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# LANL-USDA Tim Widmer, Meet and Greet

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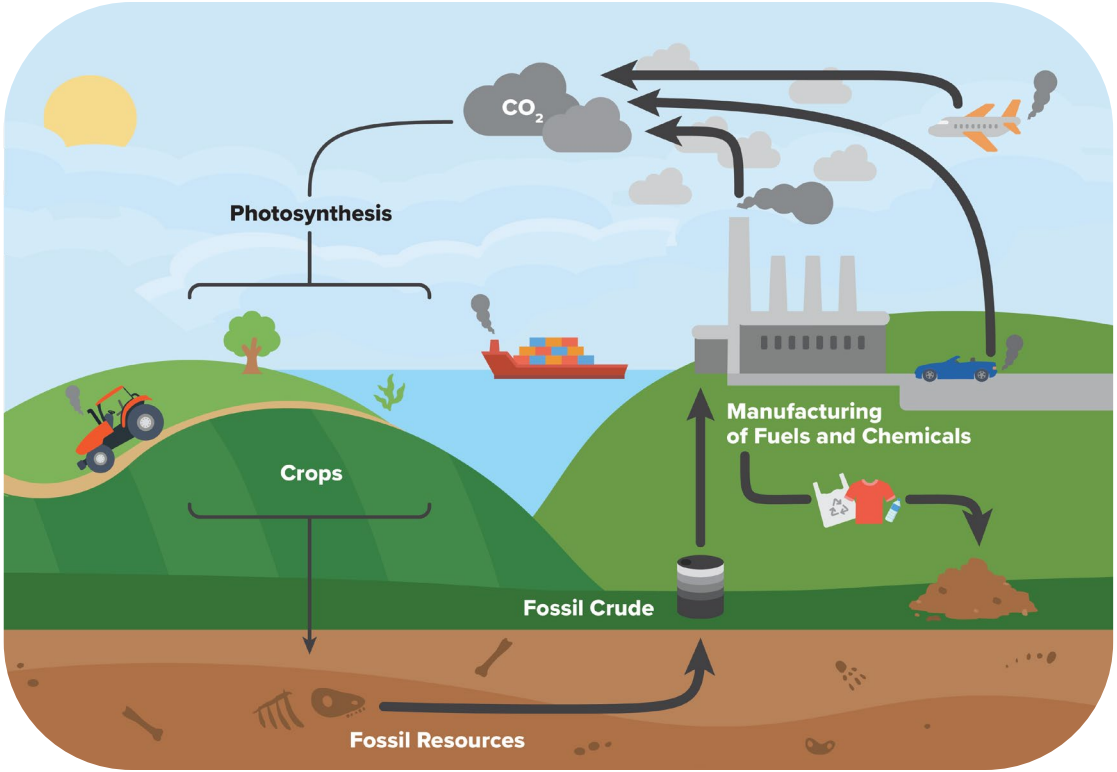
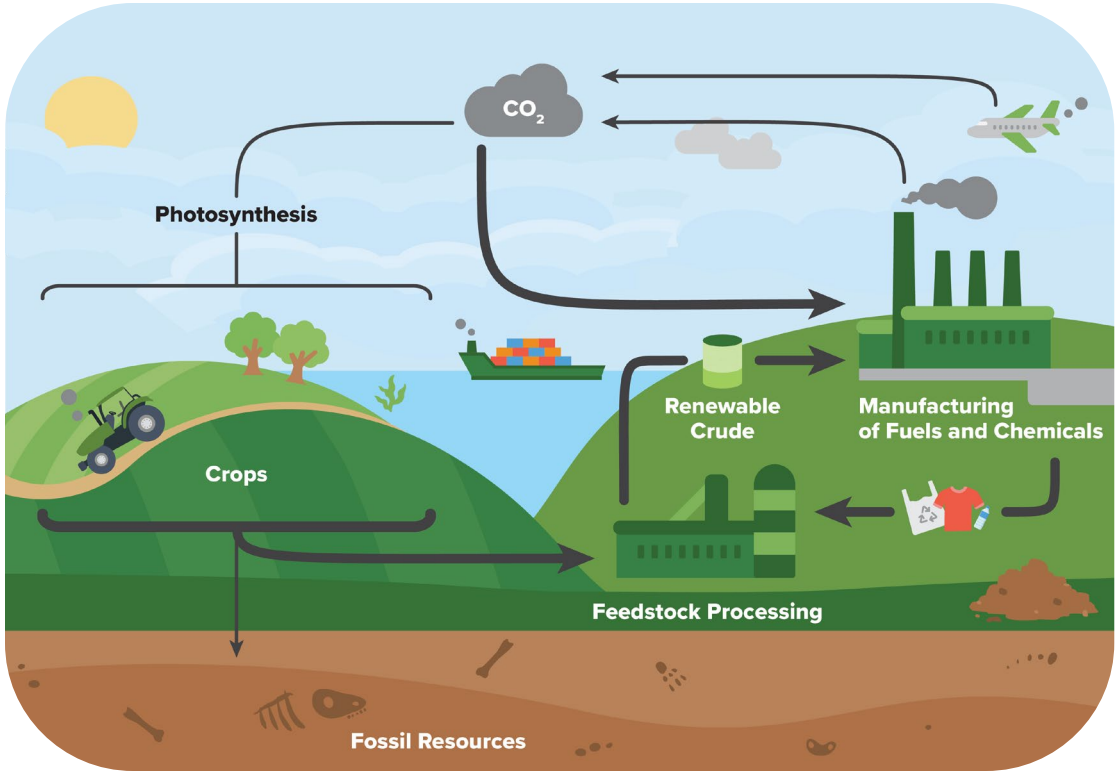
November 17, 2022

