



# LOOKING TO THE **FUTURE OF AG** SCIENCE

North Carolina State University  
Plant Sciences Building



## Flad Moderators



**Chuck Mummert**

Principal

*Event Host and Facilitator*



**Jamie Matthys**

Principal

*Moderator*



**Chad Zuberbuhler**

Principal Planner

*Moderator*

## Symposium Schedule

8:00–9:00 am	<i>Breakfast and Welcome Address</i>
9:00–10:00 am	<b>Keynote:</b> Adrian Percy Ph.D., NC State University
10:00–10:45 am	<b>Speaker Session 1:</b> Brad Ringeisen Ph.D., Innovative Genomics Institute, UC Berkeley
	<i>Break</i>
11:00–11:45 am	<b>Speaker Session 2:</b> Phil Taylor Ph.D., Bayer Crop Science
12:00–1:00 pm	<i>Lunch</i>
1:00–1:45 pm	<b>Speaker Session 3:</b> Elliott Kellner Ph.D., Donald Danforth Plant Science Center
	<i>Break</i>
2:00–3:00 pm	<b>Panel Discussion</b> <ul style="list-style-type: none"><li>- John Gottula Ph.D., Agriculture US-Based, SAS Institute</li><li>- Wayne Honeycutt Ph.D., Soil Health Institute</li><li>- Karen LeVert, Ag TechInventures and Pappas Capital</li><li>- Deborah Thompson Ph.D., NC State University</li><li>- Laura Westby J.D., Oerth Bio</li></ul>
3:00–3:30 pm	<i>Closing Remarks</i>

## Keynote



# Adrian Percy Ph.D.

Executive Director, North Carolina Plant Sciences Initiative  
NC State University





NC State is a public land-grant university dedicated to excellent teaching, the creation and application of knowledge, and engagement with public and private partners.



**Top 1% of Universities  
Worldwide**



**#2 Public College in  
North Carolina**

**#2 for Research Commercialization**

among public universities in the U.S., according to  
Heartland Forward

**68**

Academic departments

**300+**

Graduate and undergraduate degree programs

**12**

Colleges



## 101 Local Centers

NC State Extension has locally-focused services in every North Carolina county and the Eastern Band of Cherokee.



**37,500+**

Students

**2,400+**

Faculty

**6,900+**

Staff

## Interdisciplinarity at NC State

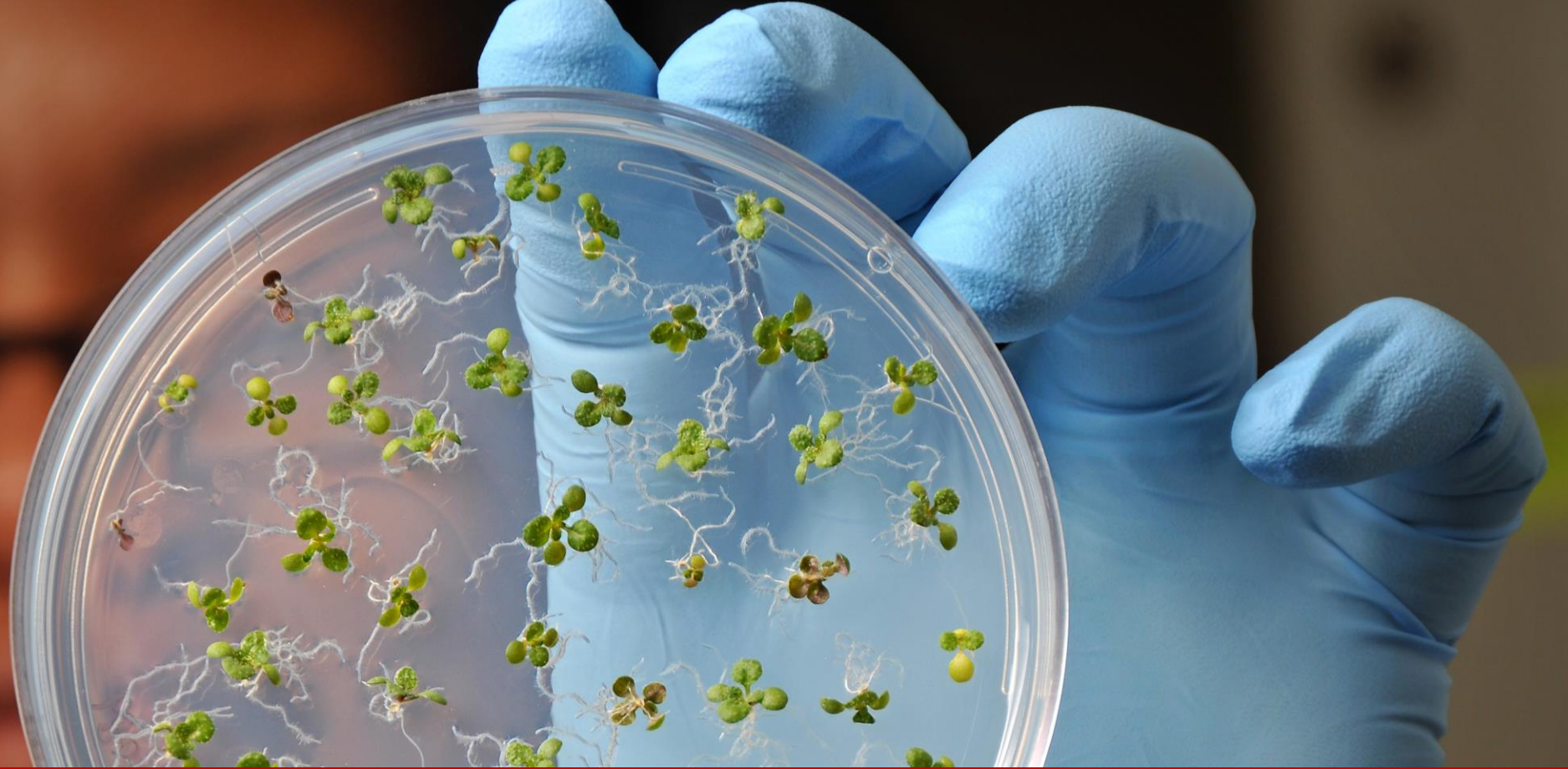
### *How do we solve difficult global challenges?*

NC State's **thriving interdisciplinary community** shows a strong commitment to diverse and convergent team research which can **unlock solutions to the worlds' biggest problems.**

NC State's commitment includes:

- University Interdisciplinary Programs
- Plant Sciences Initiative
- Interdisciplinary Research Initiatives
- Integrated Sciences Initiative
- Cluster Hires
- Chancellor's Innovation Fund
- Interdisciplinary Academies





## **N.C. Plant Sciences Initiative**

**“Harnessing Interdisciplinary Science to Tackle Grand Challenges in Agriculture”**

**Adrian Percy, Executive Director**  
**N.C. PSI**



# Agriculture faces both global and local challenges

To address population growth & increases in food demand we must tackle:

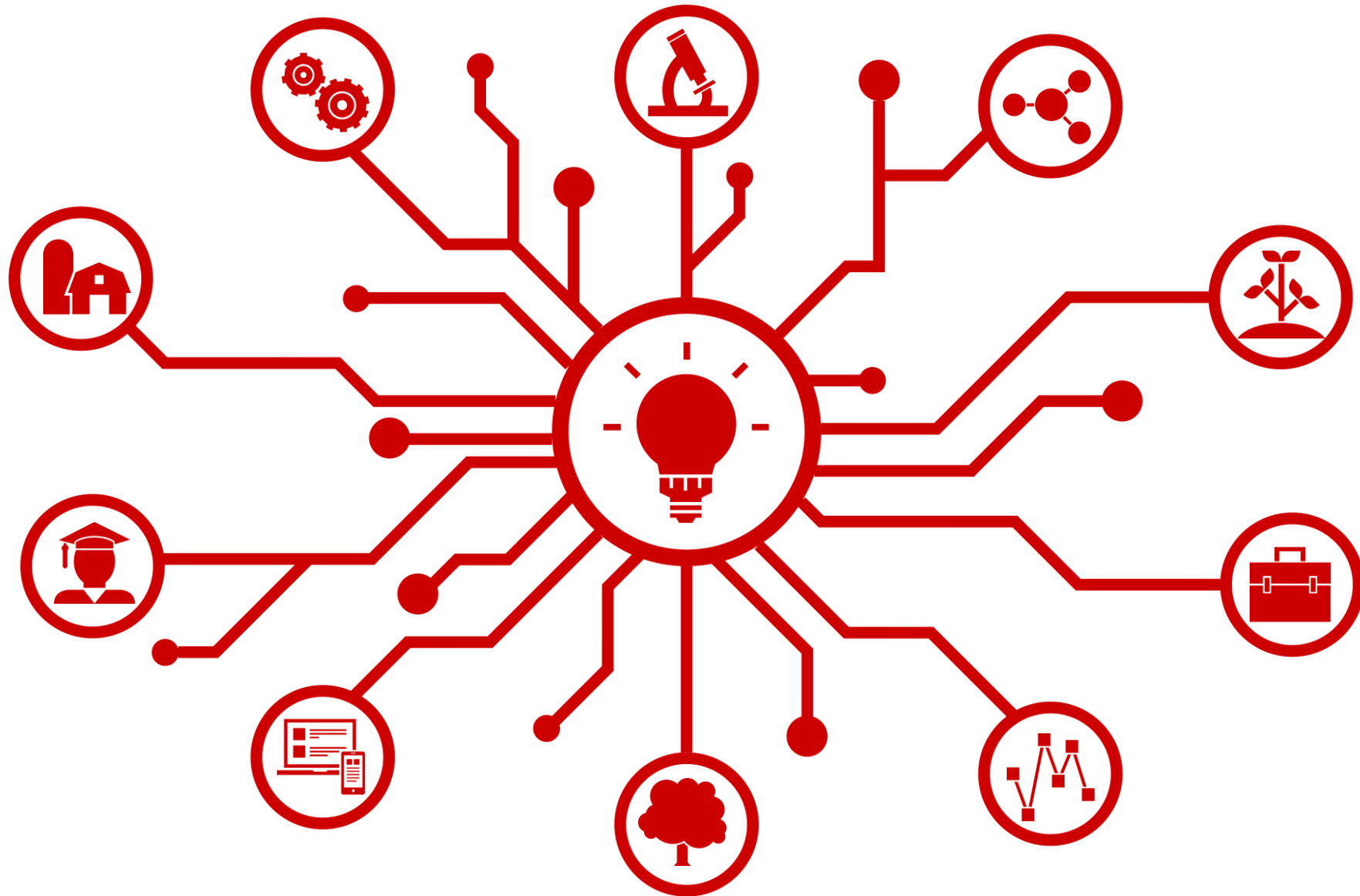
- Climate change
- Depletion of groundwater
- Deteriorating soil quality & biodiversity
- Nutrient run-off
- Lack of available labor
- Economic sustainability of farmers and rural communities
- Food waste
- Food chain deficiencies
- Changing consumer expectations



These problems cannot be addressed by singular entities or research silos



# Plant Sciences' Interdisciplinary Approach to Big Problems



## N.C. Plant Sciences Initiative

**Vision** – Create a healthier, sustainable and more prosperous future through **plant science innovation**.

**Mission** – To solve grand challenges in agriculture and the environment in North Carolina and beyond through **interdisciplinary team-based science, partnerships and talent development**.



## Values

**Collaboration** | We are partnership-focused by design

**Inclusivity** | We operate as one diverse and inclusive community

**Engagement** | We listen to the needs of those we serve

**Entrepreneurship** | We translate ideas into solutions

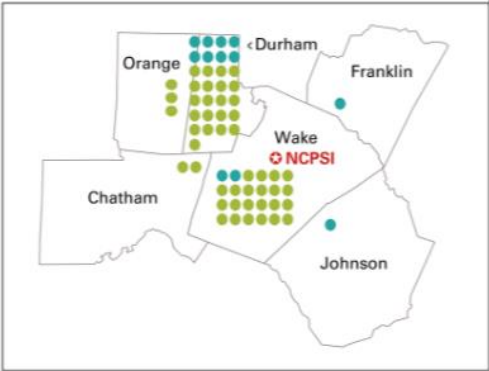
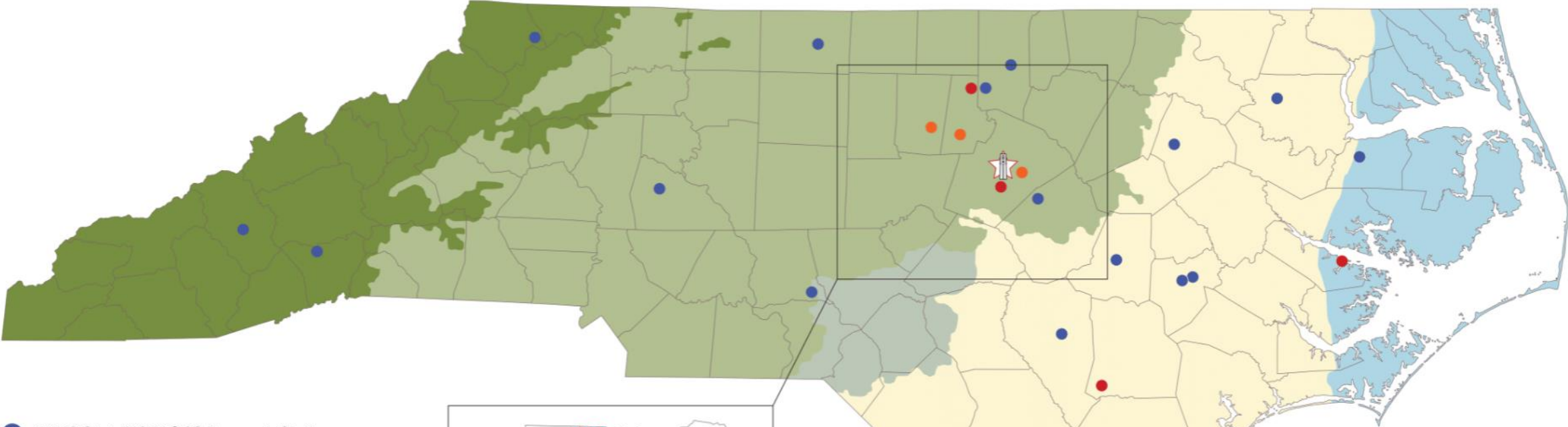
**Innovation** | We operate at the cutting edge of science and tech

**Scale Neutrality** | We develop solutions for all scales of growers

**Sustainability** | We take action today to create a better tomorrow



# N.C. PSI: Part of a Unique Ag Research Ecosystem



Research Triangle Area

**90+** Crop varieties produced in N.C.

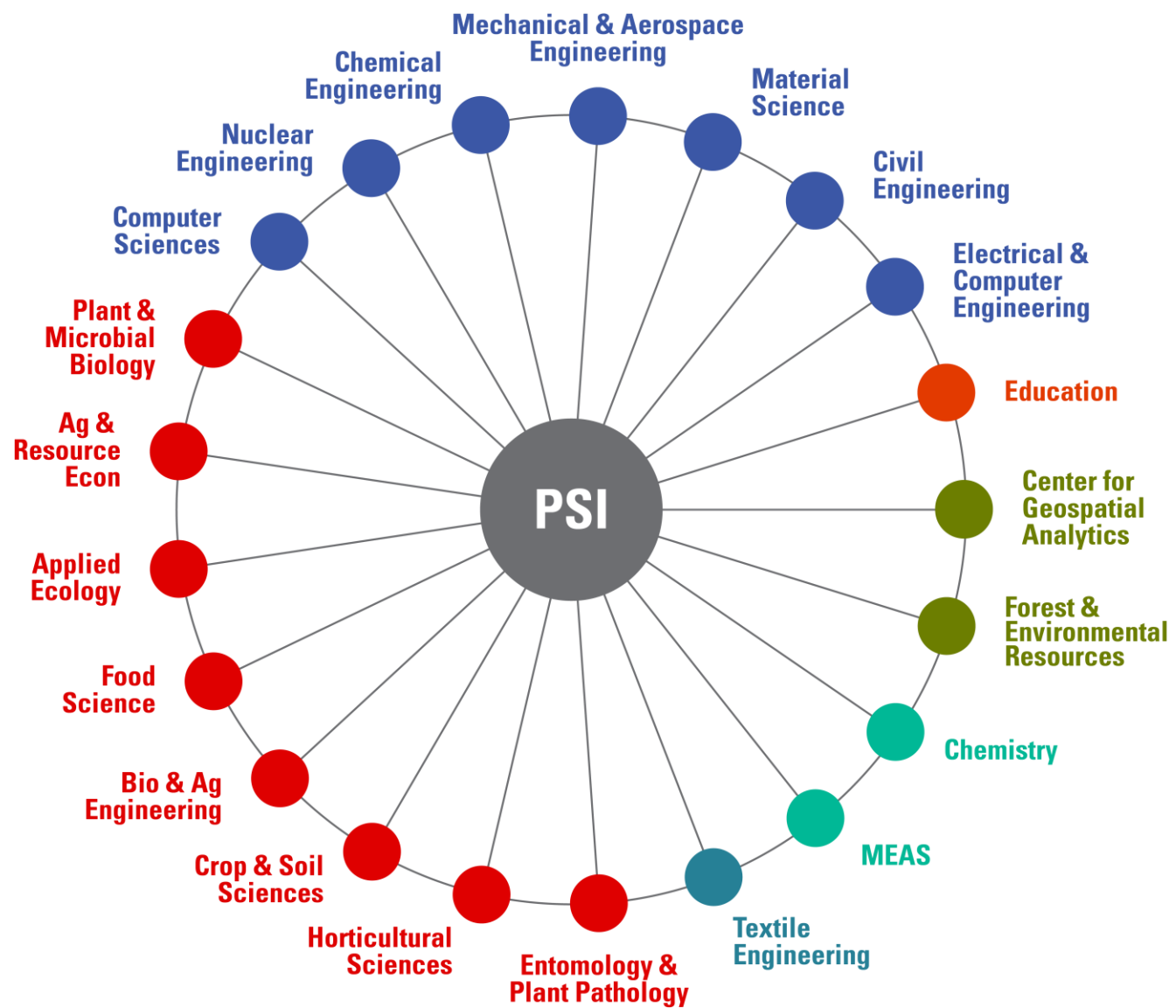
**#1** Agribusiness is N.C.'s top economic sector

5 Geographic Regions: ■ Mountains ■ Piedmont ■ Sandhills ■ Coastal Plain ■ Tidewater

# N.C. PSI - Principal Areas of Impact



# N.C. PSI Draws From Talent Across NC State



# Areas of Expertise

Data management

Molecular biology

Robotics

Agricultural Economics

Proteomics & metabolomics

Imaging systems

Regulatory science

Machine learning & deep learning

Crop production

Multi-scale modeling

Genome sequencing

Biotechnology

Genome editing

High throughput phenotyping

Climate change mitigation & carbon sequestration

Computer vision

Bioinformatics

Sensor development

Pest resilience & management



# Creating Our N.C. PSI Culture

A word cloud of values and culture-related terms for N.C. PSI. The words are arranged in a non-linear fashion, with varying font sizes and colors. The largest word is 'Community' in orange. Other prominent words include 'Collaborative' in dark red, 'Communication' in yellow, and 'Innovative' in blue. Smaller words include 'Interdisciplinary', 'Connect', 'Fun', 'Inclusive', 'Welcoming', 'Teamwork', 'Pioneering', 'Diverse', 'Partnerships', 'Outreach', 'Entrepreneurial', 'Neighborhoodly', 'Education', and 'Welcoming'.

