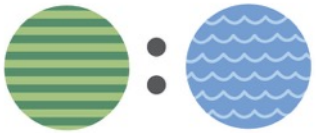
Smart Systems For 21st Century Food Systems

Sonny Ramaswamy

Annual Exit Interviews: Secretary

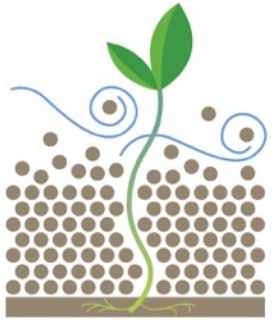
Food, Shelter, Fiber, Fuel > 9 billion

CLIMATE CHANGE

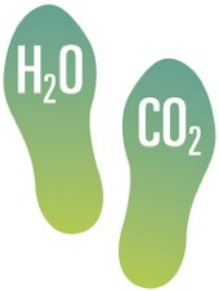


LAND & WATER CONSTRAINTS

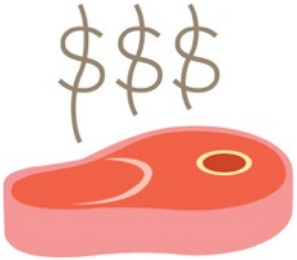
INCREASING URBANIZATION



ENVIRONMENTAL DEGRADATION



MINIMAL ECOLOGICAL FOOTPRINT



CHANGING INCOME & DIETS

POSITIVE HEALTH OUTCOMES

Path Forward

- Transformative discoveries
  - Smart Systems
  - Big Data
- 21st Century Extension
- Farming systems
  - 21st Century Farms
- Education
- Policies, regulation, marketing
- Human dimensions
- Communications

Smarter Agricultural Production?

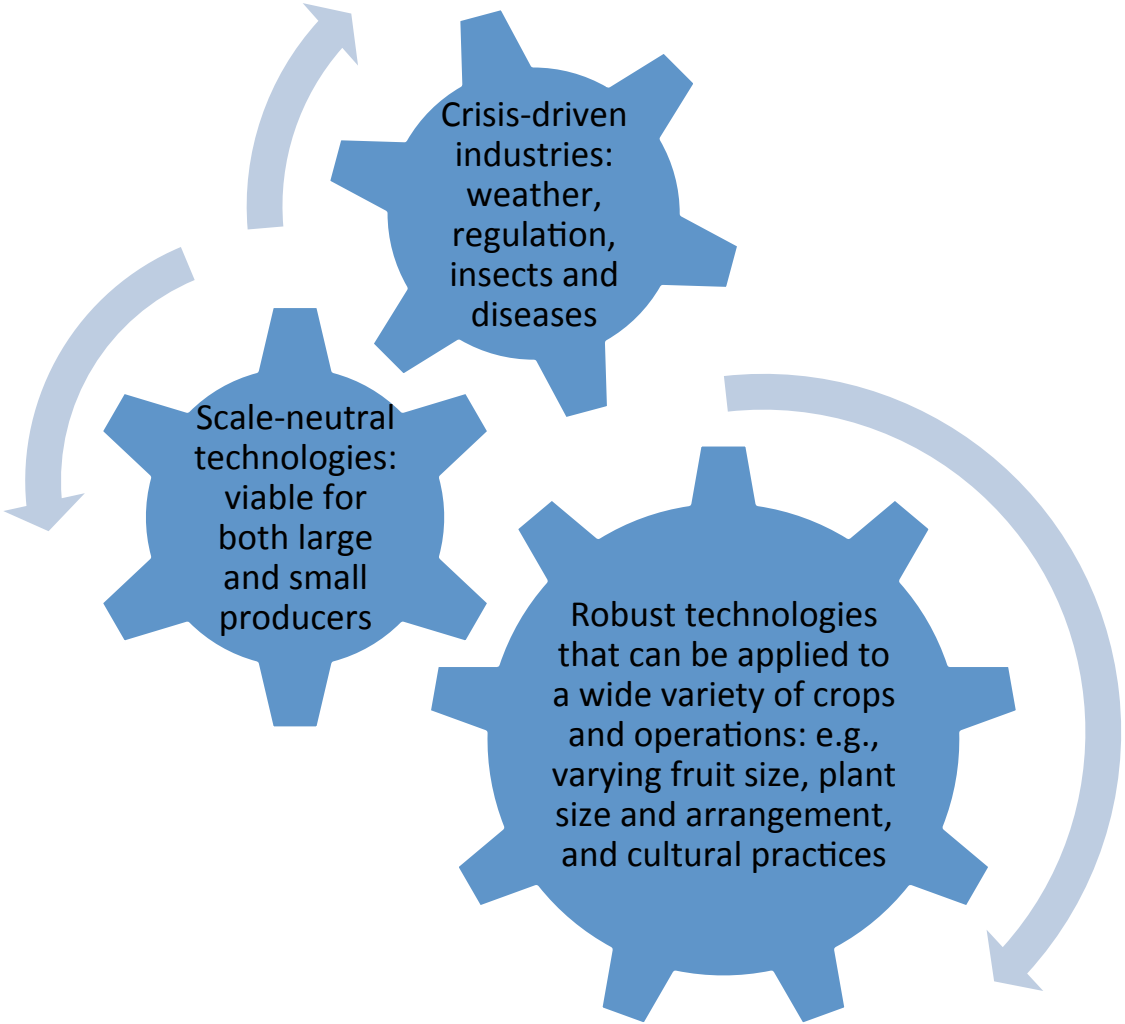
Goal – Develop new or improved engineered devices, products, or systems that:

