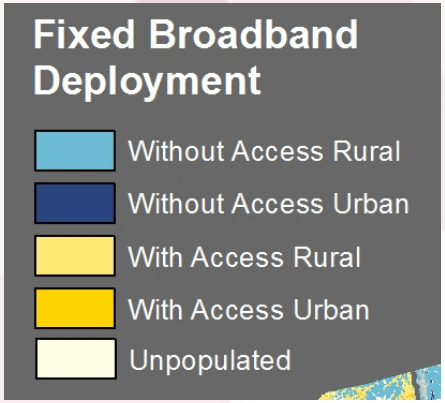
AGRICULTURE TODAY: SOCIETAL IMPORTANCE

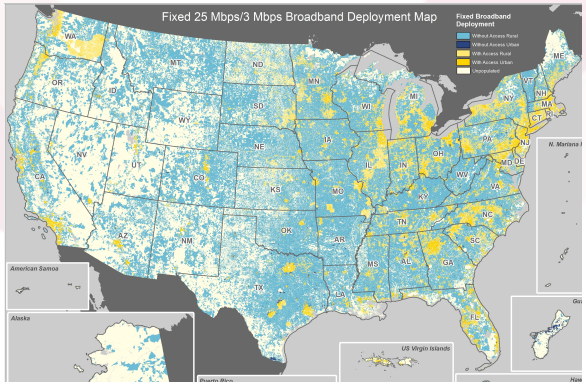
- Agriculture nourishes us with
  - Food, Fiber, Fuel
- Economic Opportunities
  - 10% of U.S. Jobs
  - Helps rural America to thrive
  - Early adopter of technology, e.g., GPS, UAV, …
- Stewart of natural resources
  - Healthy private working lands
  - Conservation, Improved Watersheds, Restored Forests



AGRICULTURE TODAY: CHALLENGES

- Social-Infrastructure Challenges
  - Aging workforce, Labor shortage
  - Low urban engagement of urban
- Environmental-Infrastructure Challenges
  - Bee colony collapse
  - More intense rains & longer dry periods
- Cyber-Infrastructure Challenges
  - Broadband & cloud computing
  - Data: Yield & disease prediction





AN INTELLIGENT INFRASTRUCTURE SUCCESS STORY : PRECISION AGRICULTURE

- Transformed agriculture
  - Improves yield
  - Reduces fertilizer use & run-offs
- Intelligent Infrastructure
  - GPS, GIS, Remote Sensing, …

Yield Monitors	Direct & Remote Sensing	Precision Navigation	Variable Rate Technology

Global Positioning Systems

Geographic Information Systems

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
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Agricultural Retailers Association
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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.

Details: Capitol Hill Presentation on Deconstructing Precision Agriculture, Computing Research News, 27(4), (ISSN 1069-384X), Computing Research Association, April 2015.

TRANSFORMATIVE OPPORTUNITIES: SOCIAL INFRASTRUCTURE

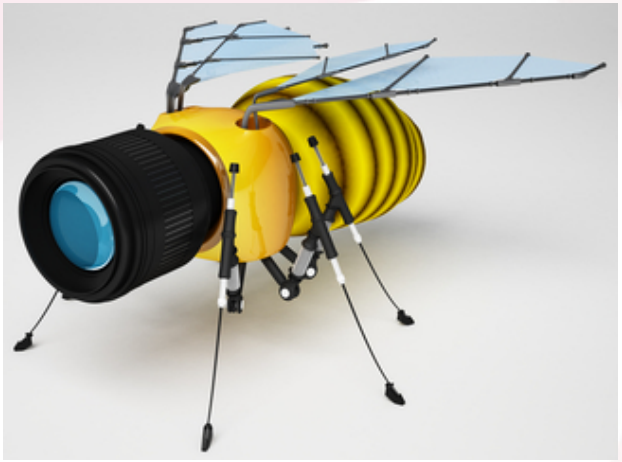
- Challenges: Aging workforce, Labor shortage, Low urban engagement
- Intelligent Infrastructure Opportunities
  - Tele-operation
  - VR-based Training Environment

Source: Autonomous Solutions Inc. and CNH Industrial unveil concept Autonomous Tractor, Aug. 30, 2016, asirobots.com

Source: L. Mathew, There is now a $300 joystick built for Farming Simulator, geek.com, 06.12.2015.