Interdisciplinary  
Connect  
Innovative  
Fun  
Communication  
Inclusive  
Welcoming  
Teamwork  
Neighborhoodly  
Entrepreneurial  
Collaborative  
Pioneering  
Education  
Diverse  
Partnerships  
Outreach  
Community

# N.C. PSI's Five Platform Directors



Ross Sozzani

**PLANT  
IMPROVEMENT**

Professor of  
Synthetic and  
Systems Biology

Department of  
Plant and Microbial  
Biology



Chris Reberg-Horton

**RESILIENT  
AGRICULTURE  
SYSTEMS**

Professor of  
Cropping Systems

Department of  
Crop and Soil  
Sciences



Cranos Williams

**DATA-DRIVEN  
PLANT SCIENCES**

Goodnight  
Distinguished  
Professor of Ag  
Analytics

Dept. of Electrical  
& Computer  
Engineering

Dept. of Plant &  
Microbial Biology



Terri Long

**EDUCATION &  
WORKFORCE  
DEVELOPMENT**

Associate  
Professor

Department of  
Plant and Microbial  
Biology



Rachel Vann

**EXTENSION  
OUTREACH &  
ENGAGEMENT**

Assistant Professor  
and Soybean  
Extension  
Specialist

Department of  
Crop and Soil  
Sciences

# Plant Improvement Platform

**Vision** — To drive innovative science and technology that expands discovery opportunities across all plant science fields to deliver applied solutions

## Areas of Focus

- Crop stress protection
- Agrisymbiotics
- New plant varieties
- Genomics and genome editing

## Goals & Strategies

1. Utilize seed funding program to drive faculty and student engagement with N.C. PSI
2. Establish an environment that drives collisions between plant breeders and fundamental researchers
3. Leverage N.C. PSI and platform infrastructure to build collaborations and drive engagement among faculty, students and industry



# Science and Technologies for Phosphorus Sustainability (STEPS) Center

an NSF Science and Technology Center

Phosphorus is an essential element to life, underpinning many critical biological processes and driving the productivity and sustainability of global food systems.

STEPS is a collaborative, nationwide Center that develops convergent research and education with the support of peers, growers, industry and government. It creates scalable, ambitious solutions to reduce, recover and reuse phosphorus to protect our planet, support our farmers and feed our growing population.

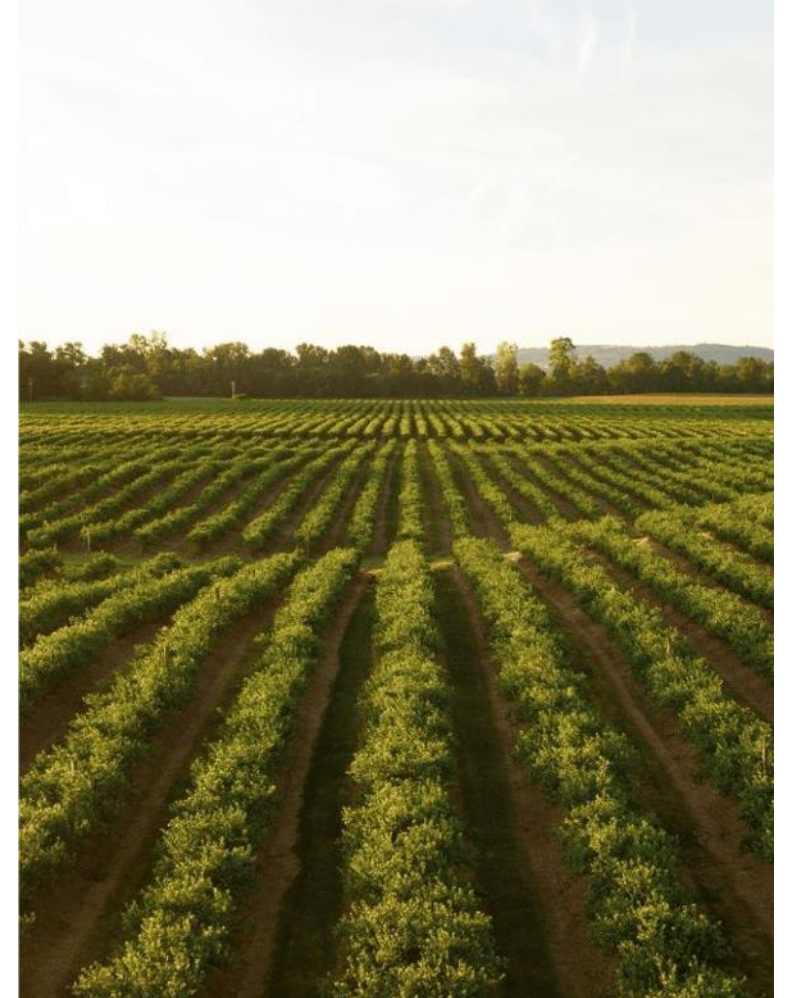
## STEPS 25-in-25 ambitions are to facilitate:

25% reduction in human dependence on mined phosphates

+

25% reduction in losses of point and non-point sources of phosphorus to soils and water resources

...within 25 years, leading to enhanced resilience, on-farm efficiencies and cost reduction, and environmental stewardship



# Collaborative Crop Resilience Program (CCRP)

The research takes a holistic view of plants and their interactions with microbes in the soil, roots and foliage. A plant's microbiome – its microbes and the ways they interact with the plant – plays a critical role in plant health and well-being, similar to the way the human gut microbiome influences human health.

Wheat will be the featured crop in various studies – including heat, cold and drought tolerance – occurring in Denmark and North Carolina. The findings in wheat may also apply to other important cereal crops, like corn and rice.



Helps farmers raise yields with less reliance on chemical treatments and irrigation.

Program includes interdisciplinary research teams at NC State and three Danish universities

\$30M grant funded by Novo Nordisk Foundation

# Resilient Agricultural Systems Platform

**Vision** — To serve as a leader in driving research and discovery that creates a more resilient food system and helps steward the natural environment and communities of North Carolina.

## Areas of Focus

- Plant and food systems
- Food security and health outcomes
- Environmental sustainability

## Goals & Strategies

1. Establish N.C. PSI as a leader in resilient agriculture among industry, federal and community partners
2. Position the N.C. PSI Makerspace as a community of practice for NC State
3. Engage students in the development of resilient agricultural systems
4. Position platform as connector of natural environment communities across university



# Climate Adaptation through Agriculture and Soil Management (CASM)

Interdisciplinary teams work across disciplines and sectors in the field and the lab to evaluate coastal farmland use, salt effects on coastal soils, soil carbon storage from compost and biochar, and greenhouse gas emissions.

Through partnerships with farmers, policy-makers and industry experts, their findings have informed conservation programs, on-farm management decisions and carbon-storage strategies.



## BIOCHAR

Optimizing biochar application for carbon capture, soil function & economic value

## SALTWATER INTRUSION

Understanding agricultural, economic & ecosystem impacts of flooding sea-level

## CARBON STABILITY & EMISSIONS

Evaluating agricultural systems for production, economics & stewardship

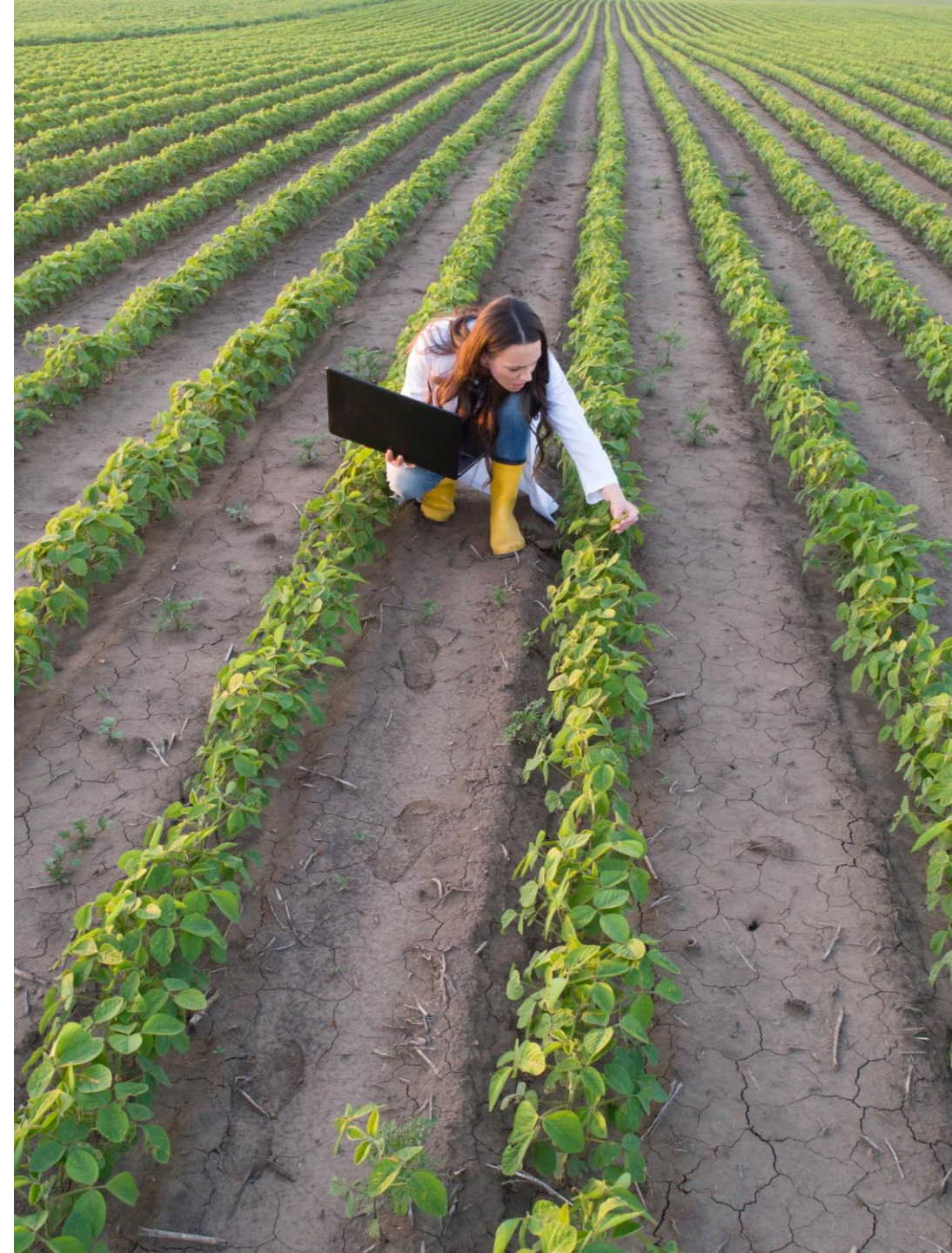
**Vision** — To serve as the data acquisition, data management, and data analytics catalyst for discovery, innovation, and translation in plant science research.

## Areas of Focus

- Precision and predictive agriculture
- Big data management and analytics
- Agricultural decision support tools

## Goals & Strategies

1. Lead the development of the N.C. PSI Makerspace as a testbed for technology innovation and discovery
2. Lead the development of new solutions and/or integration of existing solutions for storing, analyzing and maintaining large-scale datasets and data repositories
3. Increase accessibility of data science tools and training for plant scientists and agricultural researchers





# Big Data for Better Sweetpotatoes

GRIP4PSI-funded

This interdisciplinary team aims to combine information from images of hundreds of thousands of sweetpotatoes and their growth conditions to determine the factors that impact sweetpotato size and shape to increase the percentage of USDA grade 1 sweetpotatoes.

The platform will use custom imaging to detect shape, size, surface texture, internal composition and crop damage. That data then enters a computational platform to improve decision-making for North Carolina growers, producers and distributors.

This grant is part of the larger Sweet-APPS Project



Grad students are creating an android app that sweetpotato growers and packers can deploy in the field

Sorters can scan 100,000 sweetpotatoes per hour, producing 8 - 10 GB of data per minute

Partnering with SAS, Interno Life Sciences, Scott Farms and the NC Sweetpotato Commission

# Plant Aid Project

GRIP4PSI-funded

An interdisciplinary team of researchers is combining cost-effective, in-field sensors with geospatial analytics and a cloud-based database of plant stresses to create an early warning system for farmers.

The Plant-Aid database will alert farmers about the cause of plant stress and suggest possible mitigation strategies, all before symptoms are visible to the naked eye.

A continuation of this project received a \$1M Predictive Intelligence for Pandemic Preparedness (PIPP) Grant from the NSF as the only proposal of 26 total grantees dedicated to the plant sciences.



A postage-stamp sized microneedle patch collects DNA from a leaf in one minute

Economic benefits to growers who will apply fewer amendments and achieve higher yields

Working with Extension, government and industry to bring the technology into production

**Vision** — To train a diverse workforce and connect interdisciplinary career pathways that drive future innovation and impact in plant sciences.

## Areas of Focus

- Experiential learning
- Ag science leadership
- Student training and certifications

## Goals & Strategies

1. Enhance existing university relationships and drive new collaborations with K-12 partners and students throughout North Carolina
2. Connect undergraduates, graduate students and postdoctoral students with new or existing programs that enhance career readiness and promote access to workforce opportunities in agriculture



# Welcoming Future Plant Scientists



## First Annual Plant Sciences Day

N.C. PSI hosted **75 high school students** from **nine counties** in North Carolina for our first annual Plant Sciences Day. The students rotated through **four sessions** to gain information and inspiration about what a career in plant sciences could be. They took part in an industry panel, a research lab tour, a demo lab exercise, and a meet and greet with current NC State students.



High school students from the **Horticultural Science Summer Institute** learn how to make soil sensors in the Demo Lab.

# Insights from Insiders Q&A Panel

- Six panelists and over 75 attendees
- Workforce development opportunity for N.C. PSI students
- Networking with industry experts in biotech and non-profit
- Attendees split into groups to meet experts from the companies they were most interested in learning more from



**Vision** — To impact real-world agricultural and environmental challenges across the value chain by connecting N.C. PSI science with applied field issues, and leveraging the robust NC Cooperative Extension partnership to communicate with stakeholders and maximize the understanding, impact and sustainability of science for agricultural stakeholders.

## Areas of Focus

- Translating research into solutions
- Stakeholder engagement
- Cultivating connectivity

## Goals & Strategies

1. Serve as the conduit for engaging North Carolina growers and agricultural stakeholders in the work, impact and success of N.C. PSI
2. Establish Extension as the foundation of all N.C. PSI projects and activities
3. Leverage the N.C. PSI infrastructure to drive greater faculty, staff and student engagement with Extension



# Grower Advisory Council & Extension Agent Network

To execute our mission and achieve our vision, it is critical that applied expertise is incorporated from interdisciplinary project conception through execution in the field.

## Grower Advisory Council

- Provide guidance on the relevance of scientific research to production systems in the field
- Isaac Boerema, Reggie Baker, Sue Leggett, Bert Lemkes, Danny Pierce, and Bo Stone

## Extension Agent Network

- Beta-test PSI-developed technologies in the field to accelerate seamless adoption on North Carolina farms
- Host PSI-developed technology outreach events within counties



# Labs Rats to Field Mice: The Inaugural Backroad Tour

22 N.C. PSI faculty from three colleges were brought out to the fields of North Carolina to hear from growers and commodity board leaders about the grand challenges they face in agriculture.

## GOALS

1. Provide an opportunity for N.C. PSI researchers to engage with growers, listen to their challenges and encounter them firsthand in the field
2. Expand our agricultural networks with commodity board and other agricultural leaders across NC
3. Gain an understanding of the function of NC Extension at the local level
4. Build internal N.C. PSI culture





# N.C. PSI Creates Connection



# New Models for Industry Partnerships

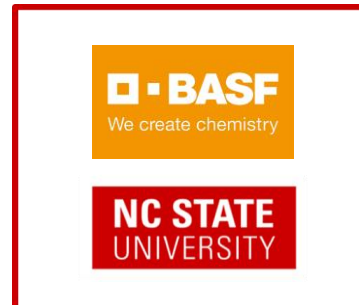


Embeds full-time data scientists within the N.C. Plant Sciences Initiative



Microsoft FarmBeats' IoT technology, Microsoft Azure cloud

SAS<sup>®</sup> Analytics will analyze the data



100+ research projects together

Crop protection & plant science innovation



5-year research agreement

\$32M Collaborative Crop Resilience program grant



Research and facilities collaboration

# N.C. PSI Anchor Collaborators



# Collaboration Opportunities Exist for Multiple Academic Programs



**Controlled Environment  
Agriculture Coalition**



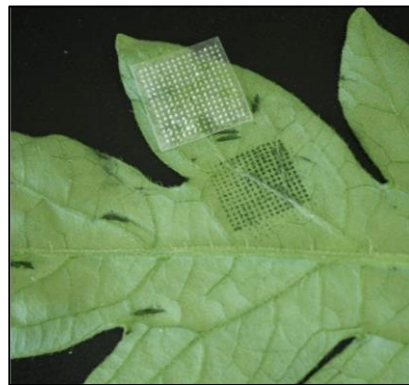
**Science and Technologies for Phosphorus  
Sustainability (STEPS) Center**



**Improving soil health & reduction of  
GHG emissions**



**Precision Sustainable  
Agriculture Network**



**Early detection of plant stress**



**Center of Excellence for Regulatory  
Science in Agriculture**

# Center of Excellence for Regulatory Science in Agriculture (CERSA)

CERSA forms research teams to tackle challenges associated with advancing scientific knowledge, regulatory transparency, and gaining public acceptance and understanding of policy decisions.

Most recently, CERSA hosted a workshop to facilitate a common understanding and public education of genome-editing technology and how it can be safely leveraged to deliver breakthrough **new microbial product solutions** to address US sustainability and climate objectives.



Designed to leverage regulatory expertise across organizations for grant proposal writing, research, and teaching

Only university-level program in regulatory science focused on agriculture.

Examining emerging trends in regulatory science needed to achieve more sustainable agricultural systems



# Climate-Responsive Opportunities for Plant Science (CROPS) Type 2 Regional Innovation Engine

*\$160M grant proposal*

In partnership with:



**North Carolina  
Biotechnology Center®**



## **Vision**

A future of climate-resilient agriculture in rural North Carolina, leading to a new generation of empowered and prosperous small- and mid-sized farmers contributing to thriving rural communities.