Precisely **sense**, "**reason**," and **respond**

Improve the **profitability**, **productivity**, and/or **efficiency** of ag-related operations of all sizes

Benefit consumers and **society**

Technology Challenges



Cyberphysical Systems, Robotics, Agriculture Technology

While producing **safe, nutritious, and affordable food** to serve a growing global population—as well as feed, fiber, and fuel—the agricultural enterprise **consumes large amounts of land, water, and petro-chemicals**.

Availability and cost of farm labor has created an economic disadvantage for many agricultural industries in the U.S. as they try to **compete** in the **global marketplace**.

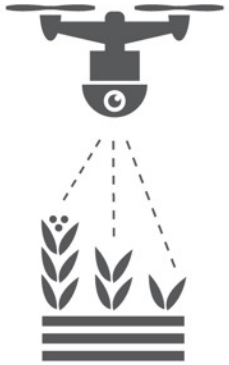
Robotics can help agriculture be more productive and efficient, and reduce its footprint in consuming resources and generating waste.

Using robotics to eliminate unskilled, unsafe, and low-wage jobs will create **new business opportunities**, with higher-wage, technically demanding jobs, that can lead to **more viable and resilient rural economies**.

Sustainability

Smart Systems For Food Production Systems

1) Assist in the production process
2) Measure plant performance
3) Track environmental conditions
4) Inform real-time decision making



DEVELOPING NEW TECHNOLOGIES

SCREENING GENOTYPES AND PHENOTYPES

Combine **next-generation sequencing** & **new sensor technologies** to acquire genotype, phenotype, and environmental data to **identify relationship between genotype and phenotype**

Long-term goal: **accelerate breeding** via marker-assisted selection and genomic selection to aid rapid seedling screening