# Carbon is intricately tied to national and global security




- Carbon as a resource is connected to global events
  - Geopolitical
  - Climate

# Rebalancing and increasing our domestic carbon supply

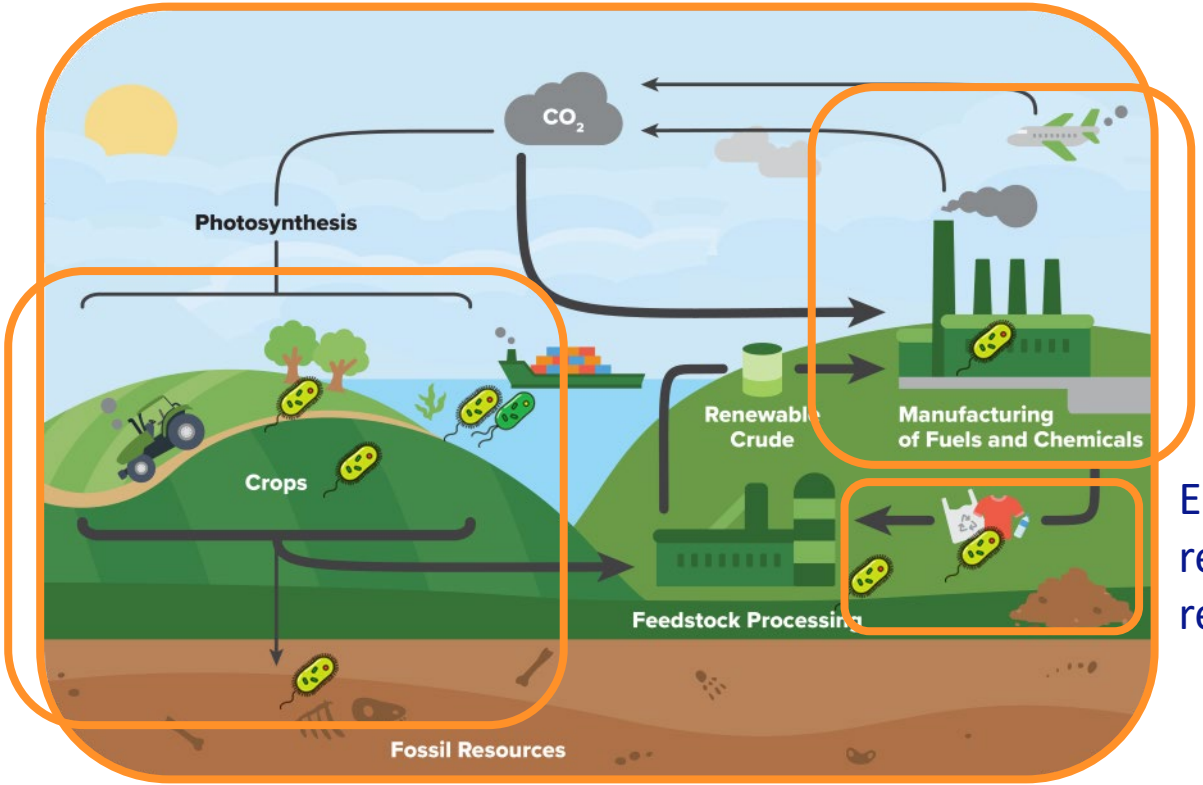



*Enable our energy, environmental, and economic security by developing a scientific understanding of, and approaches for manipulating, how carbon moves through natural and engineered biological systems*