TRANSFORMATIVE OPP.: ENVIRONMENTAL INFRASTRUCTURE

- Challenges: Bee colony collapse, Rainfall Variability
- Intelligent Infrastructure Opportunities
  - Robot Bees
  - Cyber-Physical Systems for Smart Water management
    - Water sensors + data analytics + control

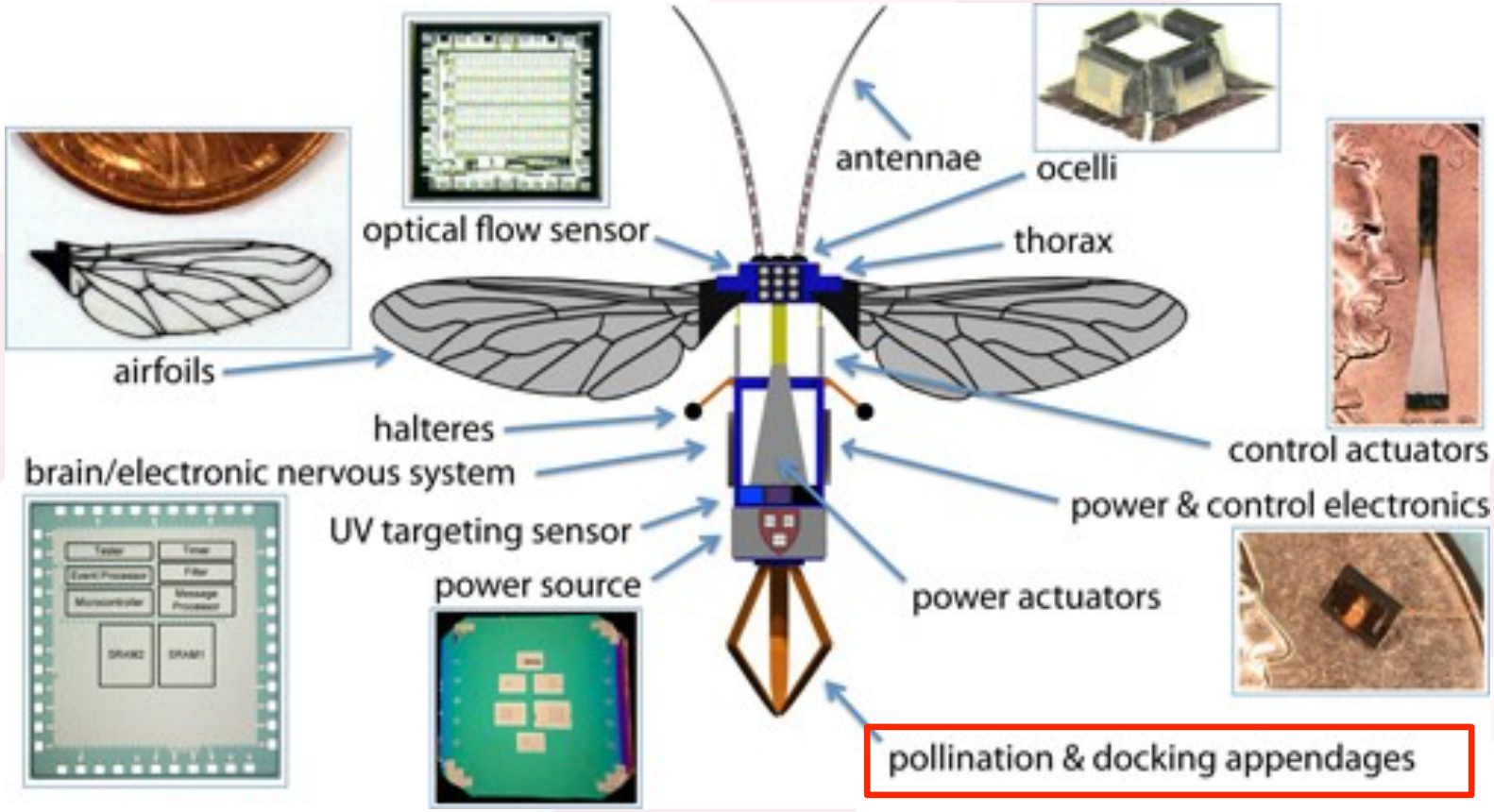


Source: Researchers using AI to build robotic bees, D. Harris, GigaOm, Oct 1, 2012.

Source: Smart Irrigation: 10 Companies to Watch in 2018, A. Shiffler, disruptorDaily.com, Dec. 27th, 2017.