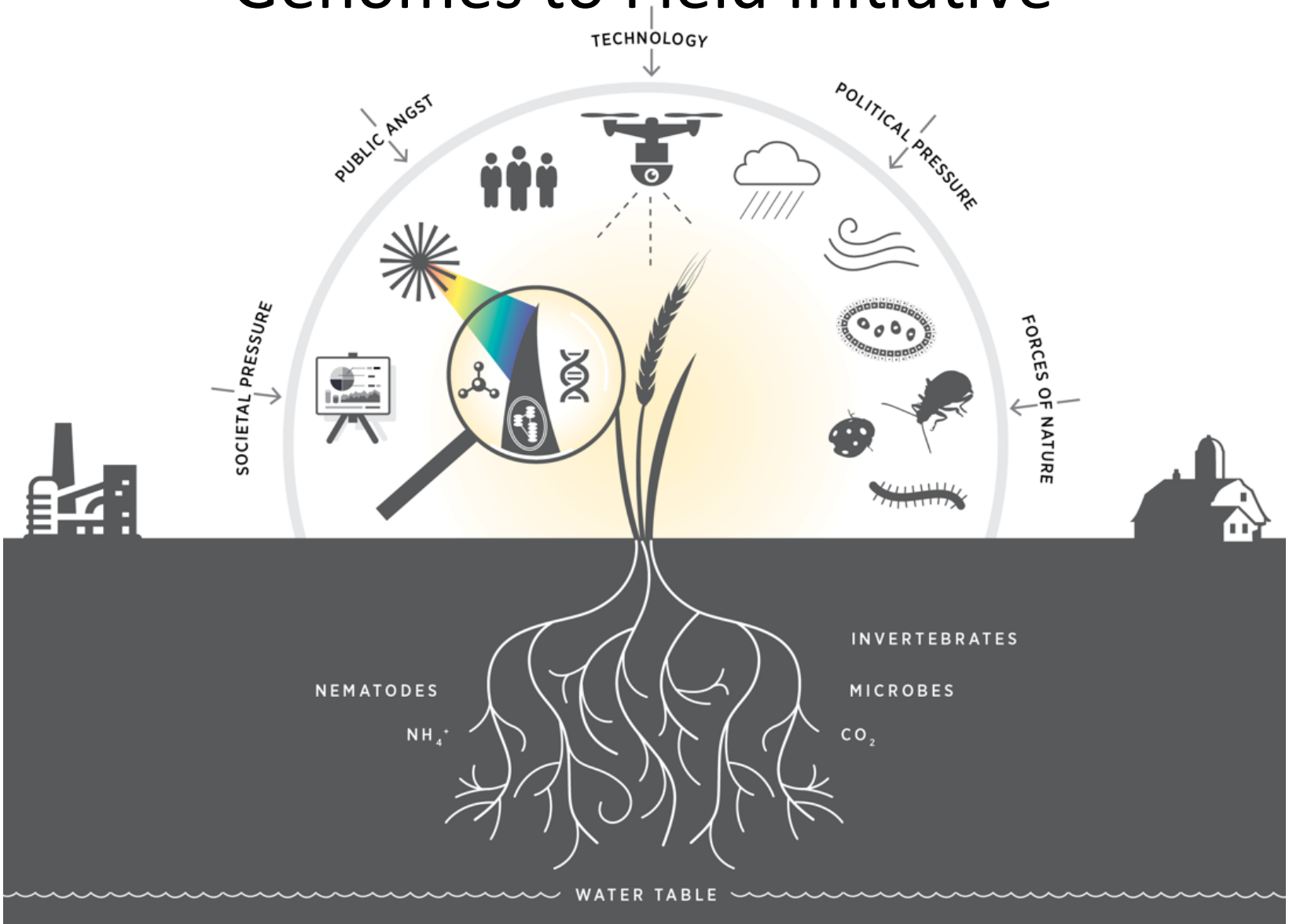
DESIGNING SMART SYSTEMS FOR PRODUCTIVITY AND MANAGING BIOTIC & ABIOTIC STRESSORS

Designing sensors, robots, and drones to measure environments and traits, production to post-harvest

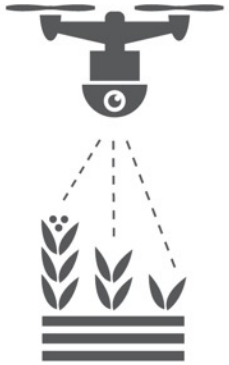
Generating large quantities of environmental, trait, and genetic data