Sustainable carbon cycling is an important underpinning of the bioeconomy

# Four primary research areas

Plant, soil, algae productivity & resilience



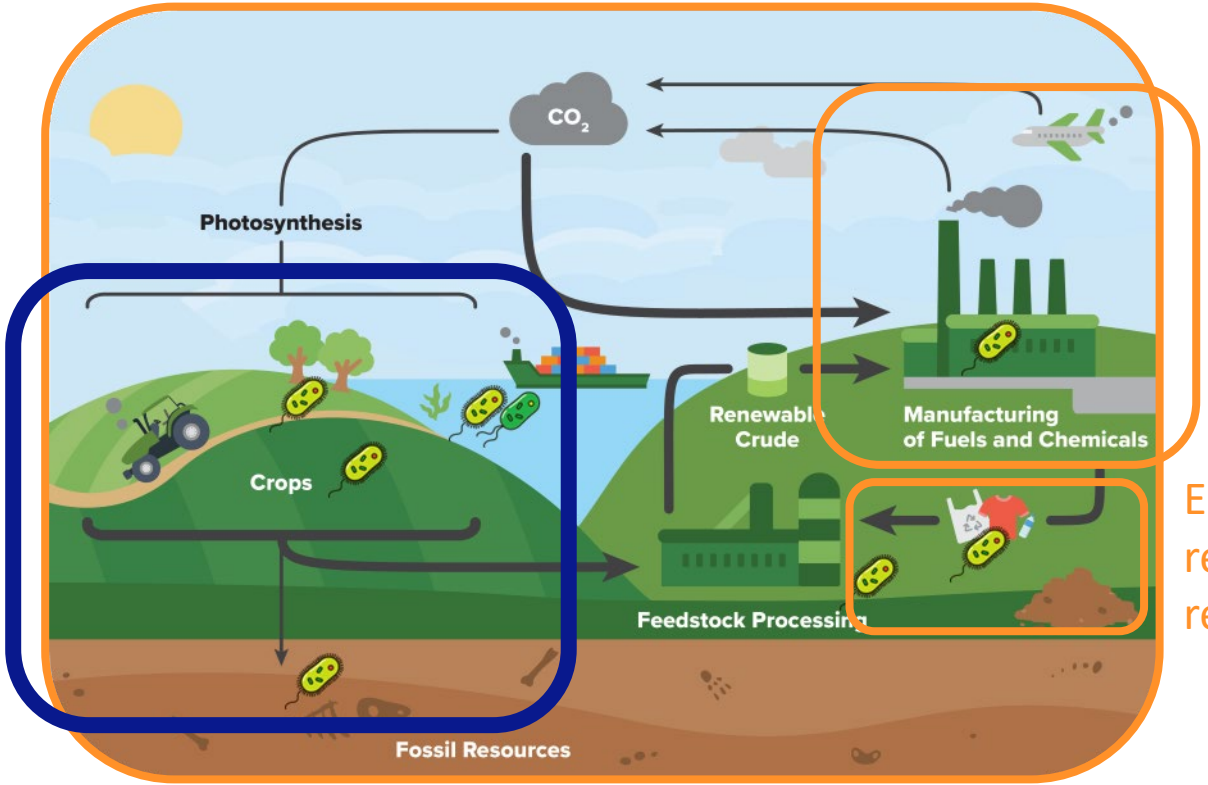

Biomanufacturing

Environmental restoration and recovery

Modeling, analysis, and place-based solutions

# Four primary research areas

Plant, soil, algae productivity & resilience



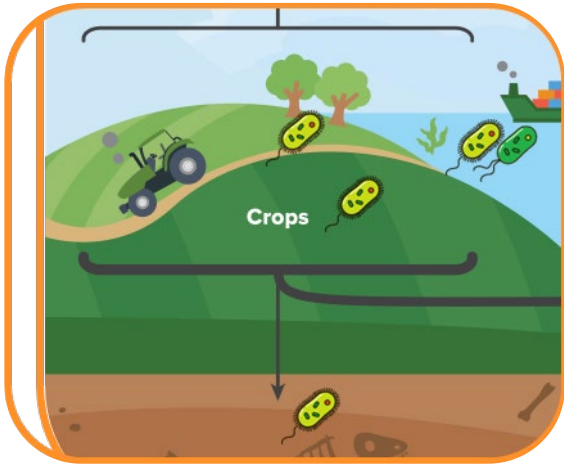

Biomanufacturing

Environmental restoration and recovery

Modeling, analysis, and place-based solutions

# Why biological (and specifically microbial) systems?

- Microbes are nearly everywhere
  - Land, air, and “sea”
- Significant influence on our lives and the environment
  - Critical roles in elemental flux in the atmosphere and on Earth (C, N, P, etc)
    - Agriculture, ecosystems, climate
  - Pests/pathogens
    - Crop, animal, and human health
- Not your standard *E. coli* or yeast
