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# Smarter Farming with Smart Systems Drones and More

Sonny Ramaswamy

Steven J. Thomson



<http://www.ars.usda.gov/sp2userfiles/Place/20721500/images/rubus3.jpg>



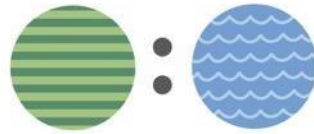
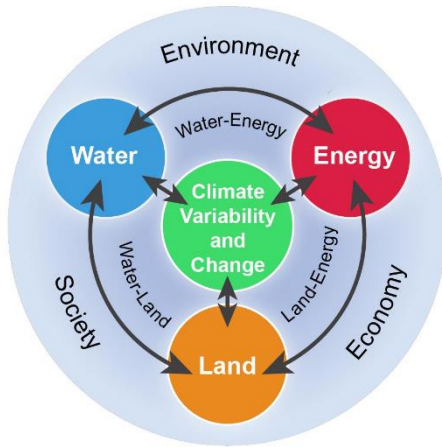
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# Nutritional Security: An Existential Threat

# Food, Shelter, Fiber, Fuel > 9 billion



**LAND & WATER  
CONSTRAINTS**



**INCREASING  
URBANIZATION**



**ENVIRONMENTAL  
DEGRADATION**



**MINIMAL  
ECOLOGICAL  
FOOTPRINT**



**CHANGING  
INCOME & DIETS**