ROBOTIC POLLINATORS

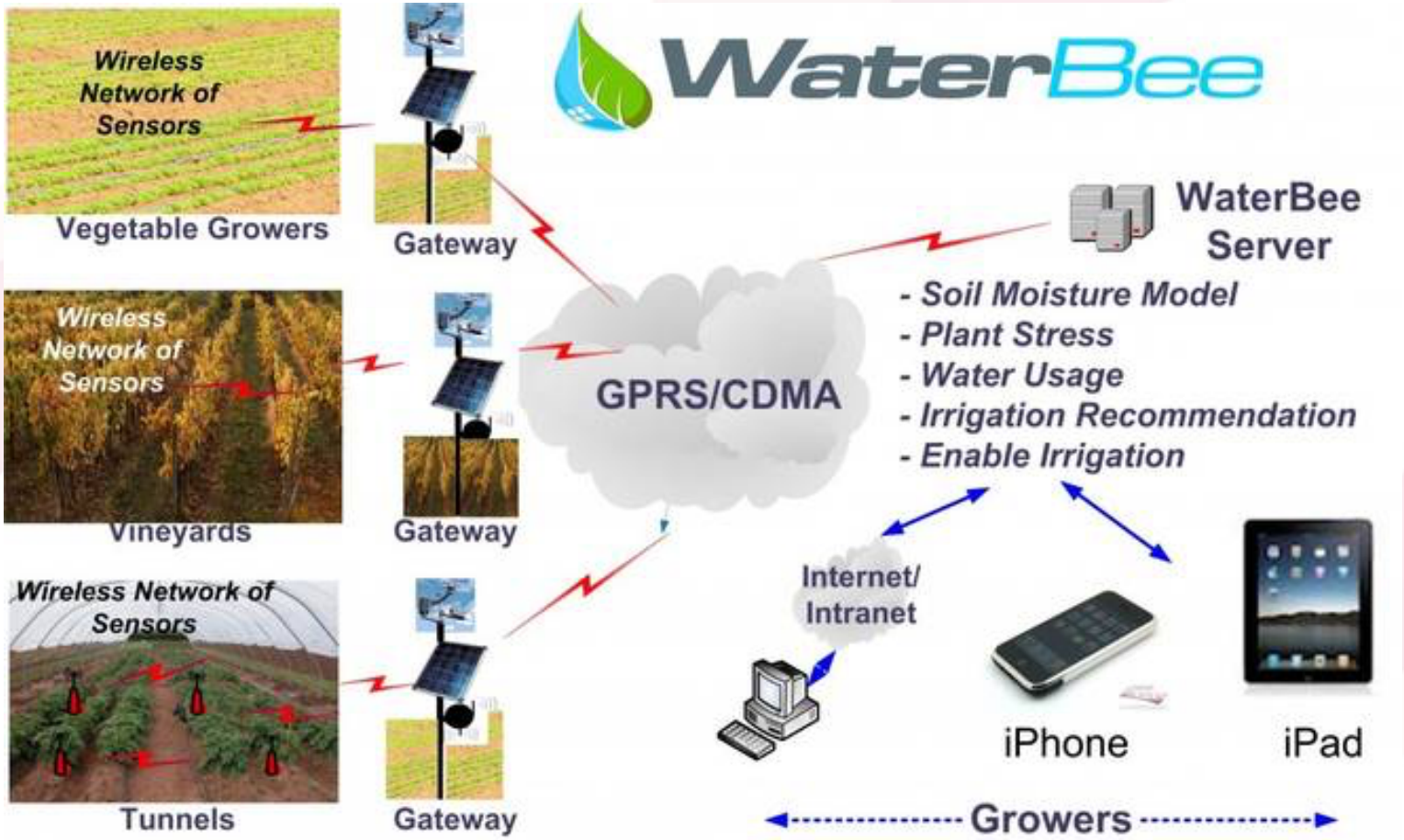
- **Robo-Bees** (Harvard U, National Science Foundation):



Source: Researchers using AI to build robotic bees, Derrick Harris,GigaOm, Oct 1, 2012.

SMART IRRIGATION: CYBER-PHYSICAL SYSTEMS

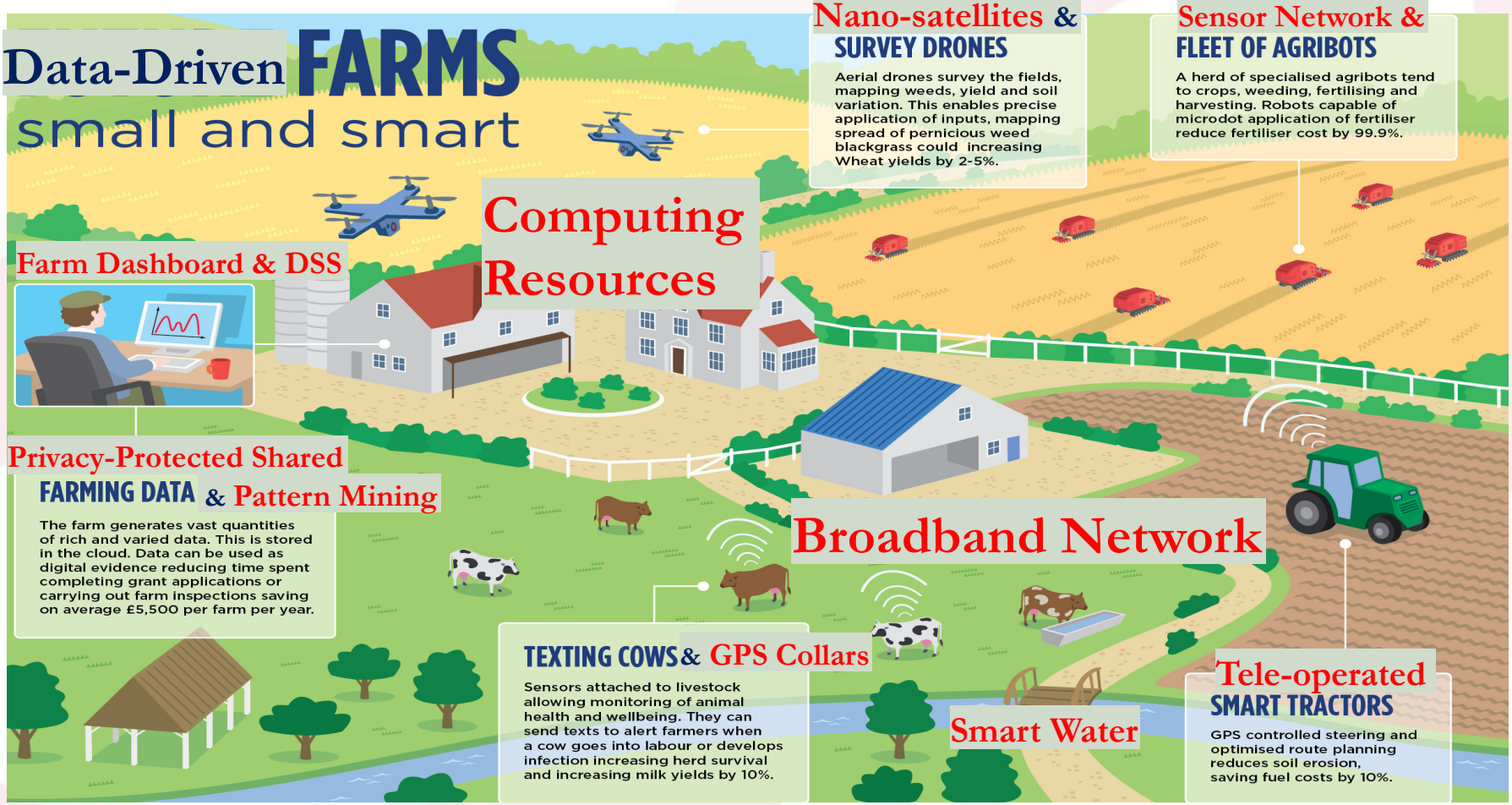
- **Cyber-Physical Systems** = sensors + data analytics + control