- Relatively simple in structure, but complex in diverse metabolism and communities
- Potential to use far beyond beer, cheese, and pharma
  - Crop solutions, biomanufacturing



# Relevant LANL Capabilities

## Microbial & fungal sciences

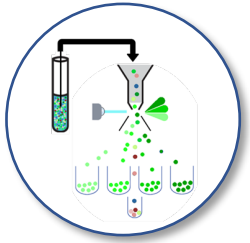
*Single cells to biomes, natural & engineered systems*

## Plant & soil sciences

*Carbon management, nutrient & stress tolerance*


## Environmental simulation

*Aquatic & terrestrial, outdoor harmonization approaches*



## High throughput screening

*Assay development & application*

## ‘Omics data & analysis

*Meta-’omics, sequencing & analysis tools*

## Modeling & decision support

*Machine learning, epidemiology, sustainability*

**Plus: Testbed & field partnerships, marginal land emphasis**

# LANL plant science capabilities and plant:microbe evolution

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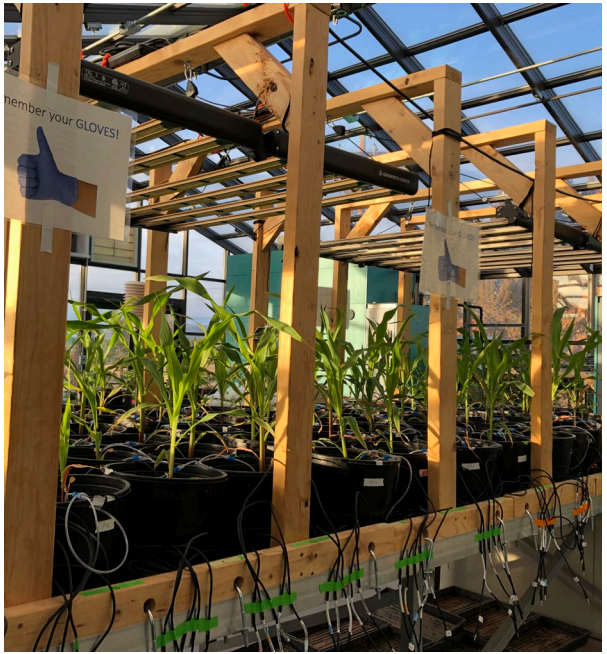
Tim Widmer USDA visit, November 17th, 2022