## **Mission**

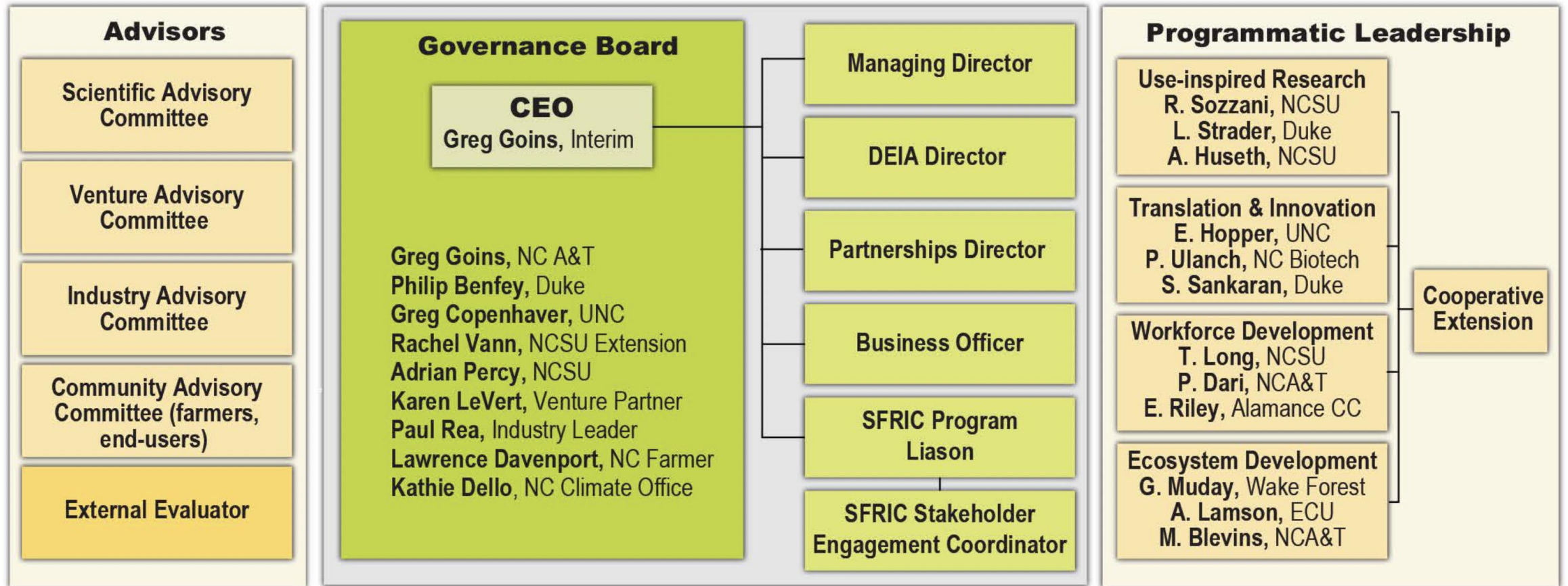
Catalyze an economic transformation in persistent-poverty NC counties, resulting in a doubling of farm income and a two-fold reduction in climate-related losses.

- ❖ Shifts the way science is translated and applied with the goal of achieving more inclusive, sustainable, and resilient agriculture systems.
- ❖ Establishes an end-to-end ecosystem that includes farmers, extension agents, farmer cooperatives, research institutions, investors, entrepreneurs, economic developers, industry professionals, government agencies, non-profit organizations, and community groups.

This *Innovation System* will co-create new opportunities for economic development, job creation, and cultural enrichment unlocking the full potential of the agricultural sector in the face of climate change.

# Climate-Responsive Opportunities for Plant Science (CROPS)

## Leadership Structure



# N.C. PSI - Startups on the Rise



## Hoofprint Biome

Sustainable livestock through **bioengineered, probiotic feed additives**



## Raleigh Biosciences

**Improved plant traits** through spatial gene expression, AI, genome editing & 3D Bio printing



## Flip Biosystems

**Removal of atmospheric carbon** via engineered composting of biomass



## TreeCo

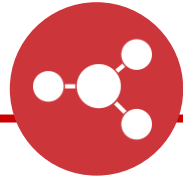
Revolutionizing **tree breeding with CRISPR gene editing**



# N.C. PSI Successes



**\$100+**  
MILLION  
in N.C. PSI  
funded projects



**20**  
SCIENTIFIC  
PROGRAMS  
occupying space in  
the PSB



**4**  
USDA  
PROGRAMS



**1**  
NSF  
Science &  
Technology Center



**3**  
CORE  
FACILITIES  
CMIF, GSL, METRIC



**1,000+**  
STAKEHOLDERS  
engaged with N.C.  
PSI events

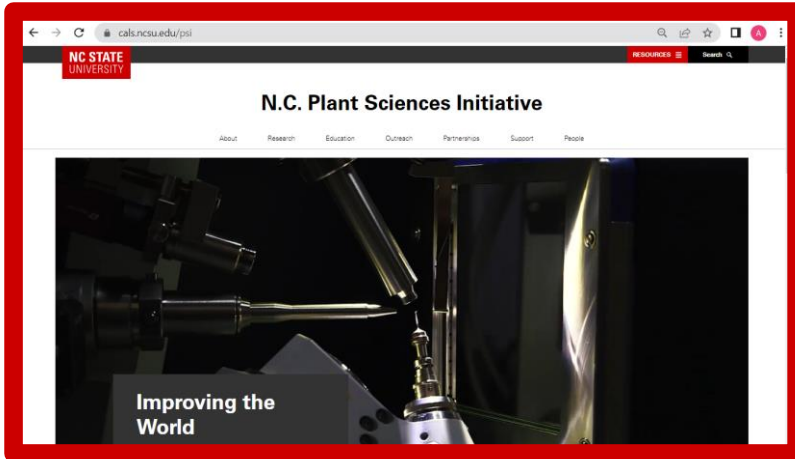


**2**  
CERTIFICATES  
in interdisciplinary  
plant sciences



**4**  
INDUSTRY  
PARTNERS  
in the PSB

# How to Engage with N.C. PSI



**N.C. PSI Website**  
[cals.ncsu.edu/psi](https://cals.ncsu.edu/psi)



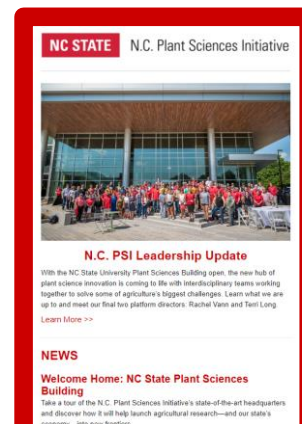
**Social Media**



**Campus Social Events**



**Quarterly Industry Partners Breakfast**



**N.C. PSI Newsletter**

**Interested in exploring research collaborations contact:**  
Deborah Thompson, Director of Research Partnerships, [dmt@ncsu.edu](mailto:dmt@ncsu.edu)

**Interested in programmatic support opportunities contact:**  
Dinah Schuster, Senior Director of Development, [daschust@ncsu.edu](mailto:daschust@ncsu.edu)



Thank You



# Brad Ringeisen Ph.D.

Executive Director, Innovative Genomics Institute  
UC Berkeley





Innovative  
Genomics  
Institute

**CRISPR Solutions for Climate & Sustainable  
Agriculture**

# Our Vision: Cutting-Edge Science with **Social Purpose**

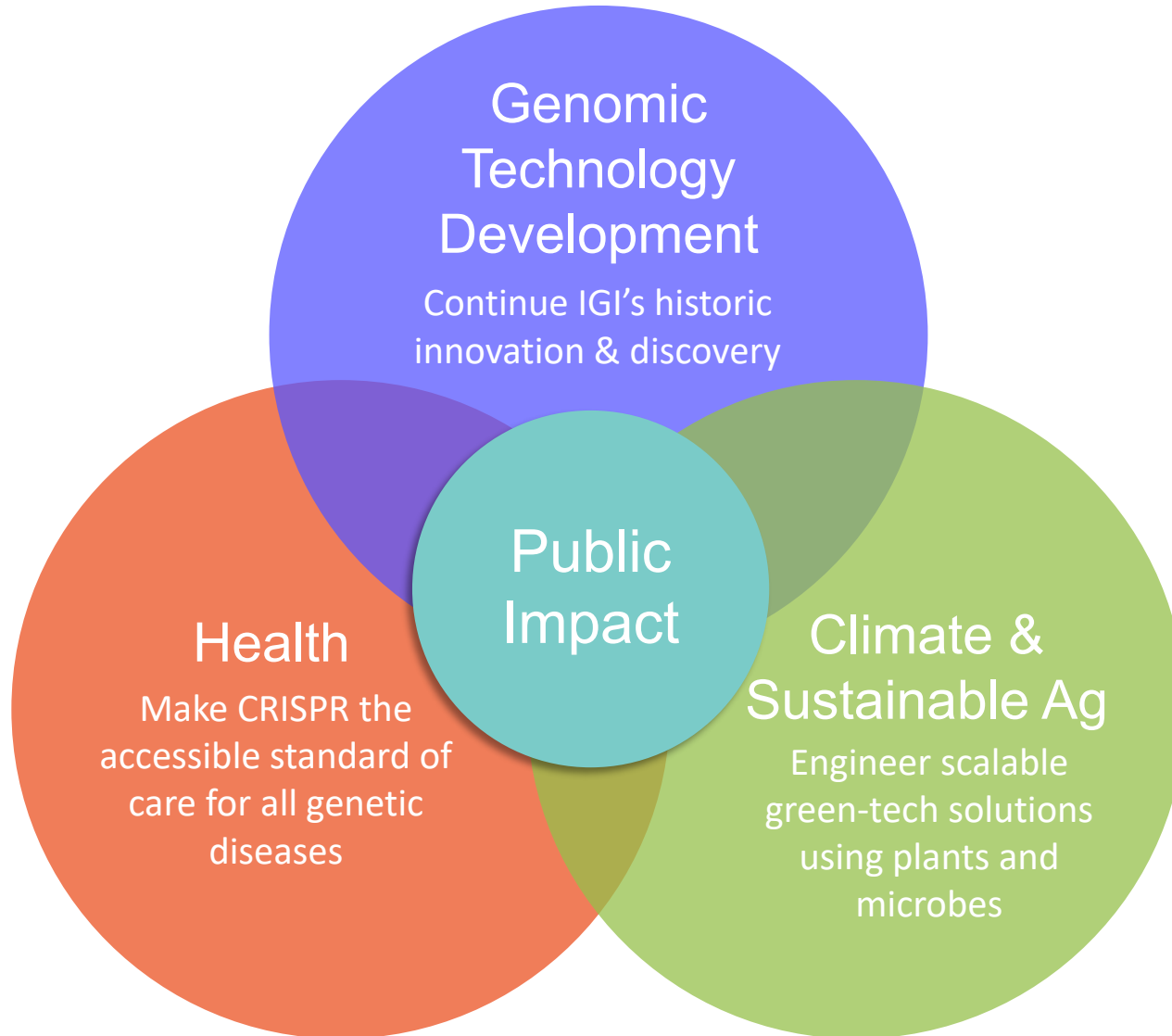
The IGI's mission is to bridge revolutionary genome-editing tool development to affordable and accessible solutions in human health, climate, and agriculture.

**“We have a responsibility to pursue CRISPR’s enormous potential to achieve previously impossible solutions to some of the world’s big challenges — solutions that will be available to anyone.”**

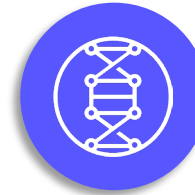
**— Jennifer Doudna**



# IGI's Scientific Strategy



## Key Outputs



- Improved editors (efficiency, safety)
- **Microbiome editing in animals, plants, and soils**
- Enhanced tissue targeting



- Rapid target discovery platform
- In-vivo therapies
- Next-gen diagnostics



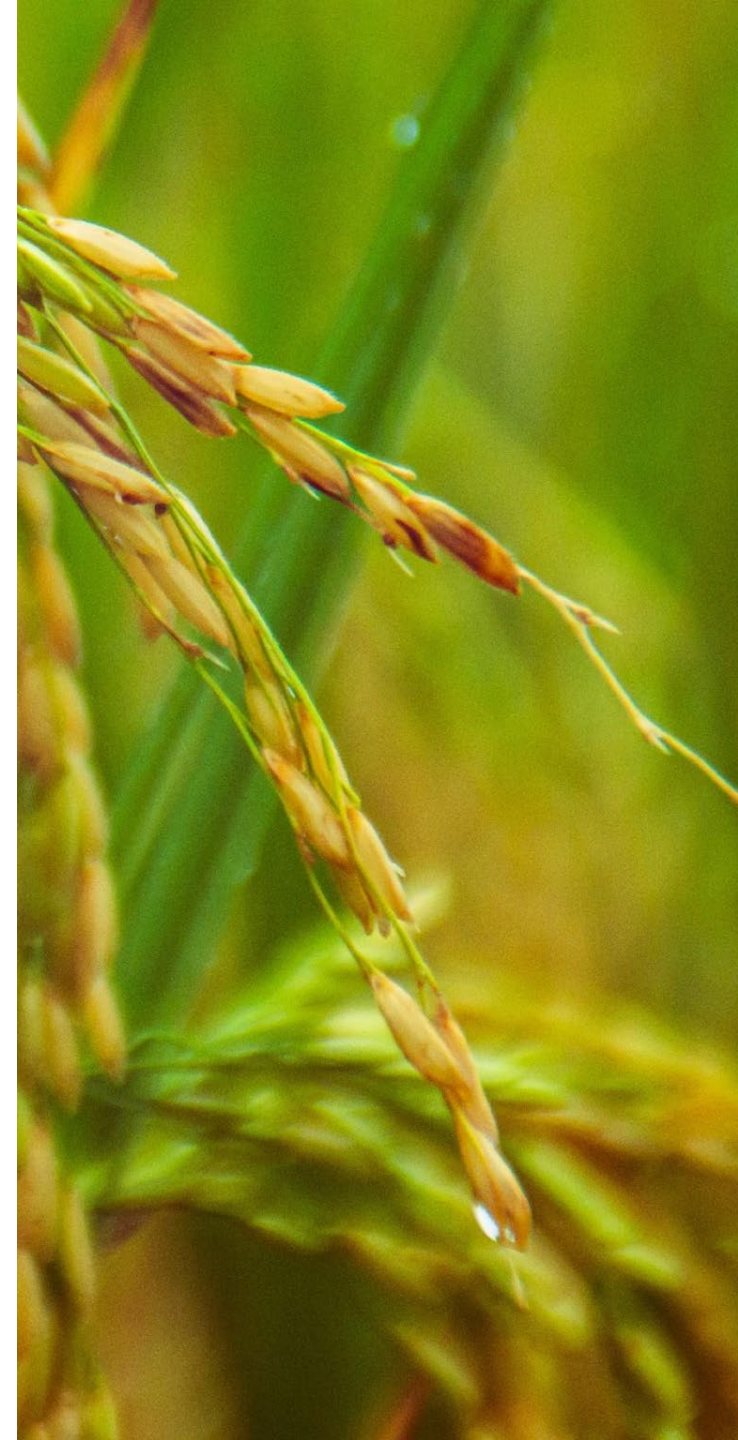
- Enhanced carbon capture approaches
- Climate-resilient crops
- Enabling net-zero farming



- Affordable, accessible, equitable solutions
- Community-guided solutions
- Improved regulatory landscape

# Why IGI?

- **Fostering collaboration across disciplines**
  - Track record of cross-cutting innovations
- **Focus on significant societal problems**
  - Longer time horizons, higher risk
  - Non-profit goal where industry won't innovate
- **Ability to innovate scalable solutions**
  - Work towards the “ideal” solution
  - Partner with industry and NGOs
- **Public impact integration**
  - Affordability, equity of access, and ethics factored into each scientific effort







**31% of all human-made greenhouse gas emissions  
come from agriculture**

FAO (2022)

# IGI's Climate and Sustainable Agriculture Program



**By 2050, the Earth will be home to around 9.7 billion people.**

**Genome engineering can help feed our growing population.**

## **IGI Goals:**

- Engineer the crops of the future: resilient against heat, storms, and drought
- Enhance disease resistance and generate plants that are immune to infection
- Develop new methods of efficiently delivering CRISPR components to crops



**Let's stop agriculture from becoming "big oil" by 2050 – The Net-Zero Farm**

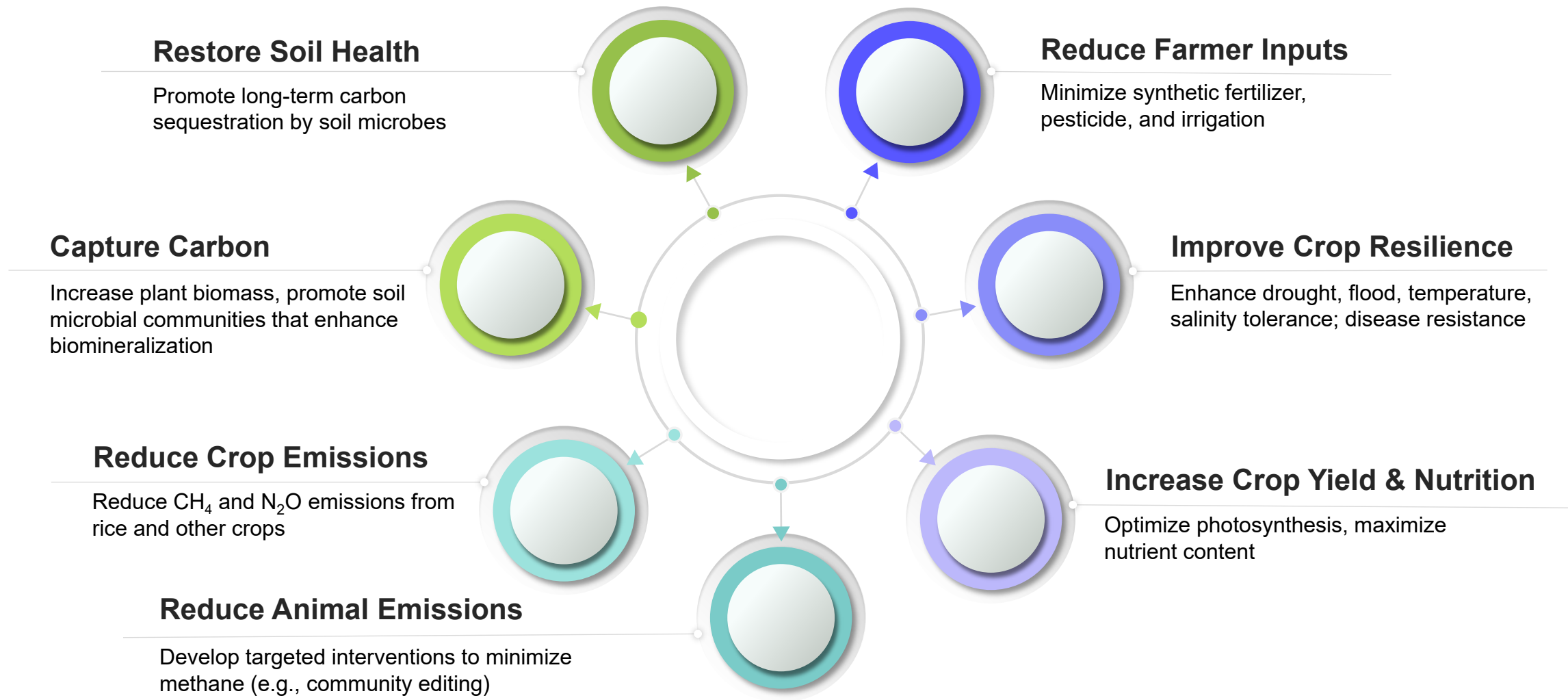
**Plants and microbes can be the solution, not part of the problem.**

## **IGI Goals:**

- Reduce greenhouse gas emissions from agriculture through genome engineering
- Increase long-term carbon sequestration in farm soils
- Reduce farmer inputs like synthetic fertilizers, pesticides, and excess water