Source: This smart irrigation and water management system is controlled by your smartphone, D. Markham, treehugger.com, July 19, 2013.

CYBER-INFRASTRUCTURE NEEDS IN DATA-DRIVEN FARMS

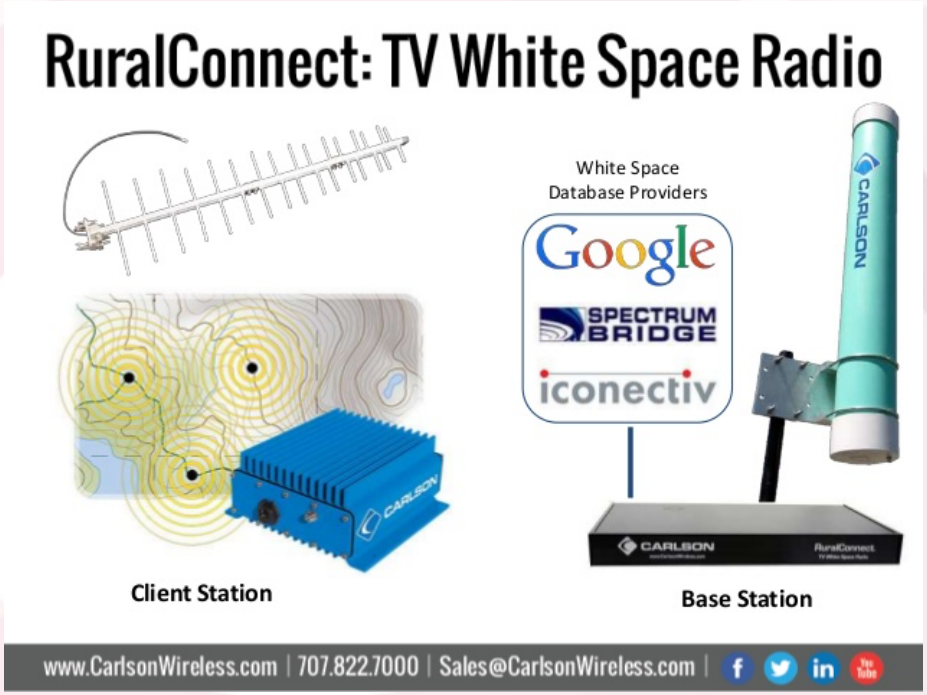
- Challenges: **Limited broadband, sensing, data & computing**