# LANL Greenhouse capability





# Temperature, light, $CO_2$ and humidity control

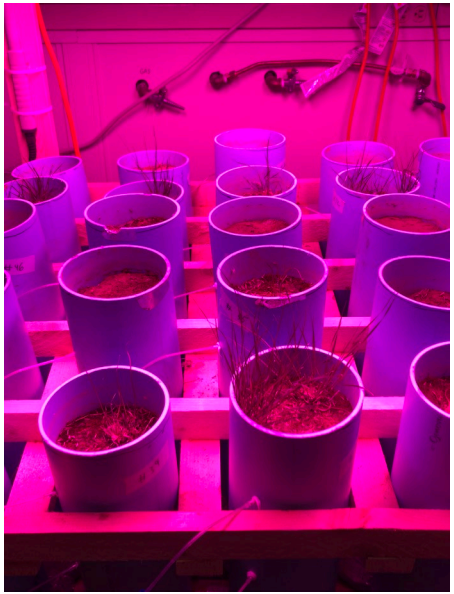
# Experimental Capabilities

Microbial inoculations

Isotopic labeling

Natural soil hydrology

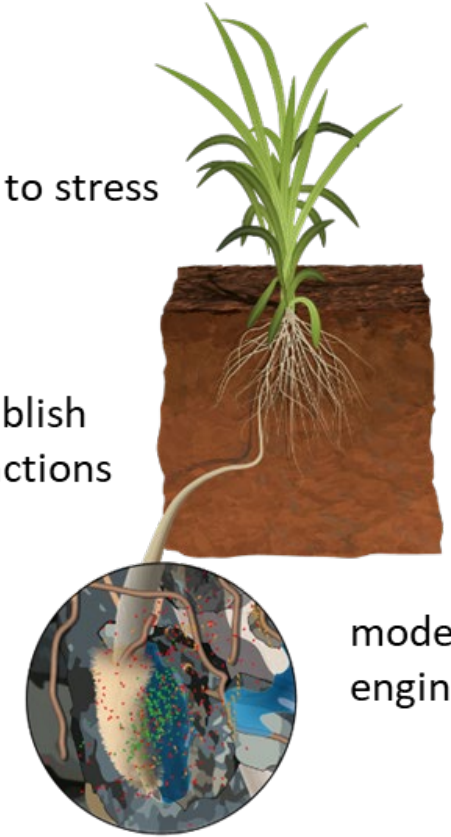
Natural soil stratification



# Plant:microbe interactions: Towards improving and engineering