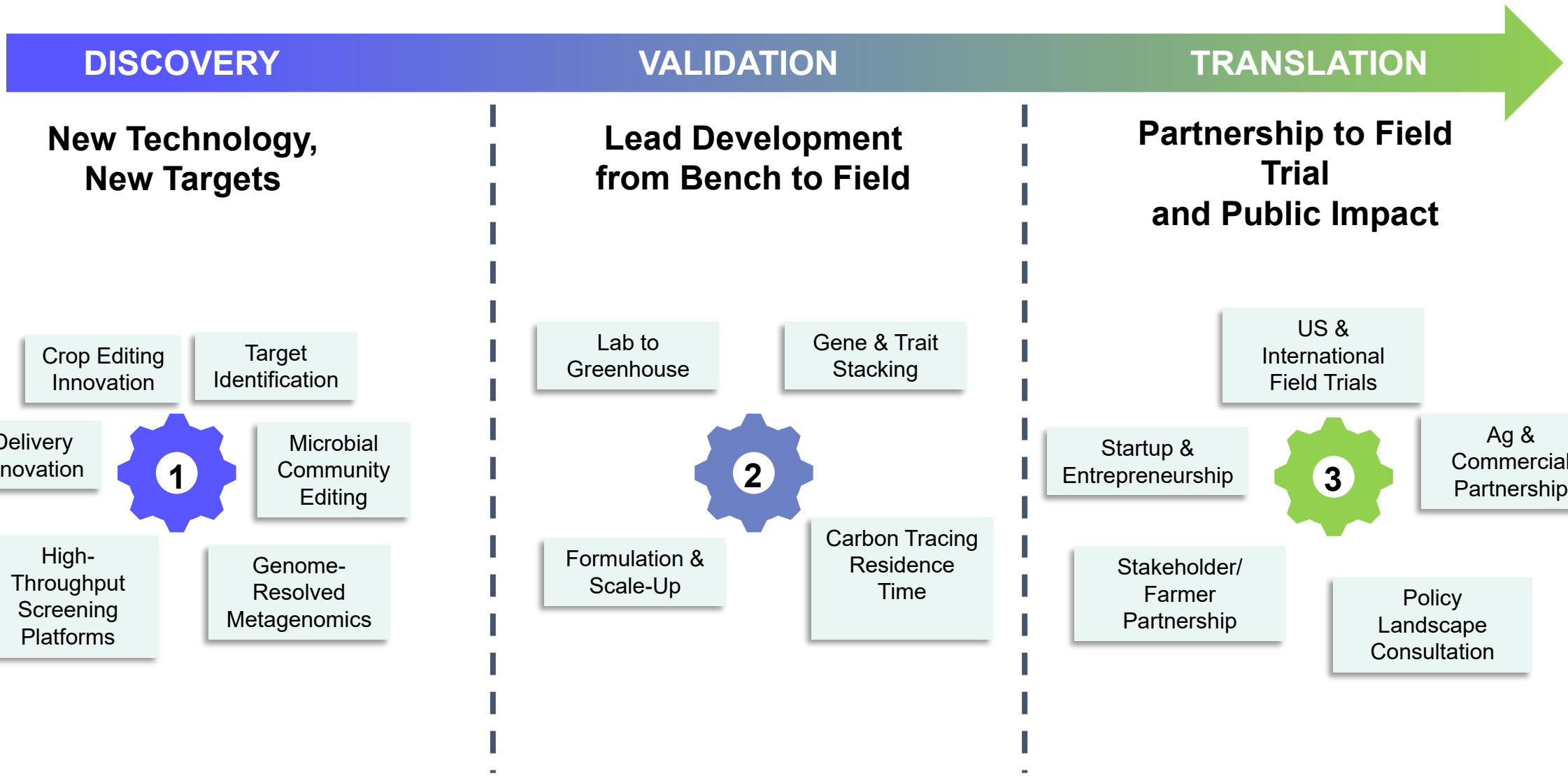


# IGI Climate & Agriculture Application Space





# IGI Climate & Agriculture Strategy



# IGI Plan to Reach Net-Zero Agriculture



1. Improve food security & reduce farmer inputs
2. Reduce agricultural emissions
3. Remove gigatons of atmospheric carbon



**1. Improve Food Security & Reduce Farmer Inputs**



# Reducing Farmer Inputs

## Improve water-use efficiency

- Optimize stomatal density
- Altering root systems

## Reduce pesticide use

- Gene stacking of durable resistance genes using CRISPR targeted insertions into safe harbor landing pads
- Develop RNP editing and homology-directed repair (HDR) in wheat and rice

## Reduce nitrogen and phosphorus fertilizer dependency

- Employ CRISPR gene editing to alter rice genes to increase nitrogen-use efficiency (NUE)
- Use microbial phosphatases to increase phosphorous bioavailability in soils



Brian Staskawicz, IGI Director of Sustainable Agriculture



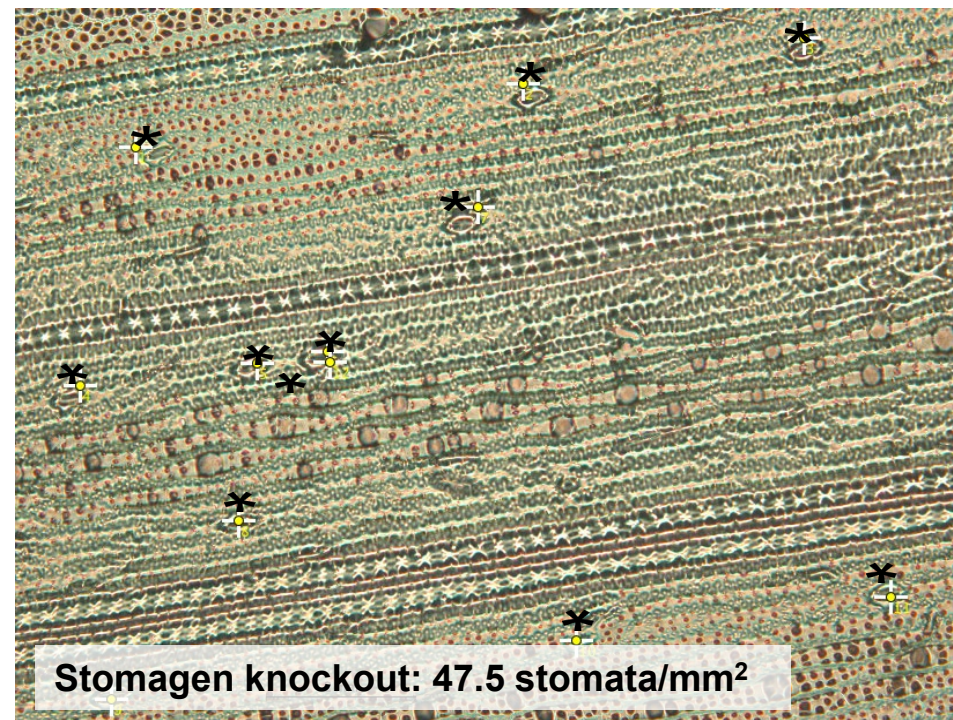
# Climate Adaptation: Drought-Tolerant Crops

Improving water use efficiency in plants can maintain yield under climate stress.

- To develop varieties adapted to increasingly drought-like conditions, IGI Dir of Sustainable Ag, Brian Staskawicz, is using CRISPR genome editing to knockout two genes responsible for higher stomatal density on leaves, reducing water loss.
- **Knocking out *epfl10* gene maintained wild-type physiological characteristics while requiring 15% less water.**

## Next steps:

IGI is working with CGIAR to conduct field trials of the stomatal knockout rice varieties in Colombia







# Climate Adaptation: Disease Resistance

Improving disease resistance by knocking out disease susceptibility gene *dmr6*

- *Dmr6* regulates/inhibits salicylic acid production (natural immune response in plants)
- Knocking out *dmr6* improves the ability of rice to resist bacterial blight (*Xanthomonas oryzae*)



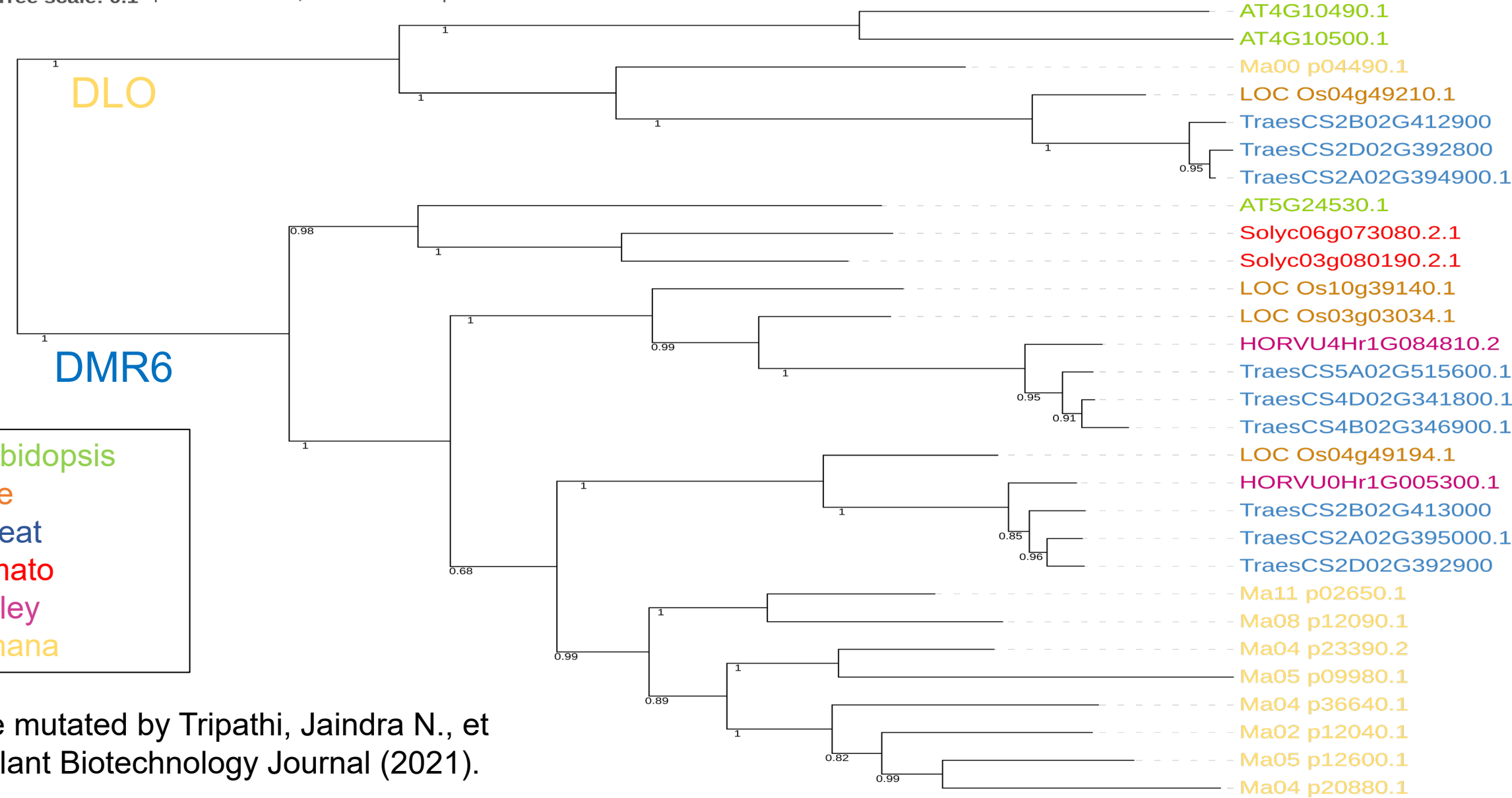
**Cultivated rice  
(disease susceptible)**

**Edited variants  
(disease resistant)**



# Promoting Disease Resistance Across Other Crops

Tree scale: 0.1



- Arabidopsis
- Rice
- Wheat
- Tomato
- Barley
- Banana

Gene mutated by Tripathi, Jindra N., et al. Plant Biotechnology Journal (2021).



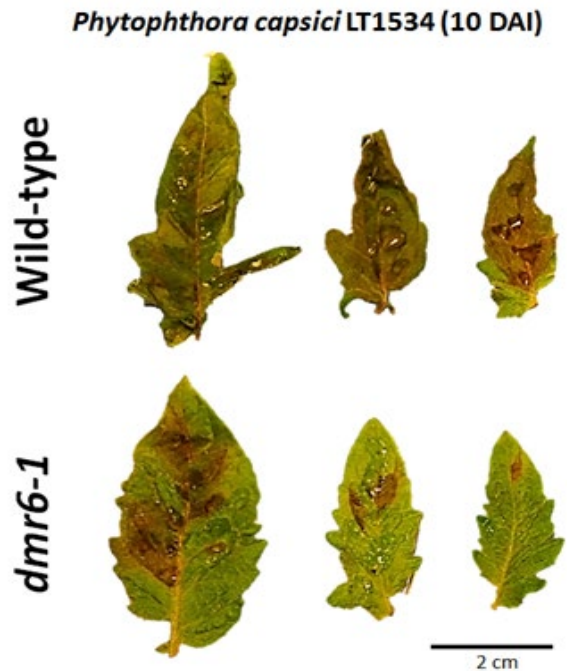
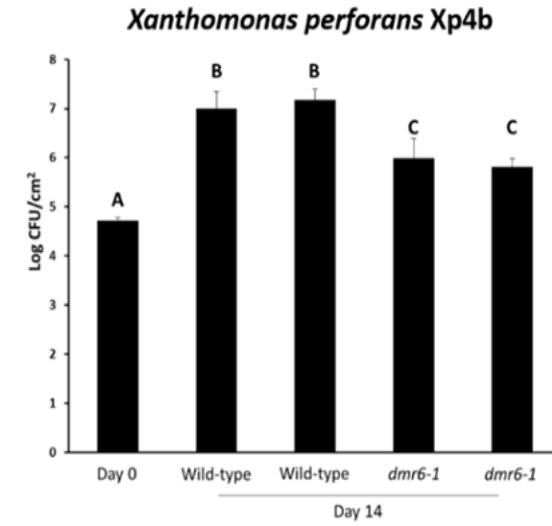
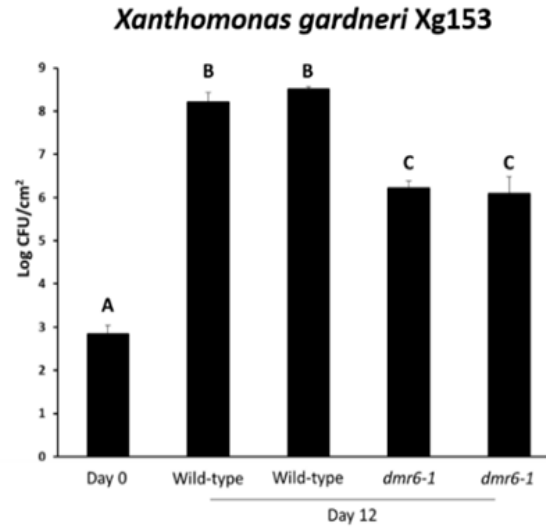
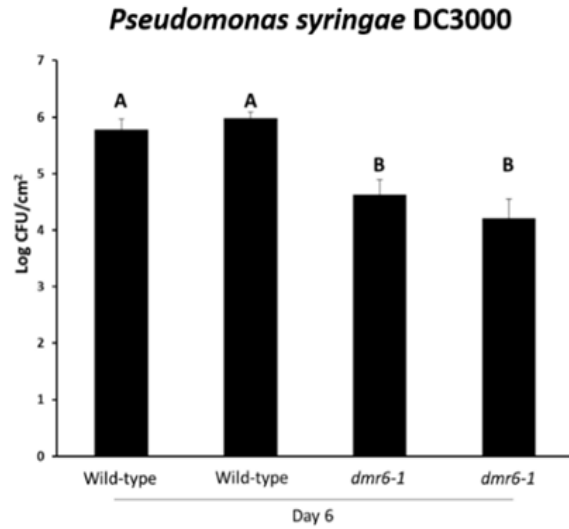
## Loss of function of a DMR6 ortholog in tomato confers broad-spectrum disease resistance

Daniela Paula de Toledo Thomazella<sup>a,b</sup>, Kyungyong Seong<sup>a</sup>, Rebecca Mackelprang<sup>a</sup>, Douglas Dahlbeck<sup>a,b</sup>, Yu Geng<sup>a</sup>, Upinder S. Gill<sup>c</sup>, Tiancong Qi<sup>a,d</sup>, Julie Pham<sup>b</sup>, Priscila Giuseppe<sup>e</sup>, Clara Youngna Lee<sup>a</sup>, Arturo Ortega<sup>a,b</sup>, Myeong-Je Cho<sup>b</sup>, Samuel F. Hutton<sup>f</sup>, and Brian Staskawicz<sup>a,b,1</sup>

<sup>a</sup>Department of Plant and Microbial Biology, University of California, Berkeley, CA 94720; <sup>b</sup>Innovative Genomics Institute, University of California, Berkeley, CA 94704; <sup>c</sup>Department of Plant Pathology, North Dakota State University, Fargo, ND 58108; <sup>d</sup>School of Life Sciences, Tsinghua University, Beijing 100084, China; <sup>e</sup>Brazilian Biorenewables National Laboratory, Brazilian Center for Research in Energy and Materials, Campinas SP 13083-100, Brazil; and <sup>f</sup>Horticultural Sciences Department, University of Florida, Gulf Coast Research and Education Center, Wimauma, FL 33598

Contributed by Brian Staskawicz, May 16, 2021 (sent for review December 21, 2020; reviewed by Sheng Yang He and Guido Van den Ackerveken)

# sldmr6-1 Mutants in Tomato Show Broad Spectrum Disease Resistance



*Oidium neolycopersici* (powdery mildew of tomato)





# Expanding Pest & Disease Resistant Crops

Many of the world's most important crops are threatened by pests and diseases. Climate change is increasing the risk to our food supply.

The Plant Genomics & Transformation Facility at the IGI has developed the protocols to edit the genomes of 30+ globally significant crop plants.

- **Wheat:** Protecting the food supply from wheat blast and future pandemics using resistance gene stacking.
- **Cacao:** Shielding 50% of the global cacao supply grown in West Africa from swollen shoot virus.
- **Banana:** Developing genome-editing protections to the global banana supply from *Fusarium* fungal infections.





$N_2O$



## 2. Reduce Agricultural Emissions



# Eliminating Agricultural Emissions

**Cows** and **rice** are the two largest contributors to food-related GHG emissions. In both cases, **microbes** are the true source of the emissions.

In 2021, IGI started studying rice microbial emissions:

- IGI Director of Microbiology, Jill Banfield, is performing the most extensive genomic and chemical analysis of the soil microbiome of rice paddies ever performed. The goal is to isolate the metabolic sources of methane and develop targeted interventions to eliminate GHG emissions associated with rice cultivation without impacting yield.
- Pam Ronald, UC Davis Professor of Plant Pathology, IGI Investigator and recipient of the 2022 International Wolf Prize in Agriculture, is investigating the effect of rice root system architecture on soil microbial communities and how selecting for specific traits in roots could reduce methane emissions.