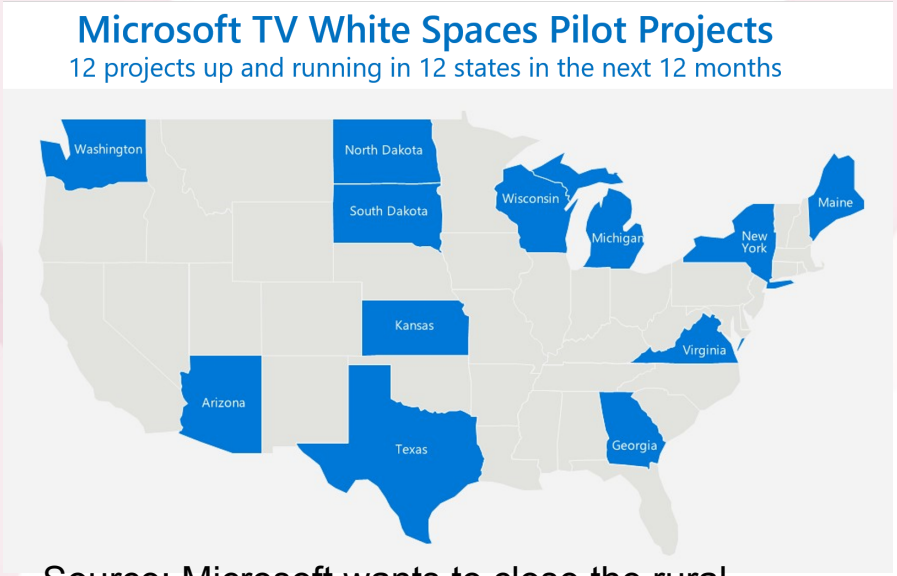


Adapted from S. Chakravarty, History of scientific farming in India, June 6, 2017, www.geospatialworld.net

TRANSFORMATIVE OPP.: BETTER CYBER-INFRASTRUCTURE

- Intelligent Infrastructure Opportunities
  - TV Whitespace Spectrum for rural broadband
  - Geospatial Cloud Computing for farms
  - Spatial Data Science to monitor disease & predicting yield





Source: Microsoft wants to close the rural broadband gap with TV white spaces, T. Warren, theverge.com, July 11, 2017.

TRANSFORMATIVE OPPORTUNITY: PRESCRIPTIVE FARMING

CLIMATE FIELDVIEW

Seamless Field Data Collection

THE CLIMATE CORPORATION

Customized Insights for Decision Making

Monsanto, DuPont and others are pitching 'prescriptive planting' services to increase crops

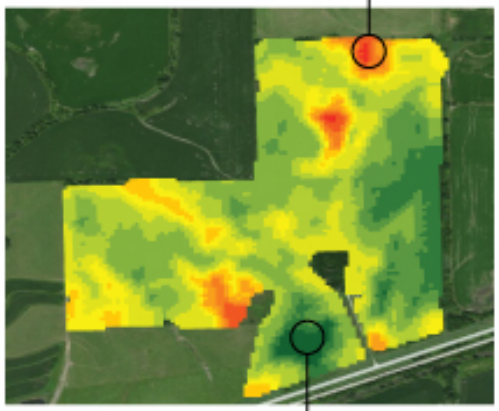
How data-driven planting services work:

1. The farmer provides field boundaries, historic crop yields, soil conditions and other data to a company.
2. The company analyzes the data and its own information about seed performance in different areas and soil types.
3. The company sends a computer file with recommendations back to the farmer, who uploads it into a planter.
4. The farmer's equipment then plants based upon the recommendations. The company monitors weather and other factors, advising farmers on how to manage crops as they grow.

Source: Monsanto

A cornfield analysis in Iowa:

Red areas: Lower number of seeds per acre recommended



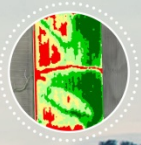
Green areas: Portions of the field that can grow more corn and can take more seeds per acre