plant resilience productivity

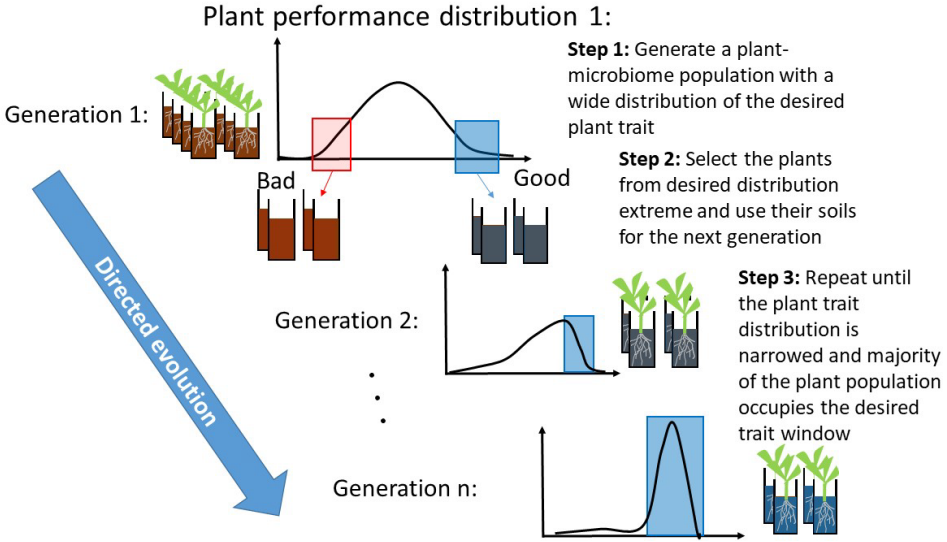
provide resilience to stress

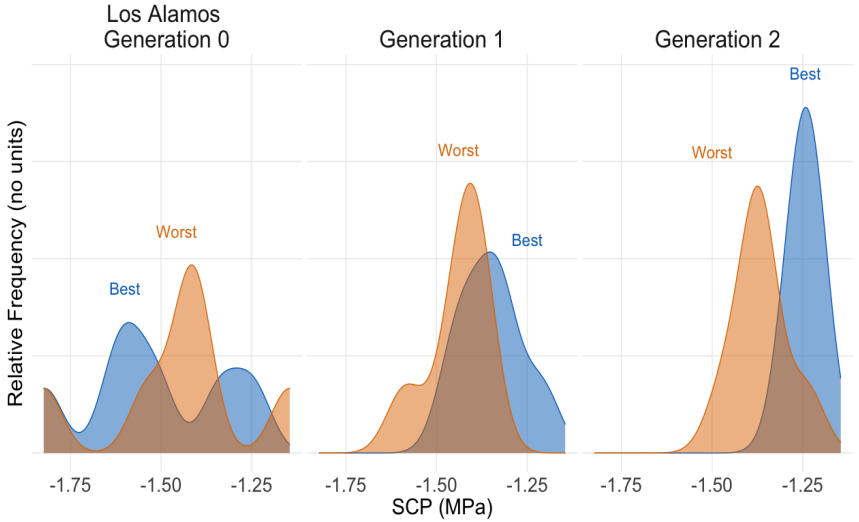
signals that establish beneficial interactions



modeling interactions with engineered microbiomes

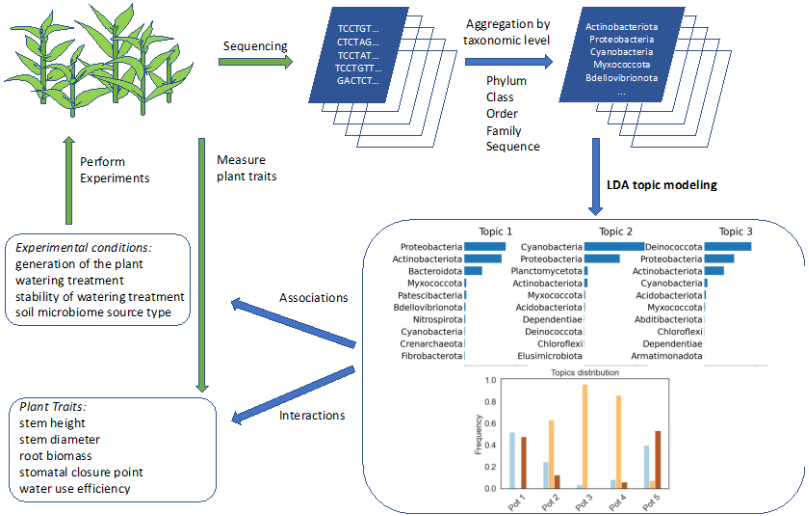
# Directed plant:microbiome evolution to control plant function