Jill Banfield, IGI Director of Microbiology & team





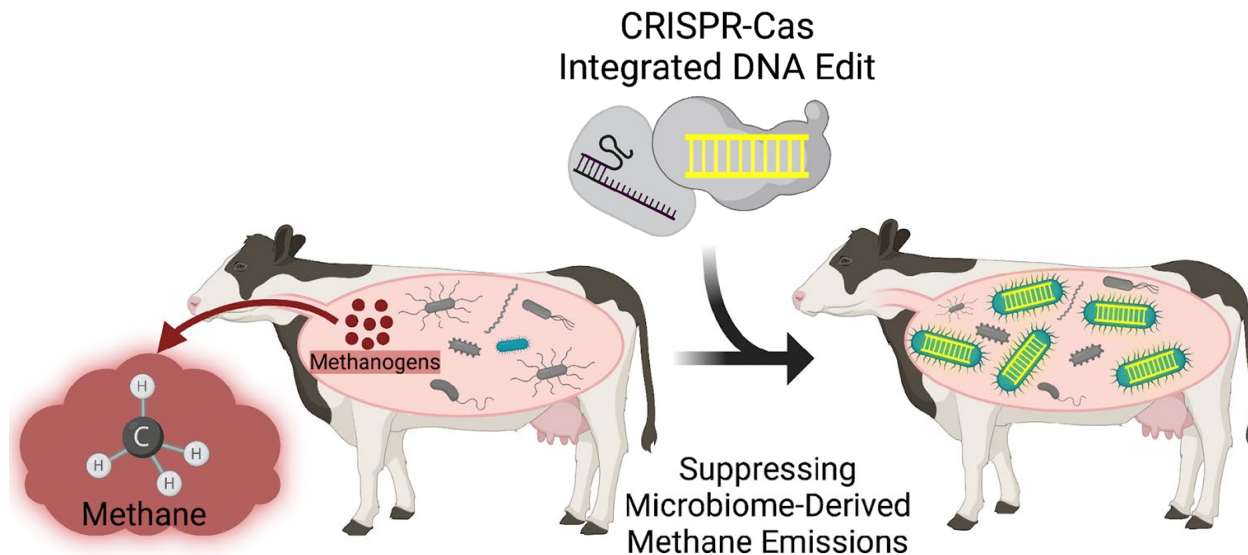


# Targeting Livestock Emissions

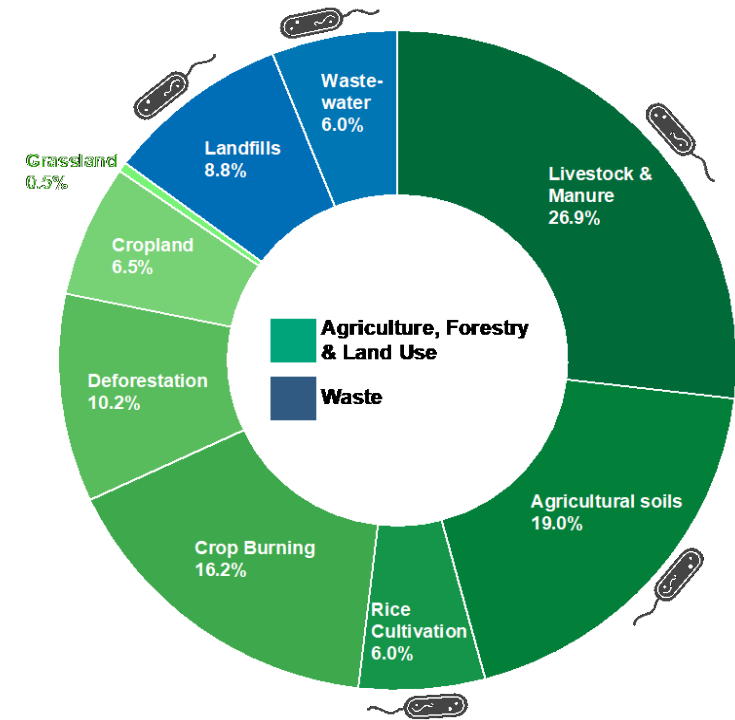
Two-thirds of emissions from agriculture and waste are caused by microbes, but current interventions are too blunt or can't scale.

## Enabling Technology

A new technique developed at the IGI can target specific microbes in a community for genome editing enabling fine-tuning of microbiomes.




## The Role of Microbes in Human Caused Emissions



(Modified from OurWorldinData.org, 2020)

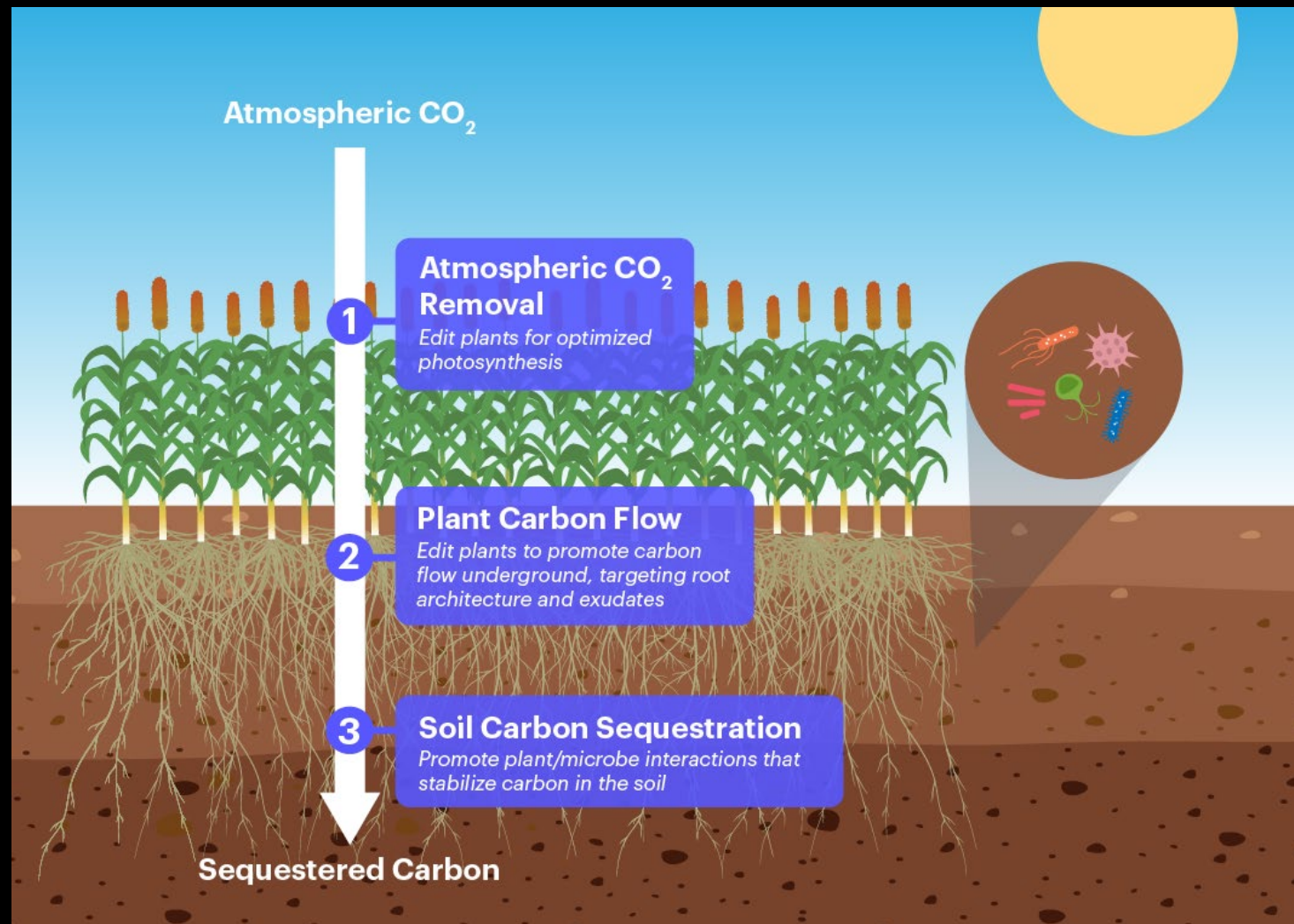
DNA-level Control of Livestock Gut Microbiomes Would Enable Climate Change Mitigation at Scale



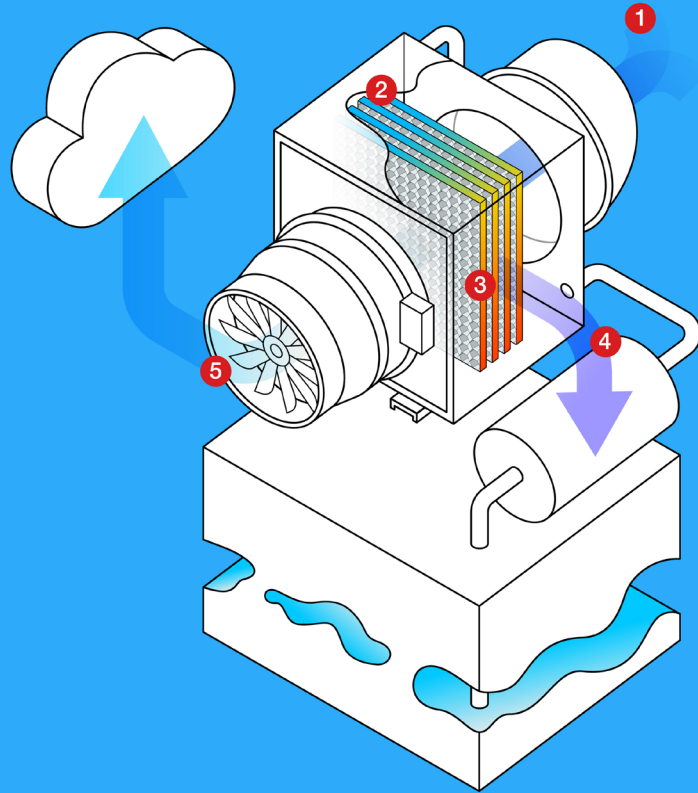
**Agricultural soils have  
lost 487 gigatons of  
CO<sub>2</sub> (equivalent)**

**3. Remove Atmospheric Carbon**

The IGI was recently funded \$11M from the Chan-Zuckerberg Initiative to enhance carbon dioxide removal in agricultural systems.



# CAPTURE CO<sub>2</sub>



## HOW IT WORKS

- 1 AIR IS DRAWN INTO THE CAPTURE PLANT
- 2 INSIDE CARBON DIOXIDE BINDS CHEMICALLY TO A FILTER.
- 3 ONCE FILTER IS SATURATED, IT IS CLOSED OFF AND HEATED TO 100°C.
- 4 PURE CO<sub>2</sub> IS RELEASES AND COLLECTED UNDERGROUND.
- 5 PURIFIED AIR IS RELEASED



**Agriculture is  
Already Global**



Global Agricultural Land (Columbia University, 2012)

# Opportunities for CRISPR to Enhance Carbon Capture and Storage

Photosynthesis



Roots



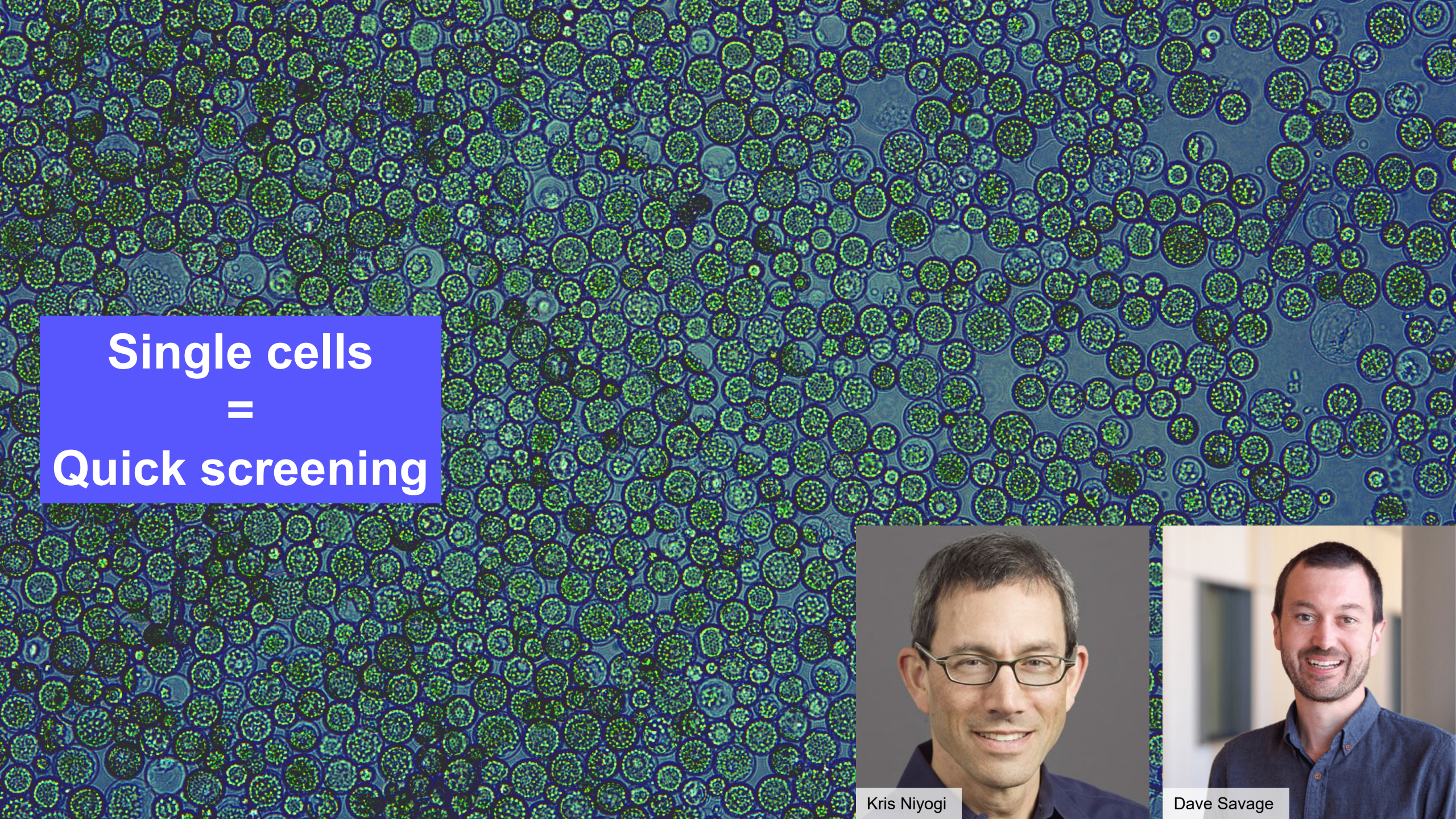
Soil Microbiome



# Enhance Photosynthesis

**CO<sub>2</sub>**





Single cells  
=  
Quick screening



Kris Niyogi

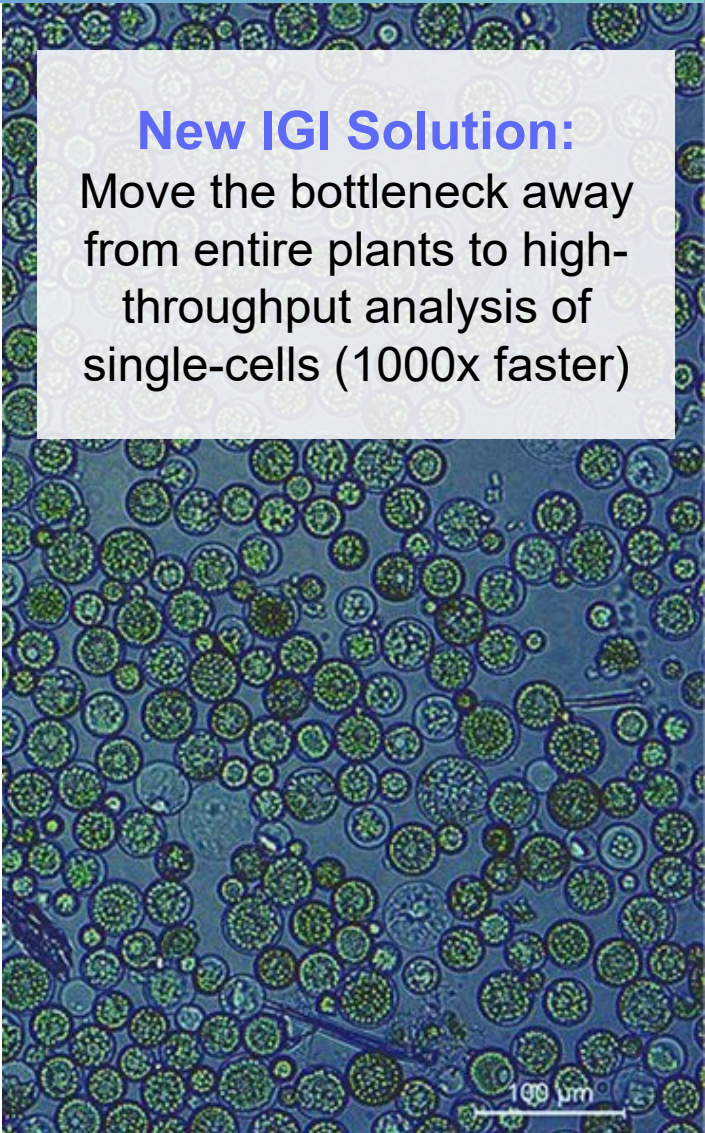
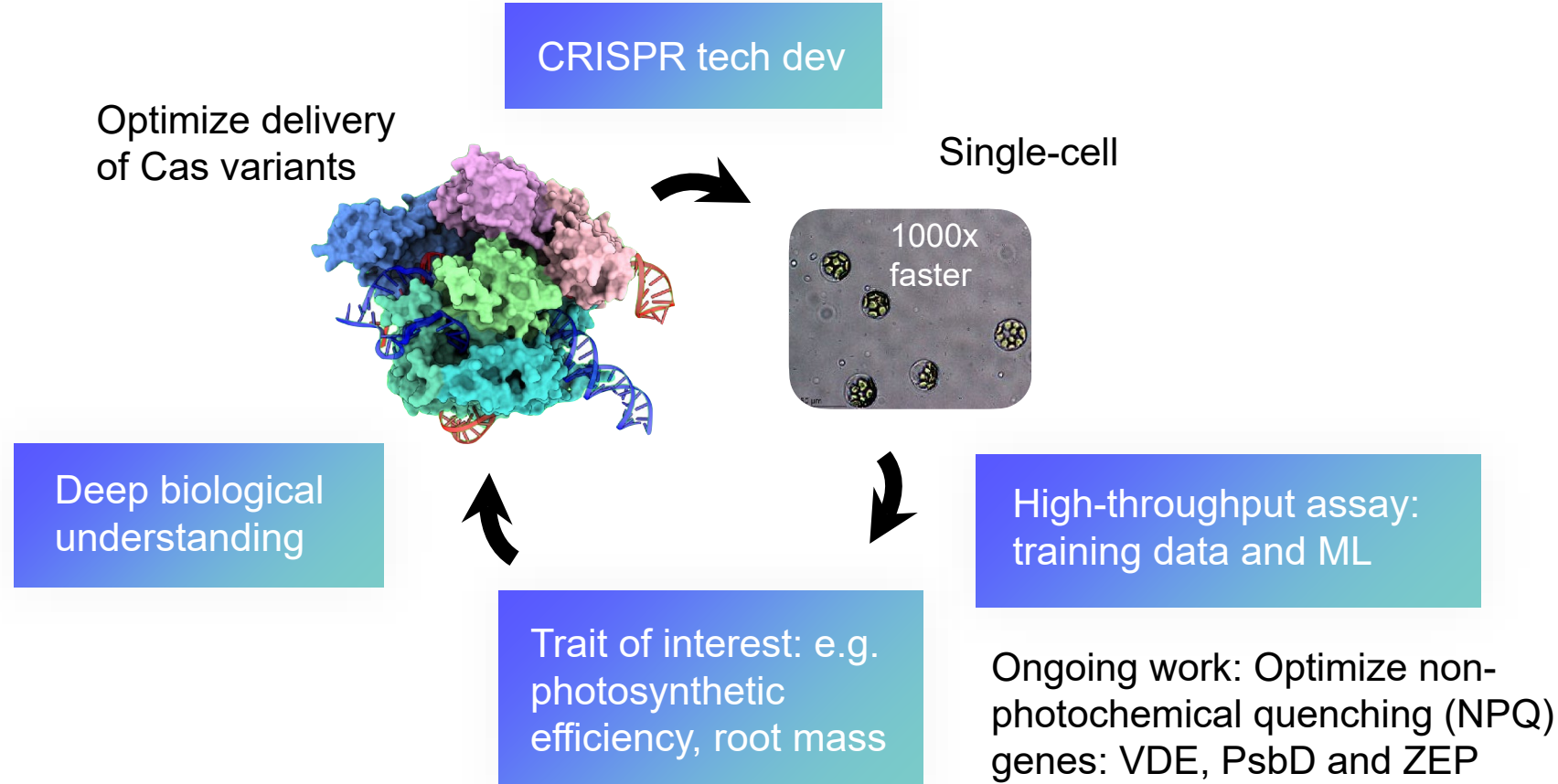