Manual Upload

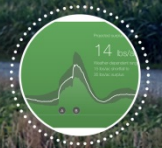
View Field Data in Real Time

Compare Data Layers

Analyze Crop Performance in Season

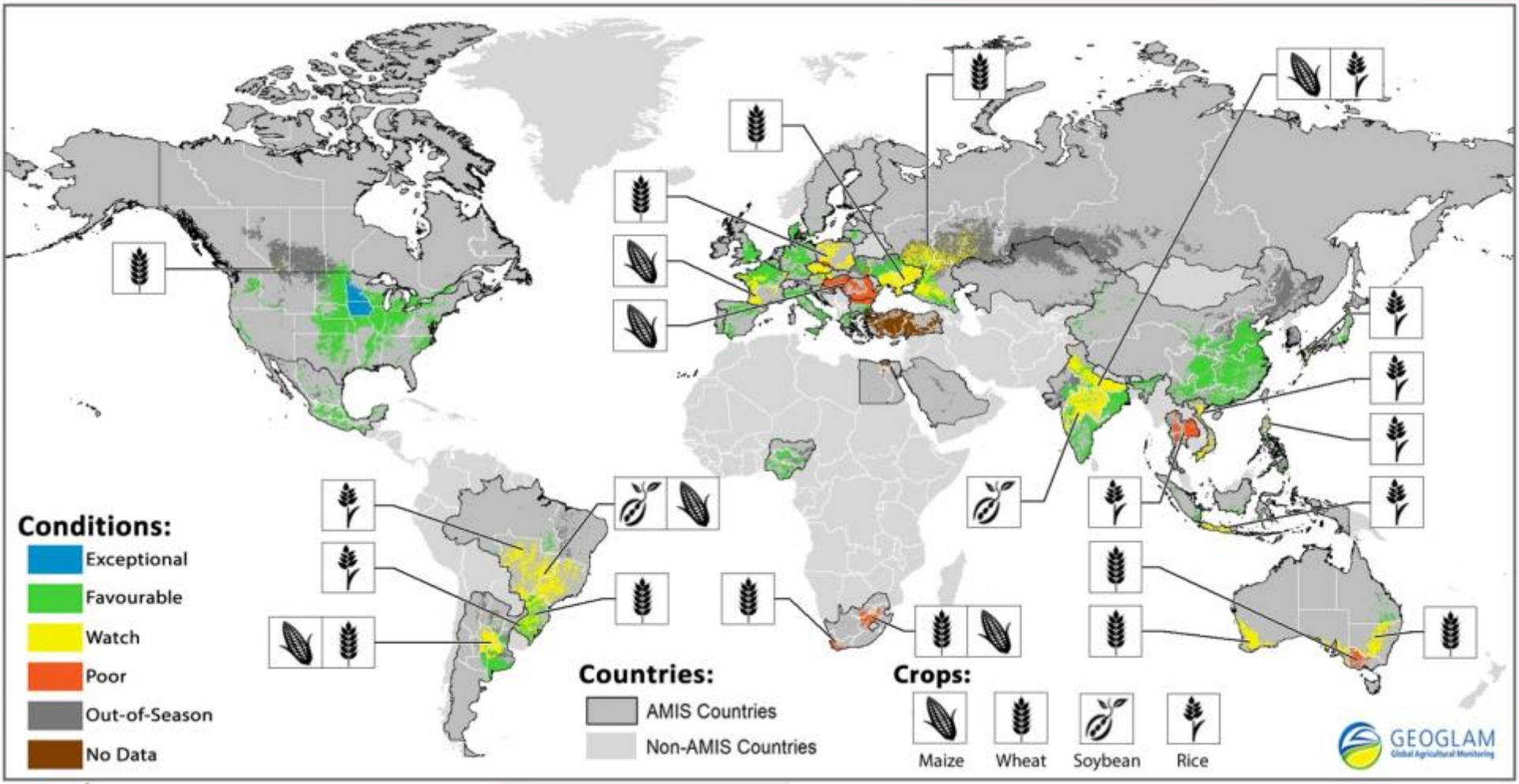


Manage Nitrogen Applicatoons



Create Seeding Prescription

OPP.: CONTINUOUS CROP MONITORING, YIELD FORECAST



AMIS Agricultural Market Information System

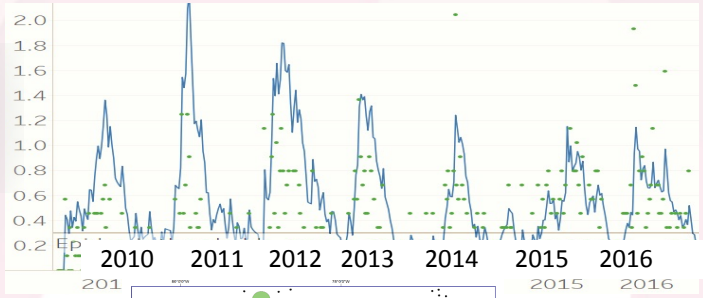
GEOGLAM Global Agricultural Monitoring

CCC Computing Community Consortium Catalyst

TRANSFORMATIVE OPP.: **SWINE MONITORING & DISEASE FORECAST**

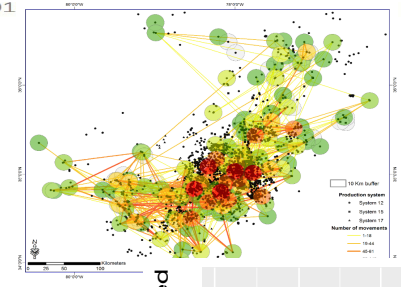
- **Track** weekly infection status
  - 50% of U.S. sow population
  - PRRS & PED virus

Industry participation



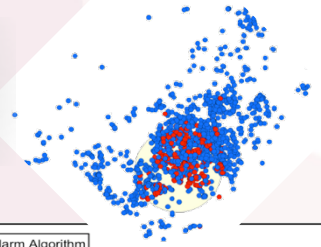
- **Forecast virus** spread
  - from pig movement across farms