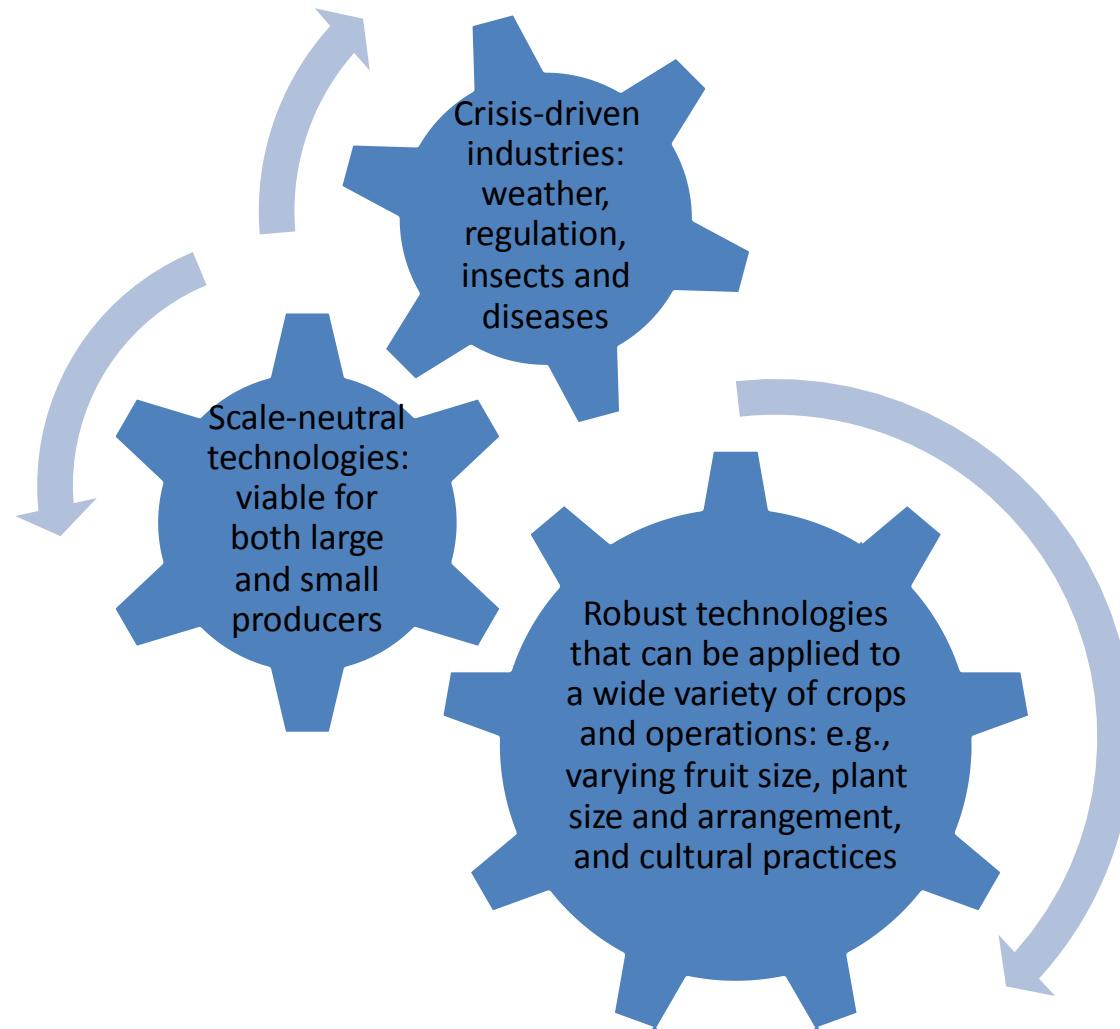


**POSITIVE HEALTH  
OUTCOMES**

# Path Forward

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

# Technology challenges



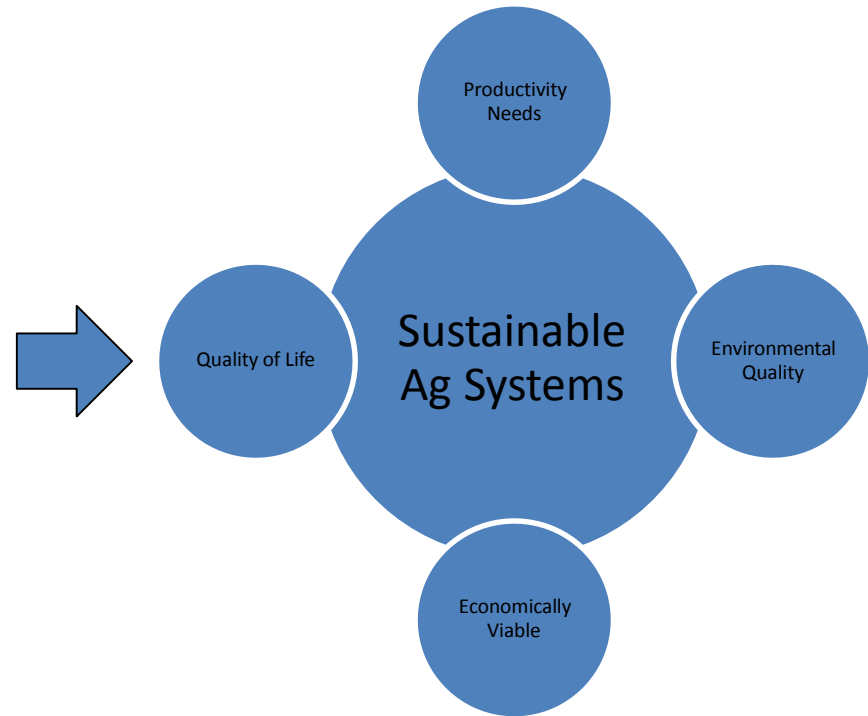
# Smarter Crop Production??

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**

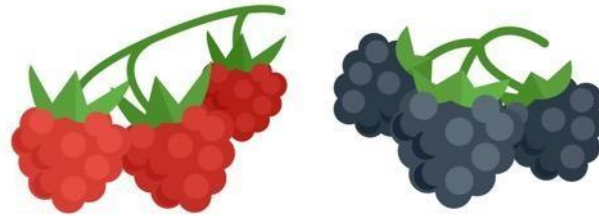




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# Agriculture is a science and engineering enterprise

How does this translate to blackberry and raspberry breeding?



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# What can smart systems do?