Dave Savage



# Accelerating the editing pipeline in plants and optimizing photosynthesis

**Challenge: Genetic modification and phenotyping of plants is *very slow***



**New IGI Solution:**  
Move the bottleneck away from entire plants to high-throughput analysis of single-cells (1000x faster)

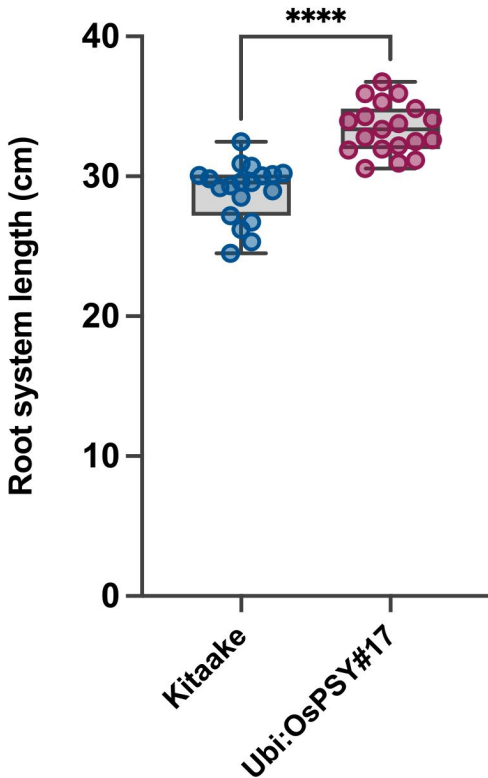


# Genetic differences alter root system architecture

Kitaake



Ubi:OsPSY1#17



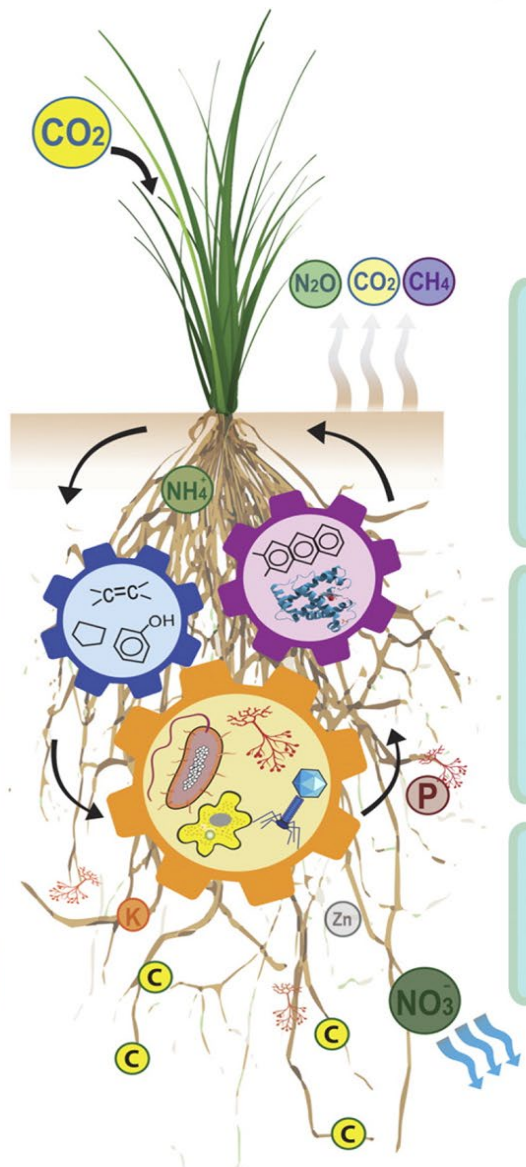
Pam Ronald

# Soil Microbiome Holds the Key to Long-term Carbon Storage



### Ecosystem services

- ↑ Carbon sequestration
- ↓ Greenhouse gas emissions
- ↑ Biodiversity
- Biomass for energy needs
- Bioproducts
- Phytoremediation
- ↓ Nitrate leaching and runoff
- ↑ Water use efficiency



### Microbiome services

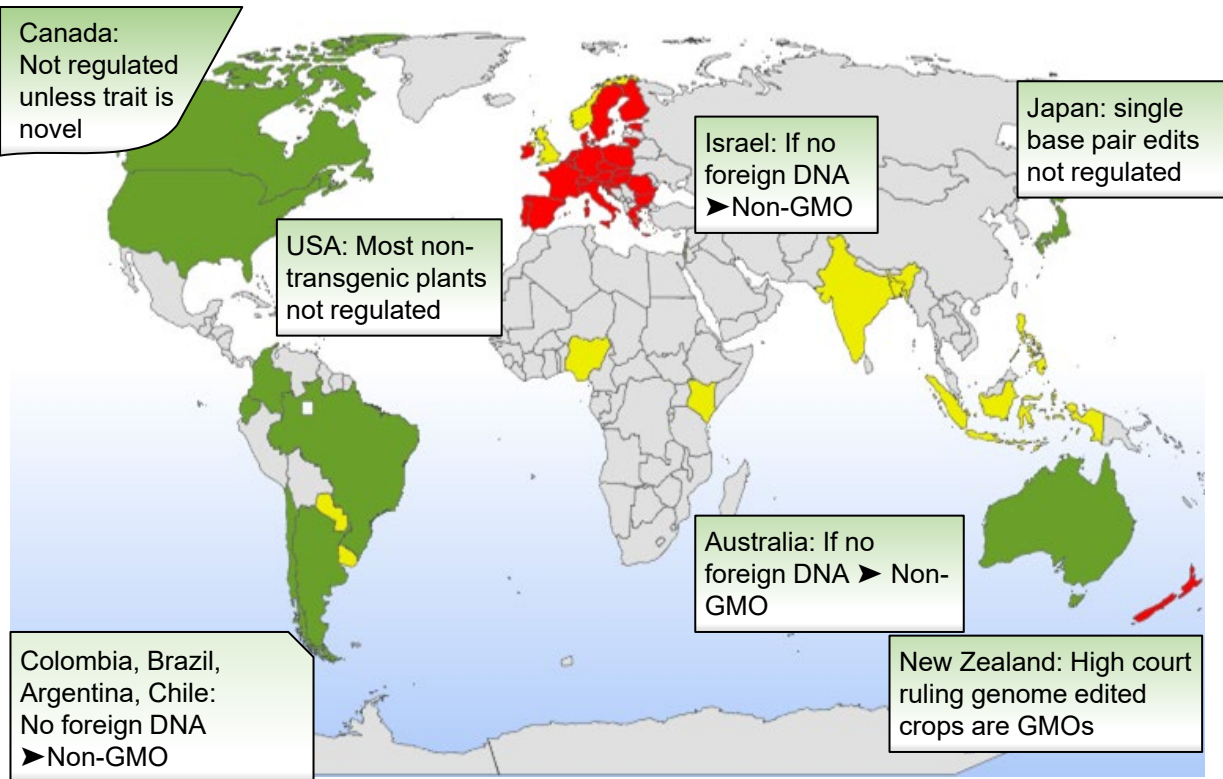
- Plant nutrient acquisition:**
  - Nitrogen fixation
  - Phosphate solubilization
  - Production of siderophores
  - Enhanced mobilization of nutrients from soil minerals
  - Mineralization of organic matter
- Defense against pathogens:**
  - Production of antimicrobials
  - Competition for nutrients
  - Predation on plant pathogens
  - Interference with quorum sensing affecting virulence
  - Induced systemic resistance
- Drought and salinity stress:**
  - Production of ACC deaminase
  - Secretion of osmolytes
  - Production of plant hormones
  - Release of antioxidants



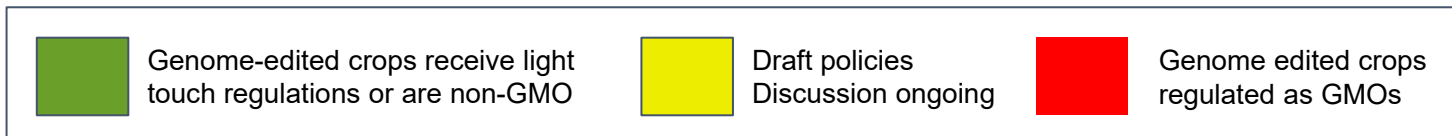
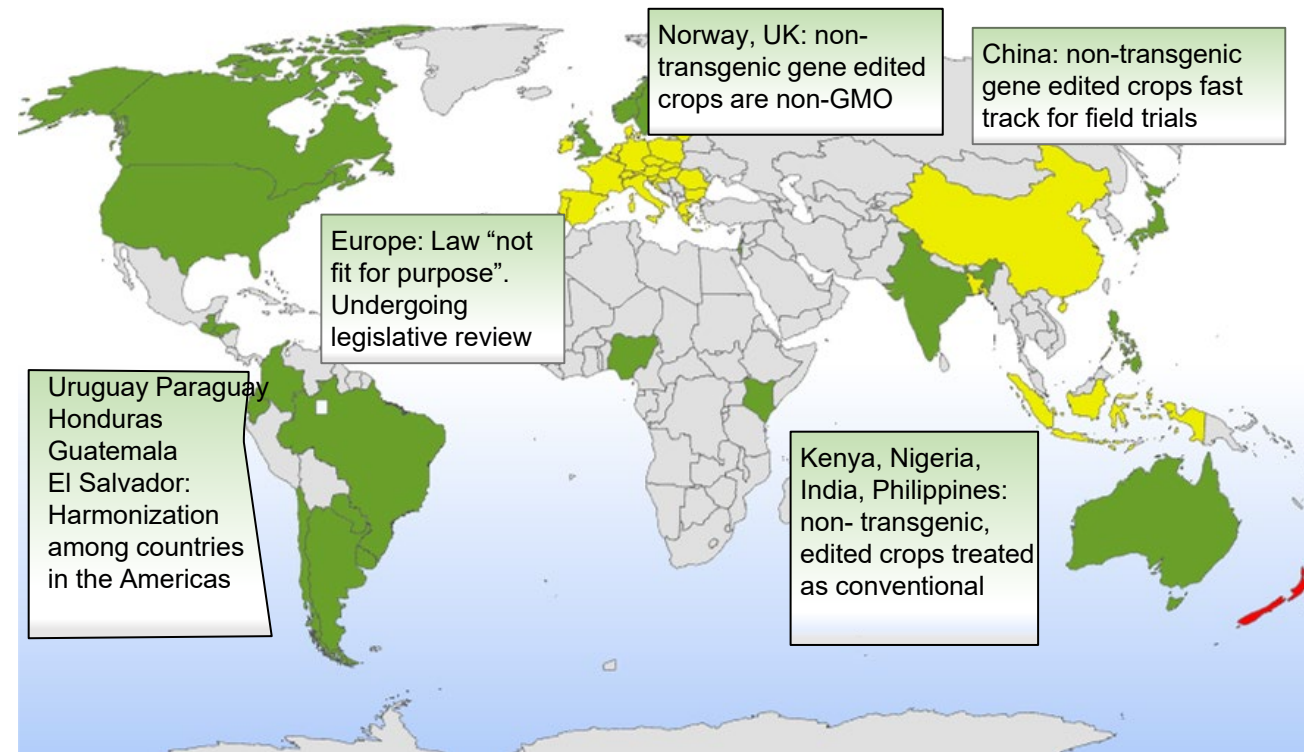


# Policy Landscape

2020

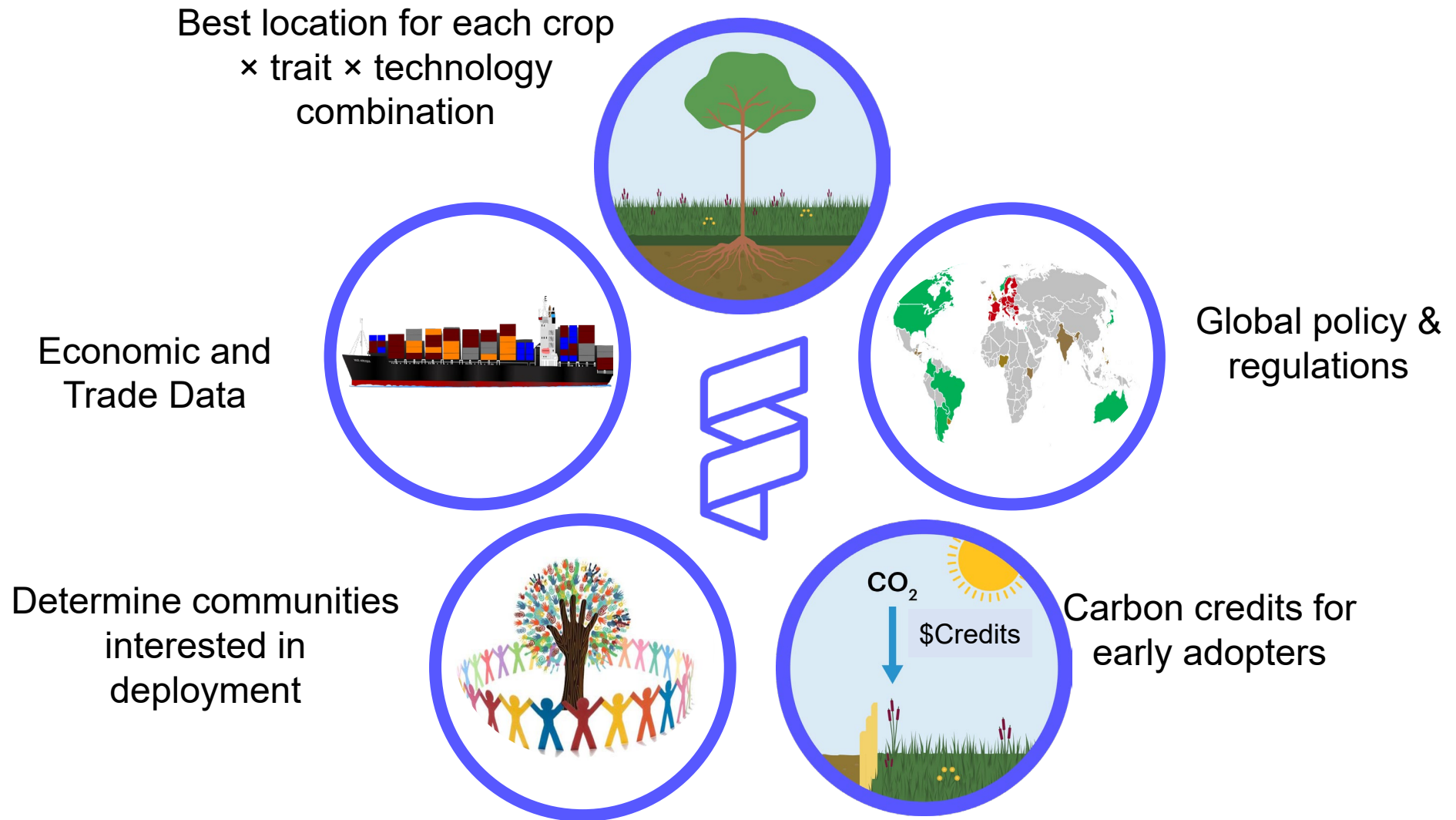


2022





# IGI Public Impact Team – Reaching Global Scale



# CGIAR Partnership for Translation



- 15 top-class Research Centers
- 108 countries
- 770,000+ germplasm accessions
- 50 years' experience

- Memorandum of understanding to share technology and resources
- Field trial and translation of IGI developed products
- Direct access to local farmers and value chains
- Seed scale up and distribution

HEEDLING WINDSHY II (HAWAN)  
NO OF FAMILIES: 300  
DATE OF TRANSPLANTING: 15 NOV 10  
FIELD LOCATION: 000

# IGI Technology Advancements & Shareholder Farmers Around the World

Gene edited crops can make a real difference in the lives of LMIC farmers by making food more nutritious, safer, higher yields grown on marginal lands, and less expensive

- **Cyanide-free cassava** to help African farmers (majority women), making cassava safer to grow and process (Gomez, et al., Front. Plant Sci., 17 March 2023)
- **Hybrid rice from clonal seeds.** Successful generation of hybrid rice plants that produce more than 95% of clonal seeds across multiple generations – maintain yields and reduce costs (Vernet, et al. Nat Comms, 27 December 2022)



# IGI is building a global CRISPR ecosystem

- Unmatched talent and track record of groundbreaking discoveries
- West Coast innovation and translation leader
- Engine for entrepreneurial activity in the CRISPR economy
- Global convener and trusted advisors for the ethical deployment of genome editing
- Accessibility and equity focus in all that we do

IGI discoveries and startups have forever changed biotech and the future of healthcare. Now we are working to impact climate and agriculture.










Innovative  
Genomics  
Institute



# Phil Taylor Ph.D.

Director of Open Innovation and Outreach  
Bayer Crop Science



A photograph of two men standing in a field of tall, golden-brown crops, likely sorghum, at sunset. The sun is low on the horizon, creating a warm, golden glow. One man is wearing a green shirt and a cap, and the other is wearing a grey jacket and a cap. They appear to be in conversation.

# *Looking to the Future of Ag & Science: How partnerships can change the world*



**Phil Taylor, Ph.D.  
Director of Open Innovation and Outreach  
Crop Science R&D, Bayer.**



**Bayer is a life science company and a global leader in health care and nutrition.** Our innovative products support efforts to overcome the major challenges presented by a growing and aging global population.