New technologies, statistical tools, and experimental design strategies are decreasing the costs of marker-assisted breeding

Genomes to Field Initiative



Smart Systems Generate Data



DEVELOPING NEW TECHNOLOGIES

SCREENING GENOTYPES AND PHENOTYPES

MANAGING BIG DATA

Storing collected **raw data**

Using **algorithms** to **generate results** from the raw data

Modeling to develop **understanding** of the data, **inform breeding** selections and field trials

DESIGNING SMART SYSTEMS FOR MANAGING AND ANALYZING DATA

Designing sensors, robots, and drones to measure environments and traits, production to post-harvest

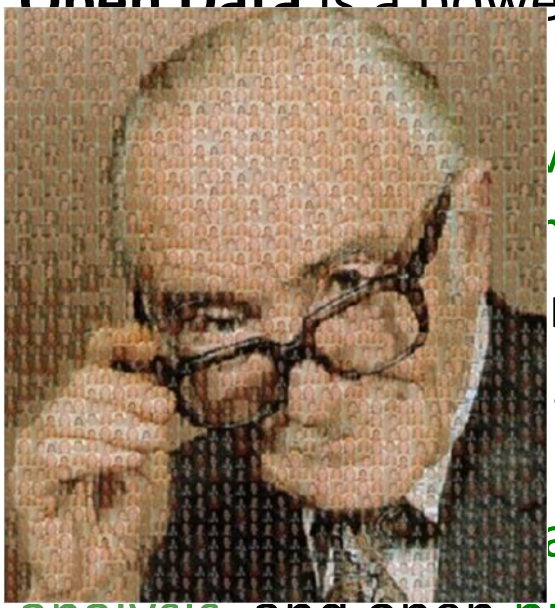
Generating large quantities of environmental, trait, and genetic data

Storing, processing, and analyzing the collected data to identify the genetic basis of desirable agronomic traits

#BigData

Big Data: Opportunities

Open Data is a powerful,
for long-
velopment
mic
mers and
.
arch, meta-
analysis, and open publication
of data are vital resources for
nutritional security.