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



**DEVELOPING  
NEW TECHNOLOGIES**

## DESIGNING SMART SYSTEMS FOR BETTER BERRIES

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





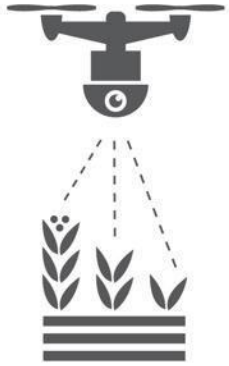
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## **Field production application to caneberries:**

- Plant crops using precision tractors with GPS locators
- Develop machines for pruning and training
- Robotic weeding

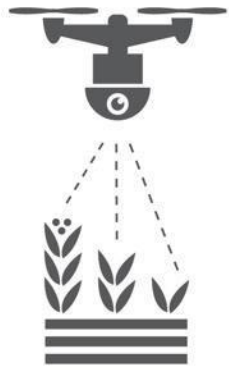
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**SCREENING  
GENOTYPES AND  
PHENOTYPES**

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 BETTER BERRIES

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

Generating large quantities of environmental, trait, and genetic data

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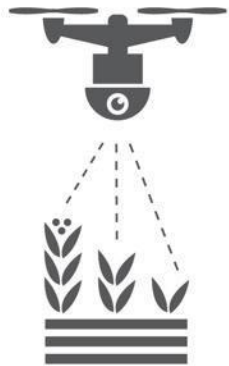
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New technologies, statistical tools, and experimental design strategies are decreasing the costs of marker-assisted breeding

NIFA-funded RosBREED researchers are developing blackberry genetic markers (sweetness), leveraging genetic resources from closely related Rosaceous species

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## What to measure?

- Pest** and **disease resistance** in raspberry (e.g., root rot, bushy dwarf virus, aphid resistance)
- Plant traits** (e.g., taste, yield, berry firmness)
- Environments** (e.g., soil moisture for precision irrigation)

## DESIGNING SMART SYSTEMS FOR BETTER BERRIES →

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

Generating large quantities of environmental, trait, and genetic data

## How might this look in the field?

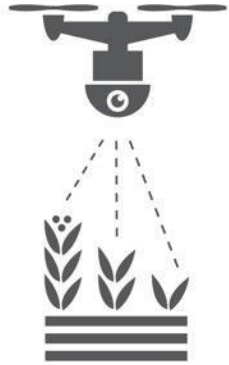
Example: Use drones equipped with multispectral or thermal cameras to identify poorly performing field plots



# An example of phenotyping in the field, from grape



# Smart systems generate lots of data



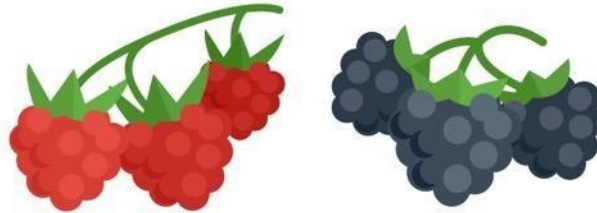
**DEVELOPING  
NEW TECHNOLOGIES**



**SCREENING  
GENOTYPES AND  
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**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 BETTER BERRIES