**Science for a better life**



# Sustainability is integral to our values, strategy and operations

**Sustainability and financial performance go hand in hand** – we follow financial, social and environmental targets.



Sustainability is not only a corporate responsibility but also generates business opportunities and **ensures the long-term growth of the company.**



# Innovative, sustainable solutions to address global challenges

## Key global challenges

## Our priorities

## Pipeline of sustainable solutions

Water quality  
Soil health

Using fewer resources

- Small molecules and complementary biological solutions focused on reducing environmental impact
- Short-stature corn to enable optimal use of inputs, while minimizing harvest losses

Climate change  
Sustainable energy sources

Advancing a carbon smart future for agriculture

- Digital tools for carbon sequestration, measurement, precise input application
- Next-generation herbicide-tolerant traits to support no-till/conservation tillage system

Growing population  
Increasing protein demand

Creating better harvests

- Higher-yielding, disease-resistant seeds
- Next-generation biotech traits and crop protection to protect and enhance yields

**Solutions must serve growers large and small; Empowering 100m smallholders by 2030**



# Next Growth Opportunity: Convergence of Leading R&D Platforms

Extensive Germplasm and Biotech Foundation, combined with Leadership in Chemistry and Biologicals and Data Science Optimization, serves as Innovation Engine to accelerate benefits across the industry

## Seeds & Traits



Breeding

Leading germplasm libraries in corn, soybean, cotton and vegetables

>1.7P calculations in cloud-based algorithms

>3,200 unique field testing locations



Biotech

First to combine RNAi technology with biotech

>1.5bn datapoints generated to deliver biotech traits and accelerate genetic gain

Reach >350m acres annually

>20 new and next-generation traits in development

## Crop Protection



Chemistry

Strong discovery platform for molecules with new mode-of-action and differentiated profiles

30-60 molecules selected for field trials annually

Expect ~100 new formulations to launch in the next decade



Biologicals

270,000 microbes in collection

>100,000 microbes characterized in-silico, in-vitro and in-planta annually

~80m acres of commercial products reached annually in row crops

## Digital Farming



Data Science

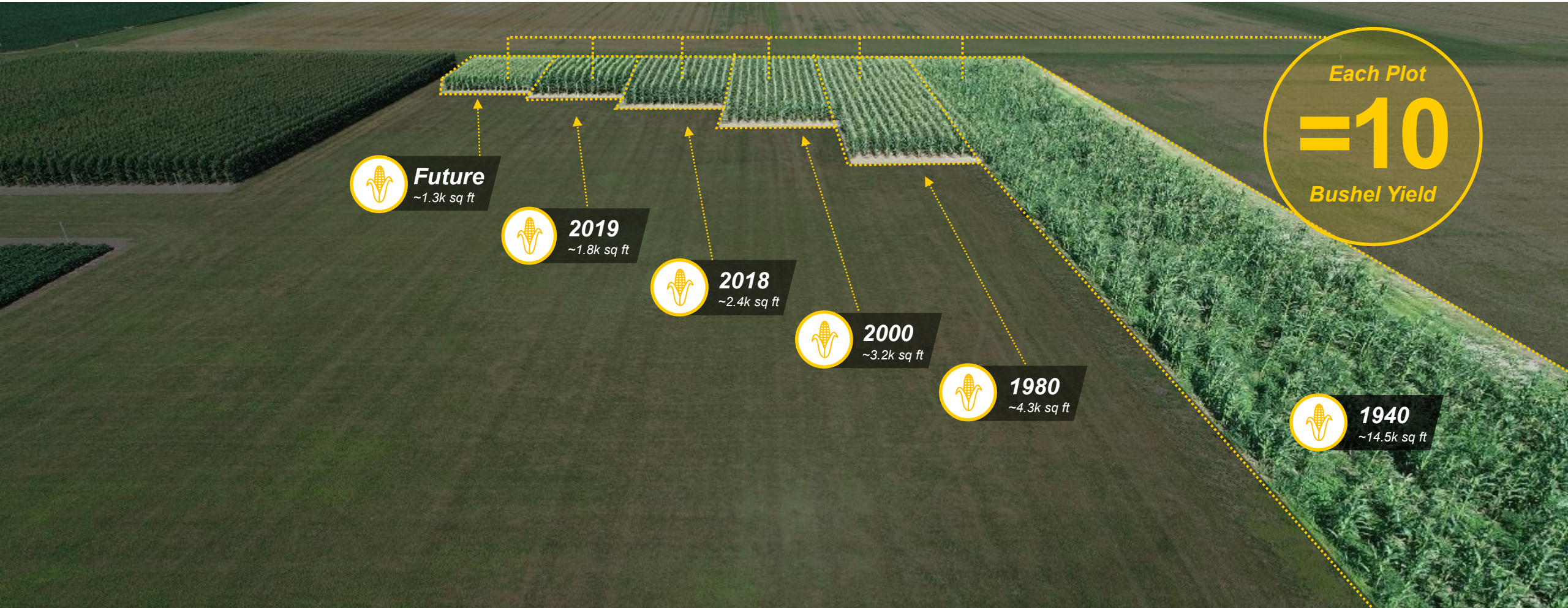
#1 database of farmer and field trial seed performance data in the industry

>69bn data points of product performance under real-world farmer management practices

>95m paid acres in U.S.A., Latin America and Europe represents industry's leading platform reach



# Innovation in agriculture allows us to grow more with less in a more sustainable manner







# Living up to Our Responsibility

through transformational commitments in sustainability

> **Advancing a carbon-zero future for agriculture**

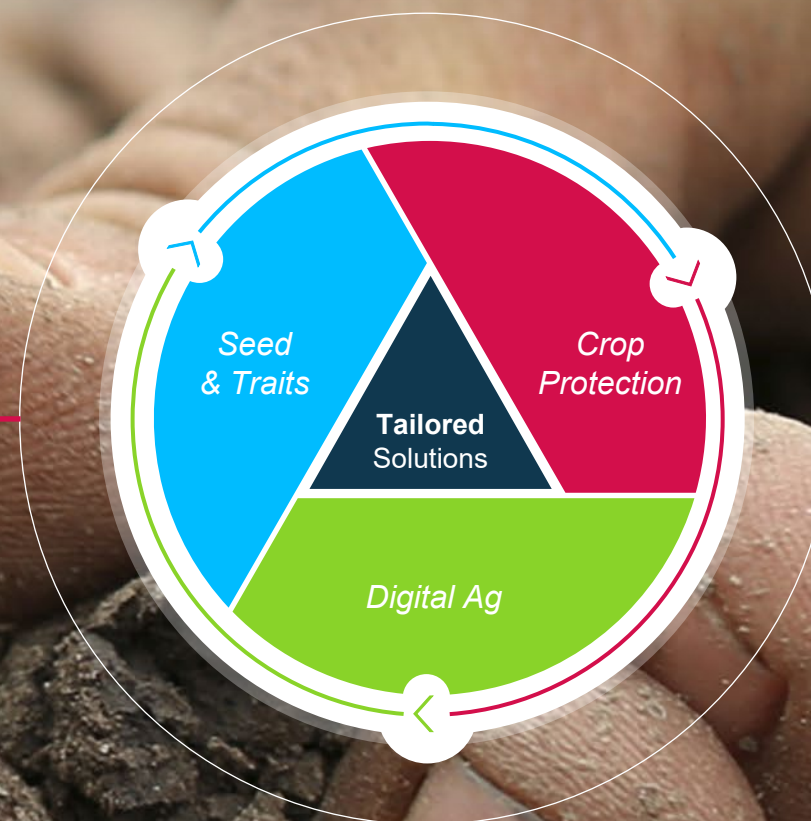
**30%** Reduction in field greenhouse gases emitted per kg of crops produced

> **Produce higher-yielding crops with fewer natural resources and inputs**

**30%** Reduction of crop protection impact on the environment

> **Empowering smallholder farmers to access sustainable agricultural solutions**

**>100<sub>M</sub>** Smallholders benefit e.g. access to education, tailored solutions & partners





# We have outstanding talent in agriculture...



**33.064**

Total number of  
employees\*



From

**88**

Countries\*



**7,100**

Total R&D employees\*



**€ 2.9bn**

investment in R&D in  
2022

\*Status: December 2020





...though partnerships are the key to success.

Why? Complexity is constantly increasing ... we cannot realize our goals alone.

Scientific Innovation



Individuals



Teams of experts



Multi-Disciplinary Dimensions



Constant Global Interconnection

Time

Business Practice



Exploring internal opportunities



Building sustainable internal capabilities



Discovering external connections



Structurally seeking external partnerships



# Leveraging Open Model for Incremental and Disruptive Innovation

Designed to ensure growers have access to the best that science can offer

## Incremental Innovation

- // Annual germplasm upgrades
- // New modes of action in weed, insect and disease control through biotech and crop protection
- // New formulations and uses in crop protection to expand spectrum and crops

## Disruptive Innovation

- // Genome-editing
- // Next generation biological science
- // Precision breeding
- // Drone application technology
- // New modalities for crop protection

## Open Innovation Model

### Technology Collaborations



### Customer-sponsored Research



### Universities & Research Institutes



### Venture Capital leaps+



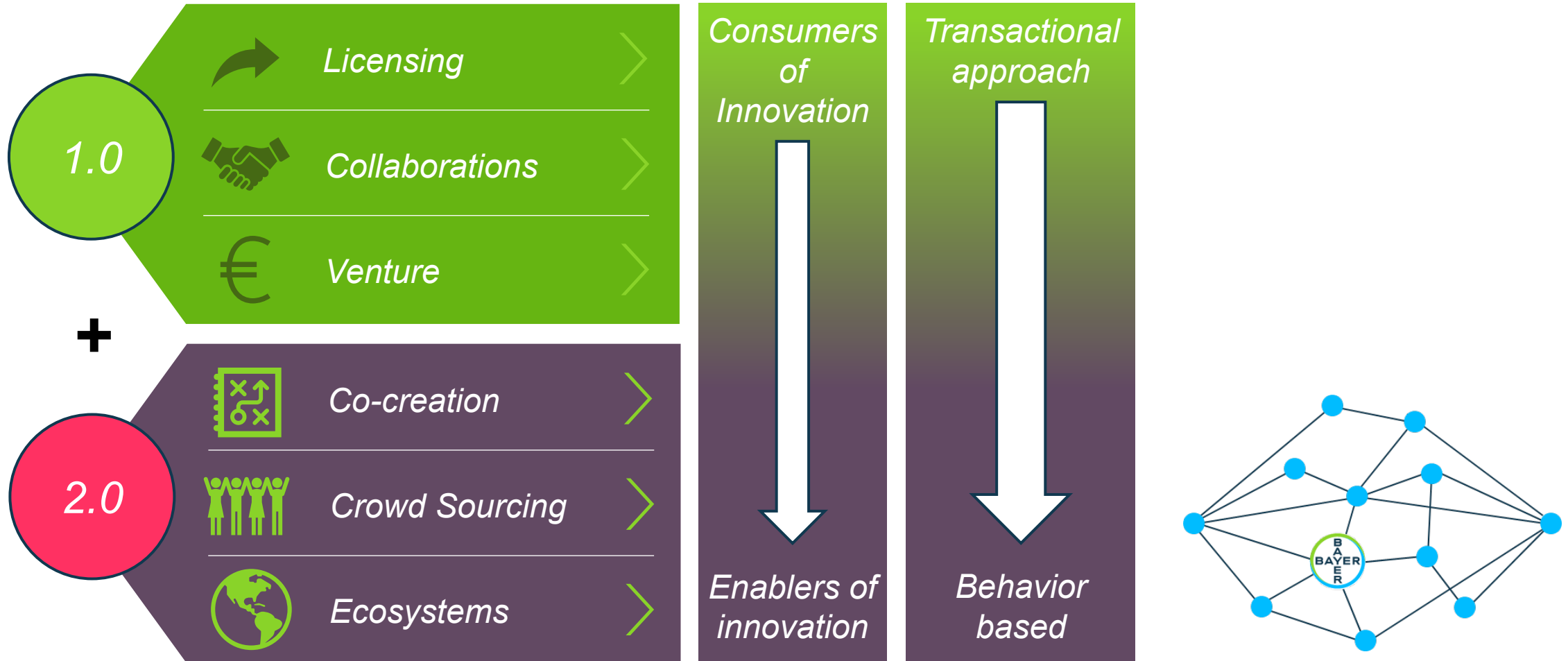
### Crowdsourcing





# The opportunities from open innovation are changing

*Timely opportunity to cement our position as a thought leader in Ag*





# Bayer Crop Science | Innovation Ecosystem



Crop Science  
**Innovation  
Ecosystem**

*Driving partnerships through  
novel programs*



**Testing  
4AG**



**THRIVE**  
by SVG VENTURES



**Grants  
4AG**



**hello  
tomorrow**

**HALO**



**Life  
Hub**

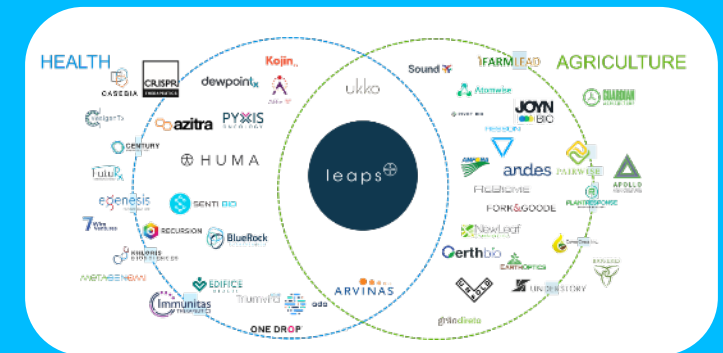
*Academic Engagement*

*Supporting innovation  
across the globe*



leaps 

*Forging cutting-edge  
venturing activities*





## Grants4Ag Program

Support for early innovations that have the potential to impact agriculture.

### **Broad**

*Awarding multiple unrestricted grants to researchers at any career stage*



### **Simple**

*No additional steps beyond submitting a proposal*



### **Low touch**

*There are no formal reporting requirements and applicants retain ownership of any IP developed*



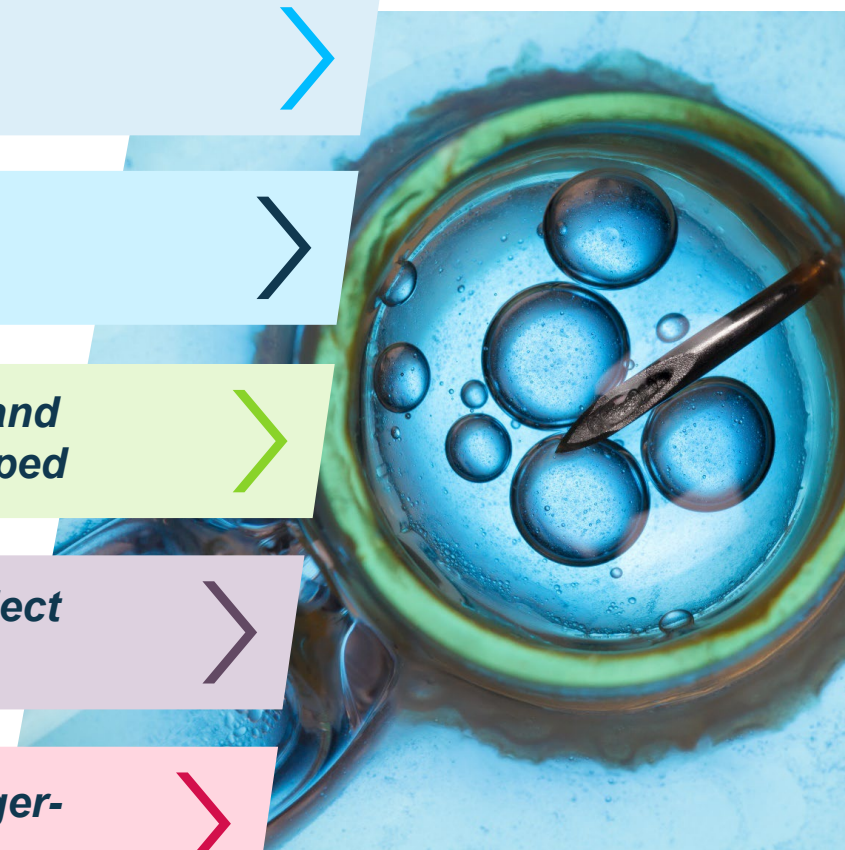
### **Supported**

*A Bayer scientist will be assigned to each project (where possible) to act as a mentor/guide*



### **Impactful**

*One of our key ways to identify partners for larger-scale long-term partnerships*

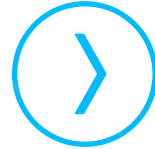


# Testing4Ag Program

Novel data generation for early innovations that have the potential to impact agriculture.

## What are we looking for?

- // Small molecules with novel molecular scaffolds
- // Compounds designed for biological efficacy
- // Engaging in scientific discussions and starting trustful relationships



## What's in it for you?

- // Access to Bayer's state-of-the-art biological assays on agriculturally-relevant plant diseases, insect pests and weed species
- // Results will be shared with you and can be freely used for publication
- // All IP rights will also remain with you and your institution
- // Follow-up collaborations may be developed with Bayer

## How does Testing4Ag work ?



**1**  
Select your  
compounds



**2**  
Submit your  
proposal



**3**  
Sign MTA & transfer  
structures



**4**  
In-silico screen  
at Bayer



**5**  
Shipment of  
selected compounds



**6**  
Biological testing



**7**  
Results are shared and  
next steps discussed





Life Hub  
Monheim



Life Innovation  
Hub Map



Life Hub  
California

*AgTech and Food Tech*



Life Hub  
Lyon

*AgTech and BioTech*



Life Hub  
Monheim

*Sustainable Agriculture*



Life Hub  
Barcelona

*Horticulture*



Life Hub  
APAC

*2 in development*



Life Hub  
Sao Paulo

*Digital Transformation (in Ag)*

### LifeHub Mission:

*Solve global challenges in agriculture through regional collaboration.*

### Approaches:

*Startup Incubation*

*Ecosystem Development*

*Dialogue*

*Innovation sourcing*

# Evolution of the LifeHub Lyon

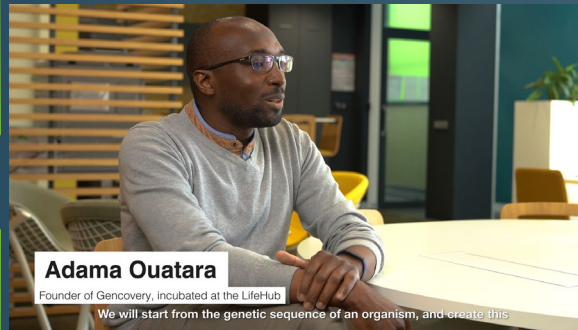
Innovation, Dialogue, Transformation

2017



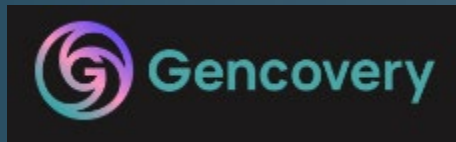
Opening of LifeHub Lyon

2020



**Adama Ouatara**

Founder of Gencoverly, incubated at the LifeHub  
We will start from the genetic sequence of an organism, and create this



Acceleration of startups begin focus "digital"

2023



Exploration of Lab Space for Startups

2025



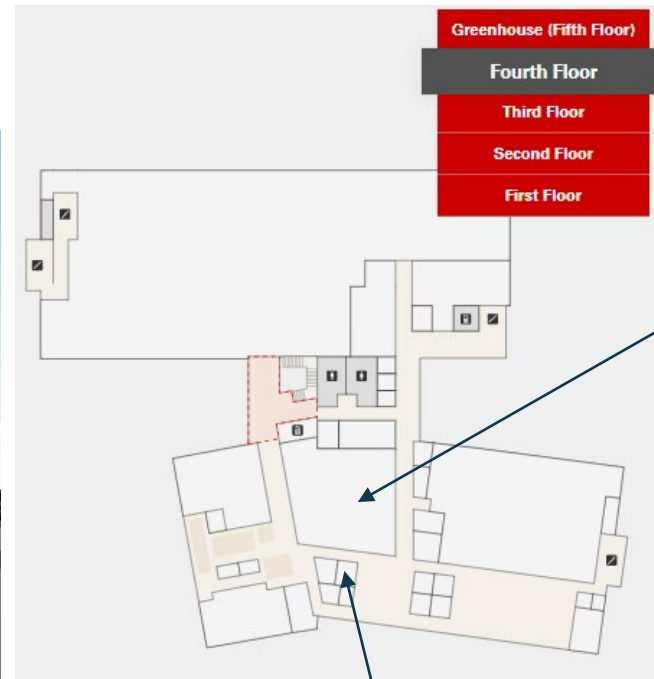
LifeHub Lyon offers lab space to AgTech Startups