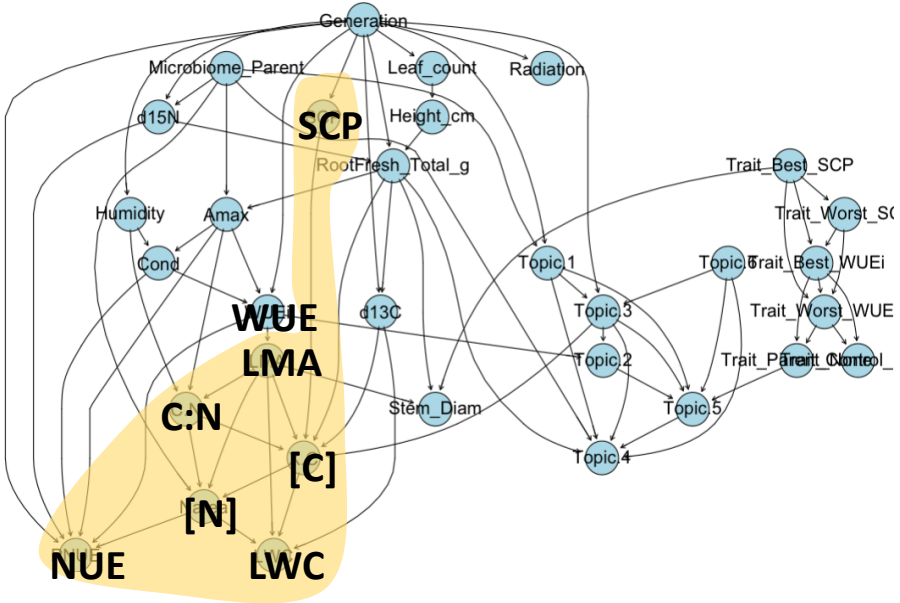



# Machine learning to understand complex systems

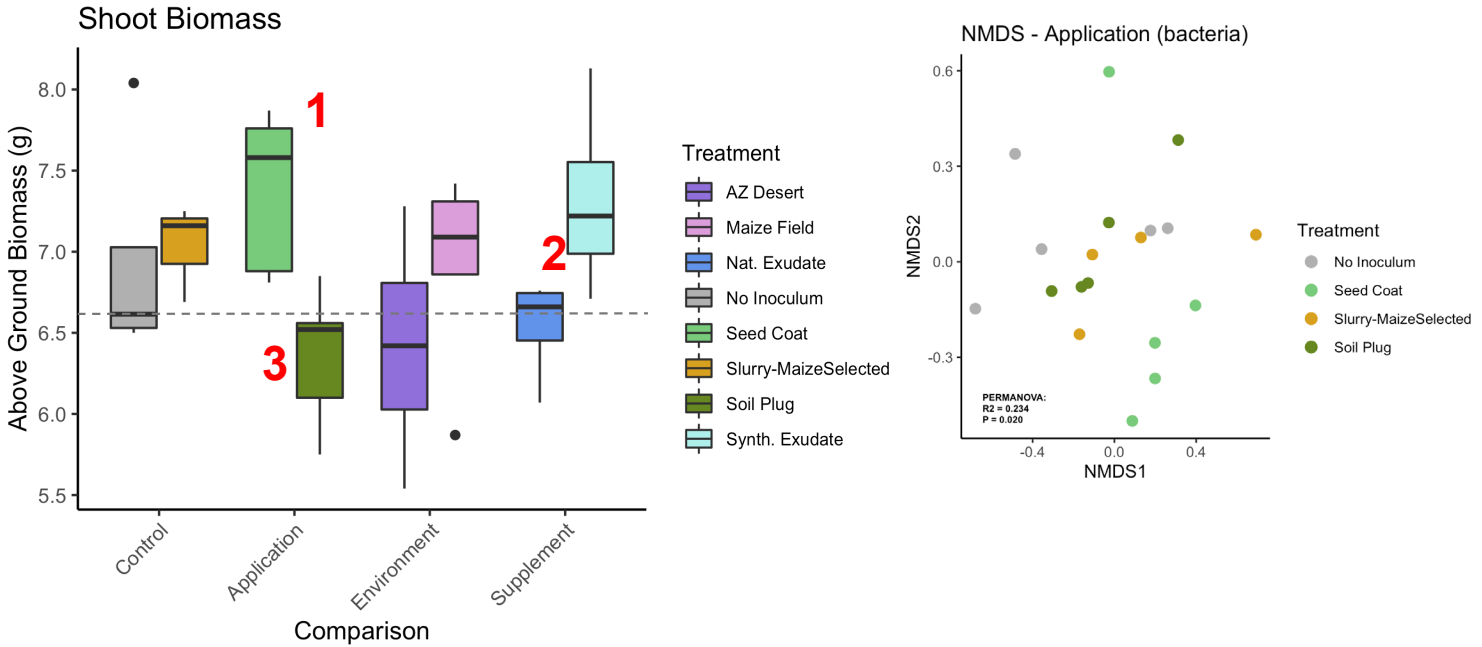
## Dimensional reduction using Latent Dirichlet Allocation