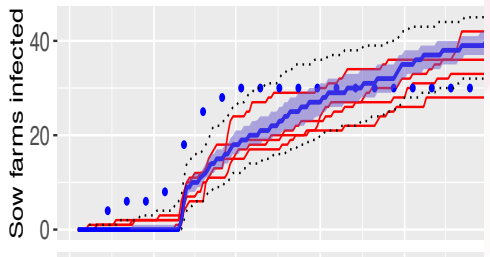
Spatial analysis & Simulation



- **Model** regional spread
  - Identify **super-spreaders**

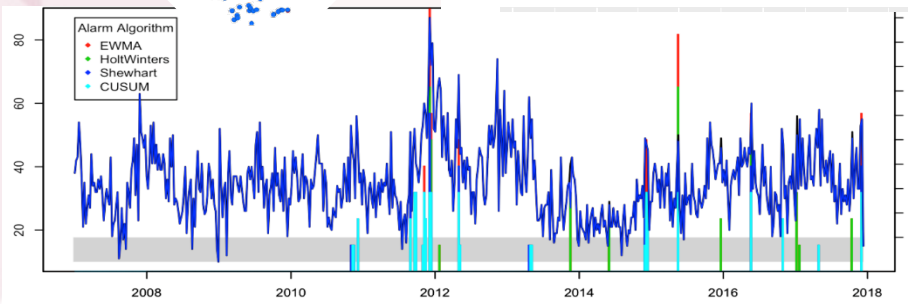
Machine Learning





- **Early Warning System**
  - Altered disease dynamics Detection

- **Challenge**: Data Sharing
  - During Epidemics (similar to E-911)
  - Protect property rights, privacy, …



Source: Prof. K. VanderWall, Univ. of Minnesota

Details: S. Shekhar et al., Agriculture Big Data (AgBD) Challenges and Opportunities From Farm To Table: A Midwest Big Data Hub Community Whitepaper, NSF Midwest Big Data Hub, December, 2017.

INTELLIGENT INFRASTRUCTURE OPPORTUNITIES

- **More examples** in community whitepaper:

  S. Shekhar et al.,

  Intelligent Infrastructure for Smart Agriculture: An Integrated Food, Energy and Water System, Computing Community Consortium whitepaper; arXiv preprint arXiv:1705.01993, 2017.

Areas	Intelligent Infrastructure and Research Needs
Workforce Development	Augmented reality; Teleoperation
Cyber Physical Systems & Robotics	Robust high-precision positioning; Automation for labor intensive tasks
Networking, Internet of Farm Things	Improving Broadband Network Access in Rural Farming Areas

ADVANCING SCIENCE DISCOVERY TO APPLICATION

- Knowledge **co-production** with users
  - **Co-Visioning**
  - **Co-define Problems**
  - **Co-select Science Questions**
  - **Co-Evaluate Discoveries**

Source: The Sheffield Mental Health Guide, sheffieldflourish.co.uk, 5 Apr 2017.

- **Co-production Initiatives**
  - CRA/CCC Visioning Workshops
  - (Midwest) Big Data Hubs & Spokes
  - NSF Sustainability Research Networks
  - NSF Smart & Connected Community

- **Co-Production Examples** in my work
  - 2005: Evacuation Planning: MN local governments
  - Current: NSF SCC Project: counties, cities in MN, FL

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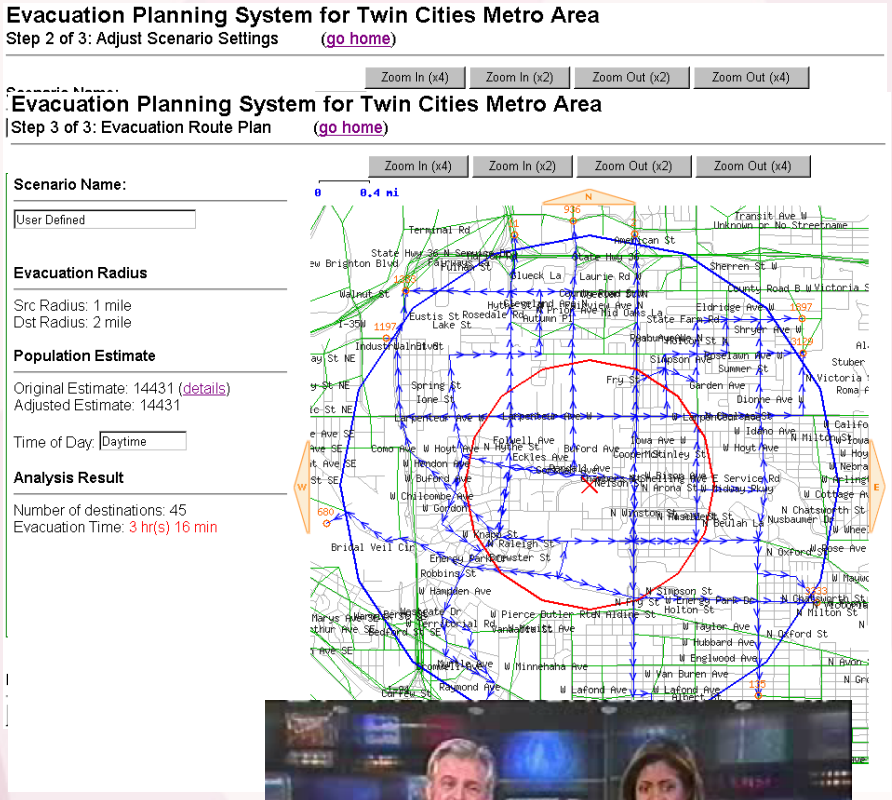
KNOWLEDGE CO-PRODUCTION: EVACUATION PLANNING (2005)

- **Team**: US DHS, MN Dept. of Transportation, URS Corp.
  - Emergency Mangers, Police, Fire Fighters, Natl. Guard
- Co-Visioning via monthly meetings
  - Challenges: evacuees & traffic maps
  - Police: focus on what can be done!
- Problem Co-Definition
  - 1-mile scenarios: 5 sites, work-day or night-time
- Co-Discovery
  - For 1st mile, walking faster than driving
- Co-Evaluation
  - Walk selected routes : avoid wooden bridge near E
  - Lock parking garages during evacuation ?