# Supporting Innovation at NC State

*Partner and leverage academic excellence as a source of innovation*

**NC STATE  
UNIVERSITY**



*“Partner Suite” (2023+)*

 **Huddle room**





# Leaps is the strategic impact investment unit of Bayer

Invested >US\$1.7 billion in >55 start-up companies in health and nutrition

## Leaps by Bayer exists to...

- // ... invest in **breakthrough technologies** and disruptive business models
- // ... **use minority equity** to found new and invest in existing start-ups
- // ... create business models **balancing financial return with sustainability**
- // ... invest to solve challenges like how to **prevent and cure cancer** or **reduce the environmental impact of agriculture**

leaps 





# Bayer Crop Science | Innovation Ecosystem



Crop Science  
**Innovation  
Ecosystem**

*Driving partnerships through  
novel programs*



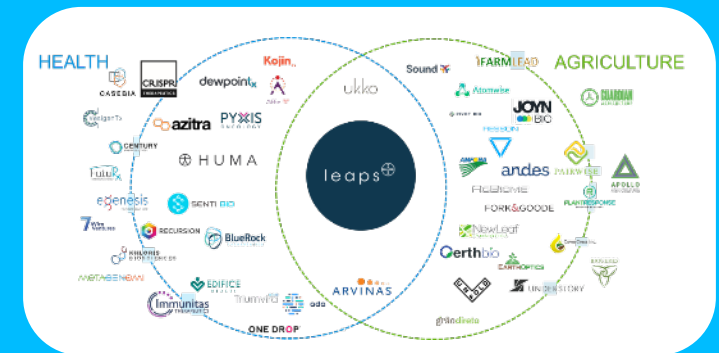
*Academic Engagement*

*Supporting innovation  
across the globe*



leaps 

*Forging cutting-edge  
venturing activities*





Thank  
you



**Phil Taylor, Ph.D.**

Director of Open Innovation & Outreach

Email: [phil.taylor@bayer.com](mailto:phil.taylor@bayer.com)

<https://www.linkedin.com/in/jphiliptaylor/>





# **Elliott Kellner Ph.D.**

Senior Program Manager

Donald Danforth Plant Science Center





DONALD DANFORTH  
PLANT SCIENCE CENTER





OUR MISSION

# Improve The Human Condition Through Plant Science



Feed the hungry and improve human health



Preserve and renew the environment



Enhance the St. Louis region as a world center for plant science



DONALD DANFORTH PLANT SCIENCE CENTER

# World's Largest Nonprofit Independent Plant Research Institute

**396**

Employees  
from  
30 countries

**31**

Scientific teams  
**199** funded  
projects

**\$40M**

Annual operating  
budget

**1718**

Scientific  
publications

**3 members**

National  
Academy of  
Science

**9 startup**

Companies  
launched by faculty

**3 Institutes**

Focused on renewable  
energy and improving food  
security crops

**\$250M**

In research funding from  
government agencies, industry  
& foundations

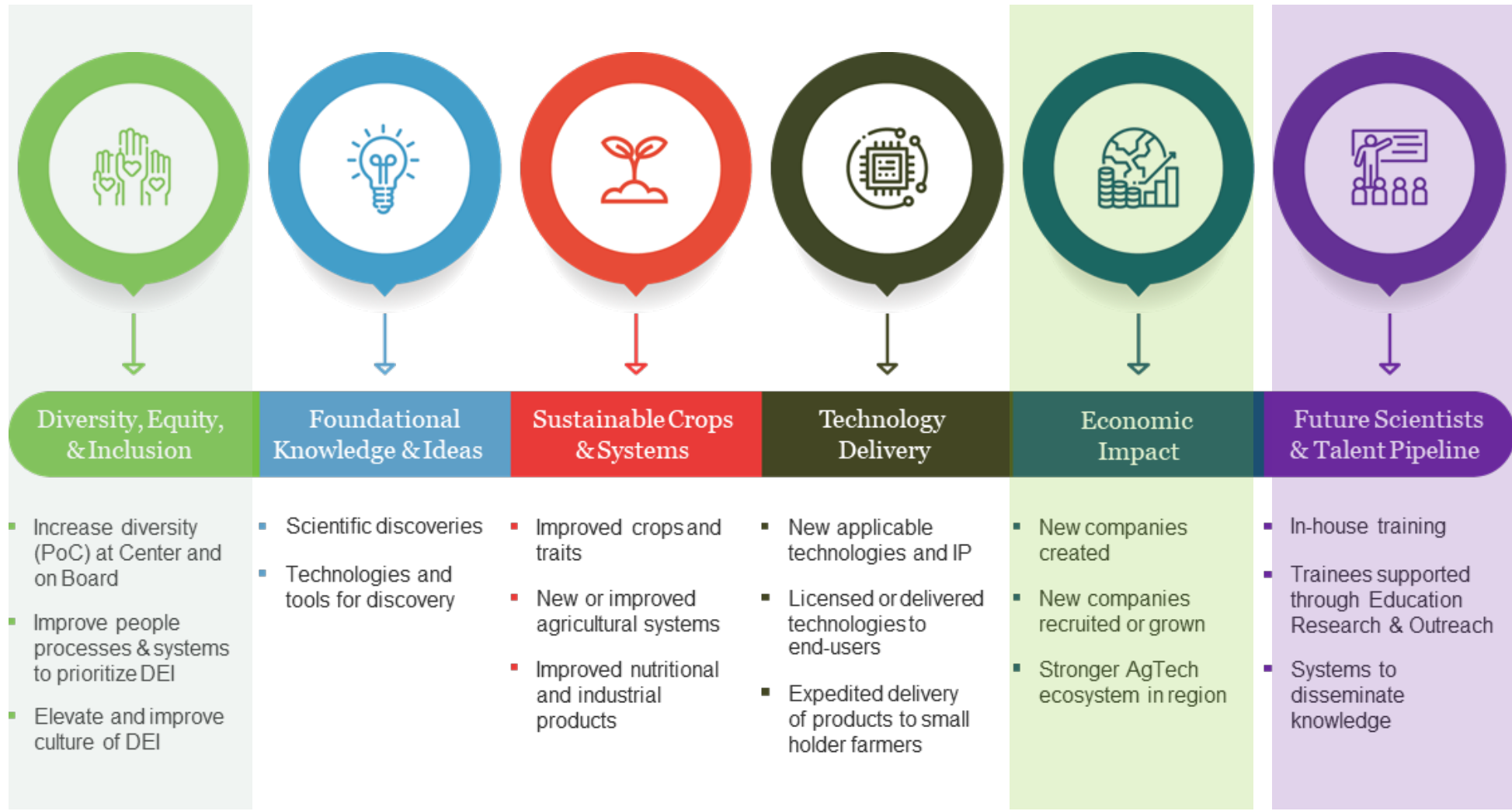
**\$352M**

In annual economic impact to  
the St. Louis region



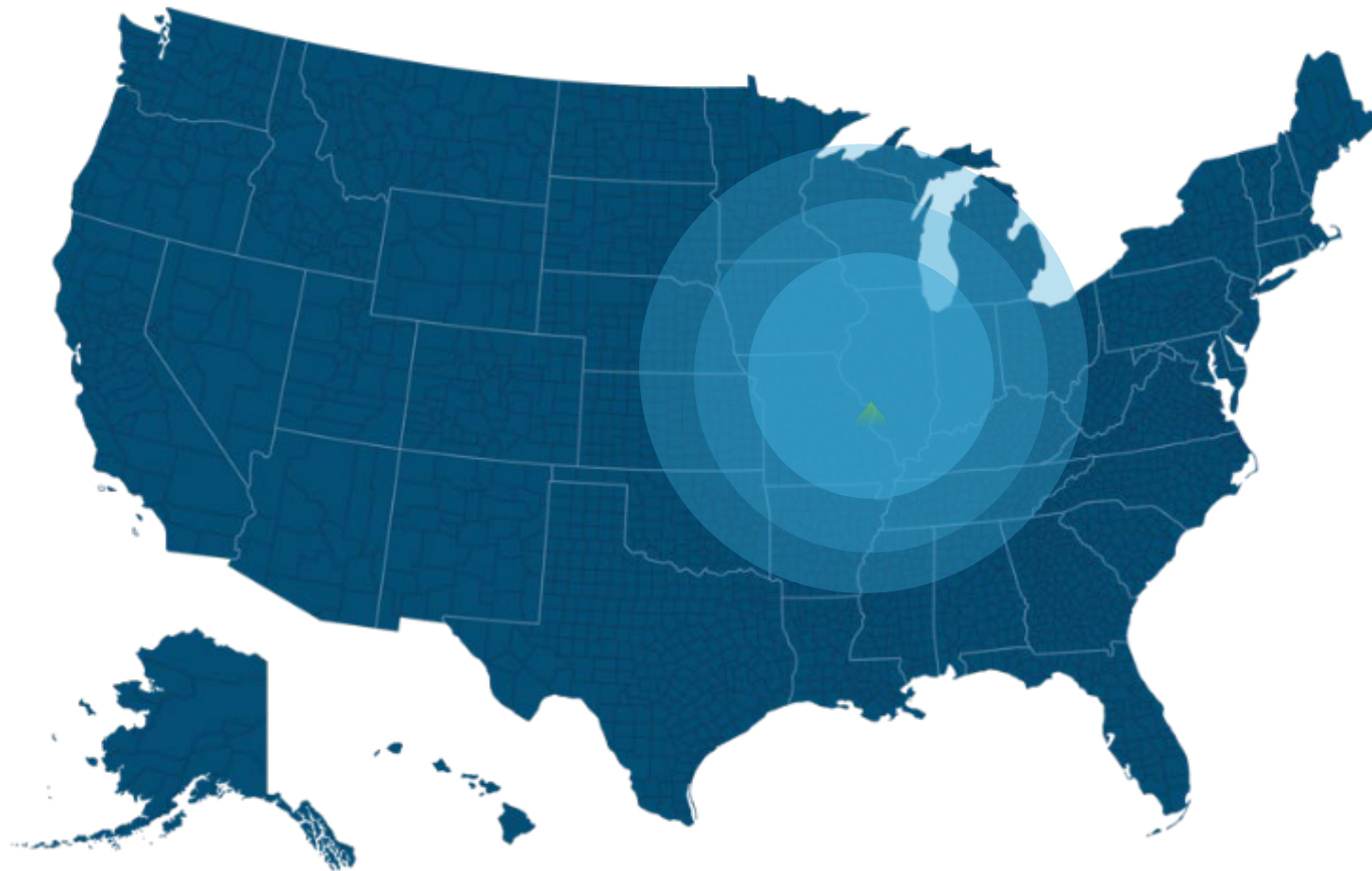


# Economic Impact as a Danforth Center Strategic Priority



# Strategic Goal:

Establish Danforth Center and 39 North as **#1 landing place for AgTech start-ups, established companies and entrepreneurs.**  
Establish mechanisms, allocate resources to **double the rate of Center start-up company formation by 2025.**





The **Danforth Center Start-Up Initiative** seeks to accelerate movement of scientific discovery into the marketplace to address global challenges in food and the environment.

- Intellectual Property (IP)
- Proof of Concept (PoC) Fund
- Entrepreneurial talent and guidance to assess new start-up ideas and technologies
- Fund launch and initial stages of start-up companies through novel mechanisms designed to increase chances of success\*
- Release start-up companies into the St. Louis AgTech ecosystem to raise additional capital, grow and compete in the marketplace

\*The Danforth Center created a for-profit subsidiary, Danforth Technology Company (DTC), to facilitate early-stage investment in start-up companies based on Center science and technologies

# Components of an Ag Innovation Ecosystem



## St. Louis Network of Collaborators



### INVENTIONS

Danforth Center  
Washington University  
University of Missouri  
St. Louis University  
Industry leaders



### TALENT

1,000+ Plant Science  
PhDs  
Education and Training  
Skilled Labor  
Culture  
Accelerators



### COMMERCIALIZATION/ BUSINESS SUPPORT

BioGenerator  
Danforth Technology Company  
CATALST  
EAGIC  
GlobalSTL  
SBDC  
T-REX  
Yield Lab  
World Trade Center



### FUNDING

Advantage Capital  
Arch Grants  
Bayer Grants4Ag  
BioGenerator  
Bunge Ventures  
Capital Innovators  
Cultivation Capital  
Leaps by Bayer  
Lewis & Clark AgriFood  
Lagomaj Capital  
Missouri Technology Corp  
Rabo Agrifinance  
Tech Accel  
Yield Lab  
Wells Fargo IN<sup>2</sup> Innovation  
Incubator



### ACCESS TO MARKET

Within 500-mile radius, 50%  
US ag production  
\$88 Billion MO industry  
National HQ of:

- National Corn Growers
- American Soybean Association
- United Soybean Board
- WISHH
- US Soybean Export Council
- US Farmers & Ranchers in Action



### INFRASTRUCTURE

Laboratories; Greenhouses; Plant Transformation; Proteomics;  
Data Science; Phenotyping, Advanced Biolmaging; BRDG Park;  
Helix Center, BioGenerator Labs; 39 North

# BRDG and EDGE@BRDG



270,00 square feet

12 enterprises

St. Louis Community  
College lab technician  
training program



## BENSON HILL

- Danforth Center spinout – co-founded by Todd Mockler, PhD
- CropOS® combines AI and genetics to deliver consumer-centered crops, faster!
- Went public on NYSE September 2021 in \$1.35B deal! #BHIL



# Wells Fargo Innovation Incubator (IN<sup>2</sup>)

- Launched in 2014, the IN<sup>2</sup> is now a \$50 million program supporting innovative technologies and innovators
- IN<sup>2</sup> is a research collaboration that **leverages the capabilities, facilities, equipment, and expertise** of the National Renewable Energy Laboratory (NREL) and the Danforth Center to **help early-stage companies de-risk technologies and speed their path to market**
- Since DDPSC became a participating research institution in 2019, 16 AgTech companies (5 in STL) have collaborated with our scientists





# Impact

- IN<sup>2</sup> companies receive \$250k in non-dilutive capital: \$200k for technical assistance and \$50k for project support
- **Since 2019, the 16 AgTech cohort companies have demonstrated a 57% growth rate**
- Collectively they have raised \$94M since participating in IN<sup>2</sup>
- IN<sup>2</sup> companies benefit from the program's expansive professional network and the prestige of working with world-class scientists at the Danforth Center and NREL



# Subterranean Influences on Nitrogen and Carbon (SINC) Center



Develop technologies to decrease the use of nitrogen fertilizer by 12% without the loss of crop productivity

Synthetic nitrogen is a major contributor to climate change and pollutes the environment

Growers apply 22 million pounds of nitrogen fertilizer to crops in the U.S. annually

Nitrous oxide, a greenhouse gas released from agriculture fields, is nearly 300 times more potent than carbon dioxide!





# Center for AgTech and Applied Location Science and Technology (CATALST)

Intentionally pairing our region's AgTech and Geospatial clusters to scale innovation-based entrepreneurship

- Source Innovation
- Conduct proof-of-concept research to validate technology readiness
- Provide an affordable skilled workforce to advance R&D
- Guide entrepreneurial activity and business growth
- Link innovators to growers as pilot customers
- Foster a diverse innovation economy

**\$1.5M EDA Build to Scale Grant**

## **PARTNERS**

Danforth Plant Science Center,  
BioSTL and T-REX

# The 39 North Innovation District

Bayer Crop Science

Helix Center

Danforth/BRDG Park

Benson Hill

39°N

- A 600-acre area of mixed-use activity and development
- Anchored by Danforth Center, BRDG Park, Helix Incubator, Benson Hill, Bayer Crop Science, The Yield Lab, and others
- Enhances our region's ability to grow, attract, and retain top talent

Learn More [39NorthSTL.com](http://39NorthSTL.com)

# Helix Center @39N

- Opened 2012 with a grant from Economic Development Agency (EDA)
- 33,000 square feet of office and lab space for start-up companies in AgTech and Biomedical
- Approximately 25 companies
- Low-cost lab & office space to grow early-stage start-ups, which are then expected to move into other space into the 39N District
- Plant tissue culture and transformation capabilities
- Will be used by students at St. Louis Community College as part of new teaching program



# St. Louis 2030 Jobs Plan

- Investment in biosciences over 20 years is proof point of past success and “**reason to believe**” in our future
- STL is at the nexus of three emerging next generation sectors – **AgTech**, Geospatial and Fintech
- **STLCC Biotech Training Program** targeted for expansion
- Action Plans for an Entrepreneurial Surge, Talent Surge and “**Quadrupling down on biosciences**” are all priorities that align with the mission, vision and strategic goals of the Danforth Center



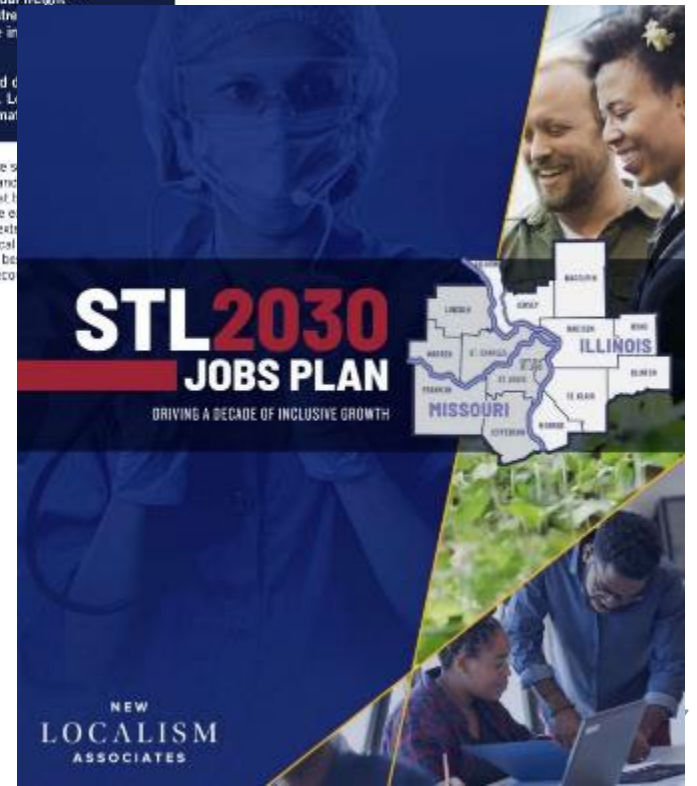
## 5. Make the St. Louis Metro a Hub for Next-Generation Industries and Technologies

### Actions

- Quadruple down on bioscience in order to supercharge this established industry cluster
- Implement the GeoFutures Strategic Roadmap and build a National Center for Location Sciences (NCLS) near Next NGA West
- Construct an Advanced Manufacturing Innovation Center (AMIC) to drive innovation and support area manufacturers
- Invest in multimodal freight infrastructure to strengthen metro's advantage in and T&L
- Expand transit and better connect St. L opportunities no ma

Advanced industries—those that invest in R&D and exports and pay—offer great economies. With high value and a wage premium that extends to technical as well as technical industries offer metros the best sustainable and inclusive eco

## Three Next-Generation Sectors



# Danforth Center as an Economic Engine





DONALD DANFORTH  
PLANT SCIENCE CENTER

Learn More at [danforthcenter.org](http://danforthcenter.org)



## Panel Discussion

*Converging Expertise and Perspectives / Breakthrough Innovations / Imagining the Future of the Industry*



**John Gottula Ph.D.**  
SAS Institute



**Wayne Honeycutt Ph.D.**  
Soil Health Institute



**Karen LeVert**  
Ag TechInventures  
Pappas Capital



**Deborah Thompson Ph.D.**  
NC State University



**Laura Westby J.D.**  
Oerth Bio



**Panel Discussion**

***Converging Expertise  
and Perspectives***



Panel Discussion

# *Breakthrough Innovations*



**Panel Discussion**

***Imagining the Future  
of the Industry***

***Thank you.***

**Flad**