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



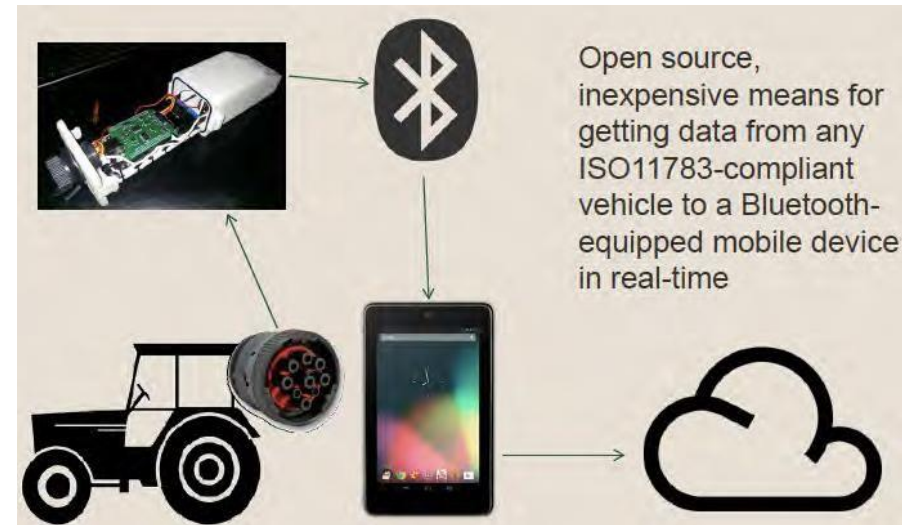
# Big Data

- Analytics
- Informatics
- Evidence-Based Tools
- Meta-Analysis and Synthesis
- Complex Systems
- Computational Sciences
- Data Engineering
- Data Mining
- Cloud Computing
- Implementation and Evaluation
- Data Security and Cybersecurity
- Predictive Modeling
- Data Visualization
- Decision Analytics
- Embedded Systems
- Machine Learning
- Multidimensional Data
- Network Science
- Sensor Networks
- Spatial Analytics
- Bandwidth
- Cyberphysical Systems

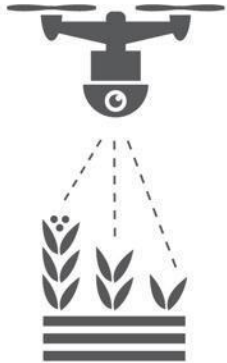
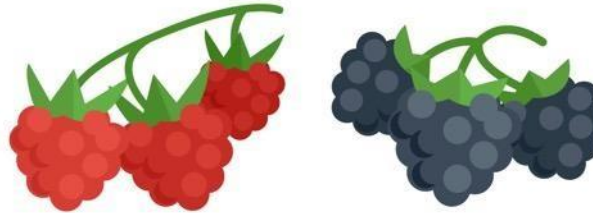


# Big Data: Challenges

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



# Smart systems generate lots of data



**DEVELOPING  
NEW TECHNOLOGIES**



**SCREENING  
GENOTYPES AND  
PHENOTYPES**



**MANAGING  
BIG DATA**

Need for education of  
workforce with the  
relevant knowledge and  
skills

## DESIGNING SMART SYSTEMS FOR BETTER BERRIES

Designing sensors,  
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Generating large  
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environmental, trait,  
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Storing, processing,  
and analyzing the  
collected data to identify  
the genetic basis of  
desirable agronomic traits

# #BigData

# 21<sup>st</sup> Century Farm



## 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, sensor-based irrigation and fertilizer management, pest control, and Big Data analytics with the help of Monsanto and Climate Corp



<http://tinyurl.com/o78mah>

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**MANAGING  
BIG DATA**



**BREEDING  
DESIRABLE  
CROP VARIETIES**

GPS harvesters  
that weigh fruit  
create yield  
maps, correlate  
with soil data to  
improve field  
uniformity,  
performance

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the genetic basis of  
desirable agronomic traits

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

Future goal:  
Use sprayer  
technology to apply  
fertilizers, pesticides  
only where needed

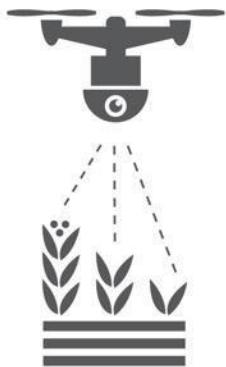
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**HARVESTING  
& DISTRIBUTING  
TO CONSUMER**

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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

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

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



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## 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



**HARVESTING  
& DISTRIBUTING  
TO CONSUMER**

## DESIGNING SMART SYSTEMS FOR BETTER BERRIES



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

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

*Photos courtesy of Dr. Bernadine Strik,  
Oregon State University*

# Harvest and post-harvest robotics: examples from blueberry and strawberry



*Photo courtesy of Dr. Changying Li,  
University of Georgia*

Berry Impact Recording Device: wireless postharvest  
data logging sensor

Aids in selecting blueberries that can withstand mechanical  
stress during harvesting, post-harvesting, shipping, and  
handling