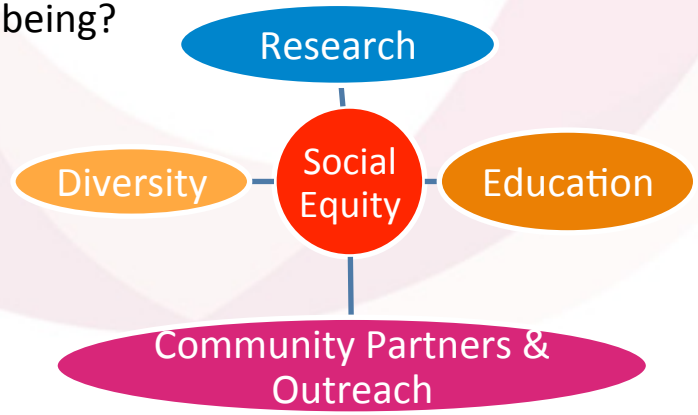


Scenario	Population	Vehicle	Walking
A	143,360	4:45	1:32
B	83,143	2:45	1:04
C	27,406	4:27	1:41
D	50,995	3:41	1:20
E	3,611	1:21	0:36

Details: FoxTV newsclip, Shashi Shekhar Disaster Area Evacuation Analytics, https://www.youtube.com/watch?v=PR9k72W8XK8

KNOWLEDGE CO-PRODUCTION:
NSF SMART & CONNECTED COMMUNITIES GRANT 1737633 (2017-2020)

- Team: U of Minnesota, Purdue U, FL State U, U of WA
  - Schools, Counties (e.g., Hennepin), Cities (e.g., Minneapolis, St. Paul, Tallahassee);
  - MetroLab Network, National League of Cities, ICLEI-USA, Intl. City/County
- Co-Visioning via meetings
  - Communities planning infrastructure for driver-less, post-carbon future with climate change
  - Advance Environment, Health, Wellbeing & Equity via infrastructure refinement
- Co-select Questions
  - Understand spatial equity in infrastructure & outcomes (wellbeing. health, environment)?
  - How does equity first approach differ from average-outcome based approaches ?
- Problem Co-Definition: How to measure spatial equity? Well-being?
- Co-Discovery
- Co-Evaluation



- Details: University of Minnesota secures $2.5 million grant to improve quality of life in cities, October 20, 2017 (https://www.cs.umn.edu/news/filter/highlights/professor-shekhar-leads-u-m-team-granted-25-million-nsf-grant)

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CONCLUSIONS & NEXT STEPS

- Agriculture is societally important and facing challenges
  - Importance: 10% of U.S. economy, …
  - Challenges: Workforce, bee colony collapse, broadband, …
- Intelligent Infrastructure has already transformed Agriculture
  - Precision Agriculture
- Many Transformative opportunities lie ahead
  - Workforce, Robo-bees, TV Whiteband, Spatial Data Science, …
- However, these will not material without
  - Federal research funding
  - **Knowledge Co-production**: farmers, academics, businesses, policy-makers

REFERENCES

1. S. Shekhar, J. Colletti, F. Munoz-Arriola, L. Ramaswamy, C. Krintz, L. Varshney, and D. Richardson, Intelligent Infrastructure for Smart Agriculture: An Integrated Food, Energy and Water System, A Computing Community Consortium whitepaper; arXiv preprint arXiv:1705.01993, 2017.

2. S. Shekhar et al., Agriculture Big Data (AgBD) Challenges and Opportunities From Farm To Table: A Midwest Big Data Hub Community Whitepaper, NSF Midwest Big Data Hub, December, 2017.

3. Data Science for Food, Energy and Water: A Workshop Report , ACM SIGKDD Explorer, 18(2): 1-4, December 2016. describes the highlights of the ACM SIGKDD Workshop on Data Science for Food, Energy and Water , 2016.

4. NSF Workshop to Identify Interdisciplinary Data Science Approaches and Challenges to Enhance Understanding of Interactions of Food Systems with Energy and Water Systems, Computing Research News (ISSN 1069-384X), Computing Research Association, 27(10), November 2015.

5. Capitol Hill Presentation on Deconstructing Precision Agriculture , Computing Research News (ISSN 1069-384X), Computing Research Association, 27(4), April 2015.

6. 40 maps that explain food in America, E. Klein et al., 2014 (https://www.vox.com/a/explain-food-america).