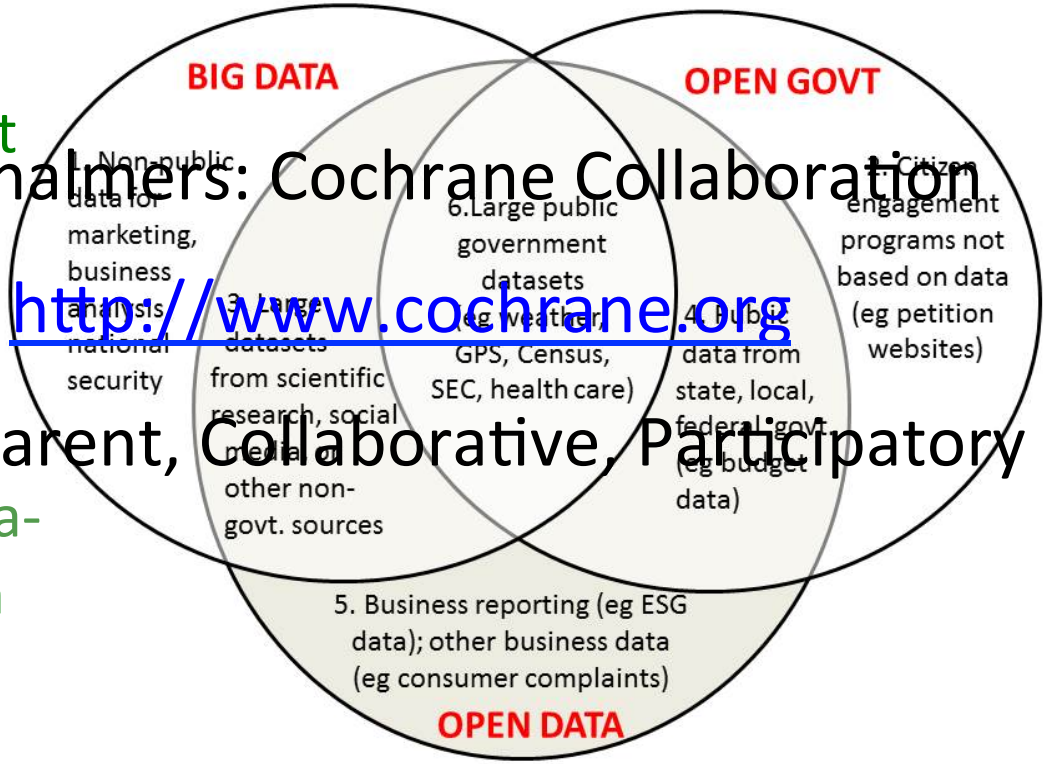


Archibald Cochrane

Iain Chalmers: Cochrane Collaboration

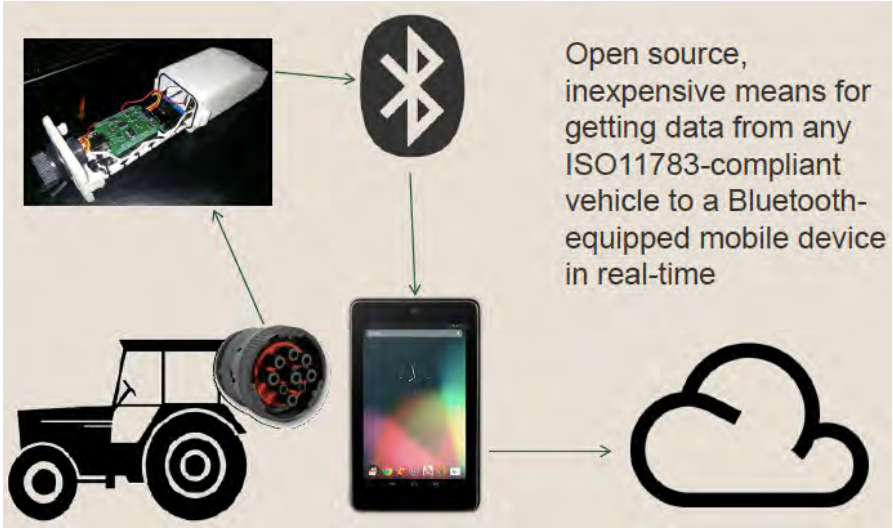
http://www.cochrane.org

Transparent, Collaborative, Participatory



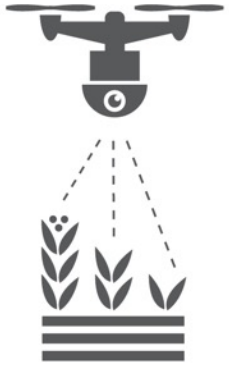
Big Data: Challenges

- Ownership
  - Open Ag Technology Systems
- Decision Support Tools
  - Open Ag Toolkit – NIFA funded
  - FarmBot
- Cost
- Bandwith
- Quality
- Curation
- Disambiguation
- Connectivity
- Cybersecurity
- Storage



Courtesy: Dennis Buckmaster; https://engineering.purdue.edu/oatsgroup/

Smart Systems From Farm to Table



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MANAGING BIG DATA

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BREEDING DESIRABLE CROP VARIETIES

Selecting, genetically screening, field testing, and scaling desirable varieties for production

HARVESTING & DISTRIBUTING TO CONSUMER

Using new technologies to harvest and transfer high-quality berries from farm to table

DESIGNING SMART SYSTEMS FROM FARM TO TABLE

Supply Chain

- On Farm Production
- Soil Health, Water, Nutrients
- Pests/Control
- Energy
- Traceability and Tracking
- Supply Chain Management
- Processing
- Inspection
- Transportation
- Storage
- Retailers
- Inventory
- Access
- Smart Refrigerators
- Food Safety
- Ripeness
- Shrink Wrap
- Waste
- Smart Services
- Etc.