Frail-bots:

Inexpensive, relatively small,  
harvest-aiding robots

Reduces harvesting time by  
transporting hand-picked crops

Protects worker health by reducing  
slipping accidents



*Video courtesy of Dr. Stavros Vougioukas, University of California Davis*



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## Keys to success moving forward

- Developing new technologies via **private-public partnerships**, transdisciplinary **collaborations**
- Using new **technologies** to build upon existing discoveries, **complement the breeders' eye**: e.g., primocane, spinefree, disease resistance
- **Education** of a new, more broadly trained ag workforce

DESIGNING SMART SYSTEMS FOR BETTER BERRIES →

*"Genetic diversity remains the foundation of crop improvement, and anything that helps in identifying or expanding diversity will lead to more great discoveries."*

-- Dr. John Clark, University of Arkansas blackberry breeder

*Fruit Grower News, October 2015*





# Agricultural Robotics

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**



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# Example Projects Funded

Program: USDA-NIFA/NSF National Robotics Initiative

RAPID: Robot Assisted Precision Irrigation Delivery, Stefano Carpin, University of California, Merced. (2017)

Robot Swarms and Human Scouts for Persistent Monitoring of Specialty Crops, Vijay Kumar, University of Pennsylvania, University of Florida. (2016)

Robotic Harvest-Aiding Orchard Platforms, Stavros Vougioukas, University of California, Davis. (2016)

Multipurpose Robotic Sampling to Optimize Crop Production, Gary McMurray, Georgia Tech Applied Research Corporation (2015)



1. Water conservation is becoming more and more important due to ongoing drought and restrictions on water usage.
2. Current technology and practices do not allow adjustment of flow at the plant level.
3. Technology is developed that enables individual adjustment of water emitters so that every plant receives a different amount of water according to soil water measurements and modeling.
4. A team of autonomous UAV robots and humans move through fields to adjust drip irrigation emitters at the plant level. Plants are individually monitored and maintained to maximize yield and quality while minimizing water consumption.



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1. Proposes a synergistic use of a swarm of Unmanned Aerial Vehicles as low-flying co-robots to operate alongside human scouts in orchards.
2. Customized imaging sensors are on-board the completely autonomous UAVs that can operate between rows to enable production of high resolution multidimensional maps. These maps can indicate crop water stress, disease stress, and nutrient sufficiency that all impact yield.
3. A single human scout will operate alongside the robot for general inspection and to optimize locations for UAV monitoring, to keep the UAVs charged, and to monitor re-launch of the UAVs.



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1. In fresh market fruit production, harvesting is one of the most labor-intensive operations incurring high cost and dependence on a large seasonal semi-skilled workforce, which is becoming less available.
2. A harvest-aid platform serves as an intermediate step towards full mechanization.
3. This project develops co-bots that collaborate with human fruit pickers. A robot platform physically carries the picker and intelligently adjusts their positioning to the fruited zone, matching their speed of picking.
4. Passive imaging will be used to detect the fruit and effect control. This has the potential of greatly increasing efficiency of picking and lowering fatigue.



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1. Robotic technology is developed to autonomously collect plant and soil samples in a field or orchard for identification and verification of the cause of the stress symptom
2. 4D models of a crop are developed based on regular high resolution in-field imaging and image reconstruction. This model will monitor variables such as plant height, leaf area index, canopy coverage, plant discoloration (chlorosis and necrosis), and their rate of change.
3. The 4D model of the crop will be reviewed by the grower to specify in which areas of the field leaf or soil samples are to be collected by the robotic system.
4. An advanced control system for a robotic arm will be developed that accurately places an end-effector based on the 4D model to enable plant and soil sampling.

# 21<sup>st</sup> Century Farm





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# Humans Matter