Smart Systems Robotics

Application to Caneberries:

State-of-the-art machine harvesters in the Pacific Northwest optimize efficient harvest of high quality fruit for the Individually Quick Frozen market

DESIGNING ROBOTICS

Color and size sorters ensure quality products in the fresh and processed packing industries

Photos courtesy of Dr. Bernadine Strik, Oregon State University

encirca VIEW

FieldScripts

Outcome of Big Data and Analytics

2014 National Corn Yield Average: 171 Bushels

Randy Dowdy, farmer from Georgia: 503 Bushels

Randy Dowdy used sensors, optimal varieties, irrigation and fertilizers, pest control, and Big Data analytics with the help of Monsanto and Climate Corp

http://tinyurl.com/o78mah

Real-time Ag Data Analytics and Control – Research Gaps

Increased production requires efficient production decisions

How can cyber-physical systems leverage "big data" real-time in a diversity of environments?

NSF/NIFA joint funding opportunity:

Cyber-Physical Systems (closes June 7, 2016)

Real-time Ag Data Analytics and Control – Drones & Sensors

Applications of drones:

-Fire fighting

-Scouting for insect pests

-Field monitoring

Advantages of drones:

-Cheap

-Lightweight

-Can carry a variety of sensors/cameras

Funding opportunity: Small Business Innovation Research

NIFA-Funded: Open Data , Open Access Tools, and Cyberinfrastructure

- MaizeGDB (corn)
- SoyBase (soybean)
- Legume Information System (legumes)
- T3: The Triticeae Toolbox
- GrainGenes (wheat, barley, oat)
- Gramene (rice, grape, other model plant systems)
- Genome Database for Rosaceae

Smart Systems to Accelerate Breeding: Funding Opportunities

- AFRI Foundational Plant Health and Production and Plant Products Program
  - Pre-breeding and germplasm enhancement, cultivar development, selection theory, applied quantitative genetics, and breeding
  - Conventional breeding for development of publicly available cultivars
- AFRI Foundational CARE and ERG program
- AFRI Food Security Challenge Area
  - Breeding and phenomics of crops to produce varieties with improved resilience to extreme weather and increased protection from pests
  - Enhanced nutritional composition for improved human health
  - Training next generation of plant breeders
- AFRI Education and Literacy Initiative
  - Undergraduate, predoctoral, and postdoctoral fellowships

Smart Systems to Accelerate Breeding: Funding Opportunities

- NIFA International Wheat Yield Partnership
  - Breakthrough breeding, genetics, and genomics
- NIFA/DOE Joint Plant Feedstock Genomics for Bioenergy Program
  - Breeding and genomics to develop new feedstocks
- Early Concept Grants for Exploratory Research (EAGER) NSF/NIFA Joint Funding
  - Breakthrough technologies for animal and plant phenomics and microbiomes
- Plant Biotic Interactions Program NSF/NIFA Joint Funding
  - Processes mediating beneficial and antagonistic interactions between plants, symbionts, and pests
- NIFA/ARPA-E
  - TERRA Genomes to Phenomes/Field program

NIFA SUPPORTS RESEARCH AND EDUCATION THAT SUSTAINABLY INCREASE PRODUCTIVITY BY:

INCREASING photosynthetic, water use, and nutrient use efficiency in crops and animals

DIVERSIFYING the product stream through novel crops, organisms, and processing technologies

PROTECTING these products against predators, parasites, diseases, and pathogens to ensure food safety

DEVELOPING & DEPLOYING the industrial, physical, and digital technologies to revolutionize planting, cultivation, harvest, storage, and transportation

PREPARING the next generation of agriculture professionals through education, training, and leadership development.

Humans Matter