## Non-linear interactions with Probabilistic Graphical Modeling



# Microbial inoculations in natural soil from USDA-ARS Fort Collins




- Test conduced in the greenhouse in natural soil, with wick systems providing natural hydrology & in the field at USDA ARS Fort Collins, CO field site
- Inoculum application method matters: Seed coating or soil plug perform best
- Results pending from the field

# Plant growth promoting microbes

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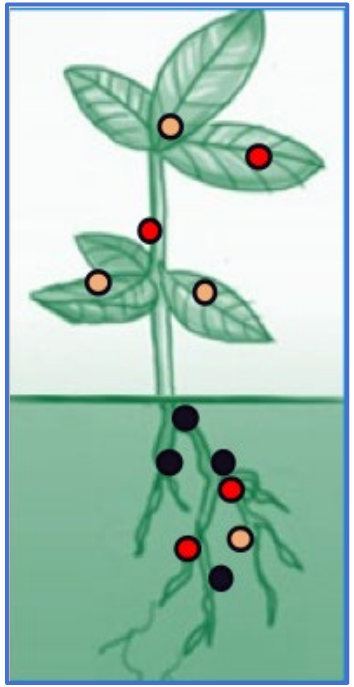
Tim Widmer USDA visit, November 17th, 2022

# Why Plant Growth Promoting Microbes (PGPMs)?

**Factors affecting plant growth**

1. Biotic: Bacteria, fungus, and insects
2. **Abiotic: Salinity, drought, temperature, and pH,**

***Camelina sativa***



**How can beneficial endophytes help?**

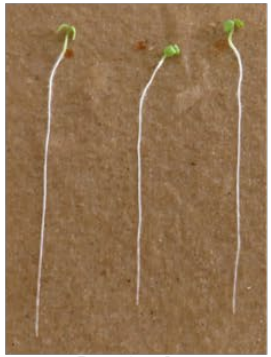
**Biofertilizers/biostimulants/ biopesticides**

- **Growth promotion**
- **Yield enhancement**
- **Stress tolerance**
- **Nutrient availability**
- **Biocontrol**
- **Eco-friendly**

- Multipurpose oilseed crop (jet fuel and edible oil)
- Cash cover crop
- Collaboration with USDA-ARS Maricopa

# Development of high throughput root phenotyping method

**20 bacterial endophytes screened, 5 best performing endophytes selected, 4 combinations tested (1000 seedlings screened)**

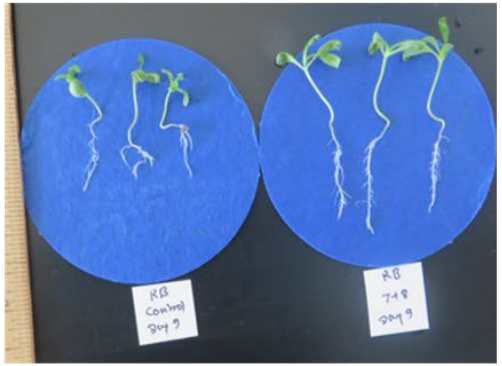


Control

Treated

Auxin overproduction


Individual and combined endophyte effect on root phenotype

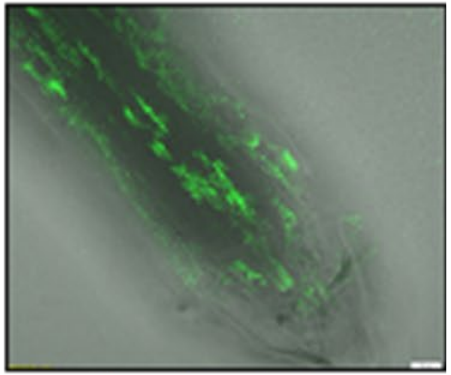



Effect of a consortium (5 endophytes) on root phenotype

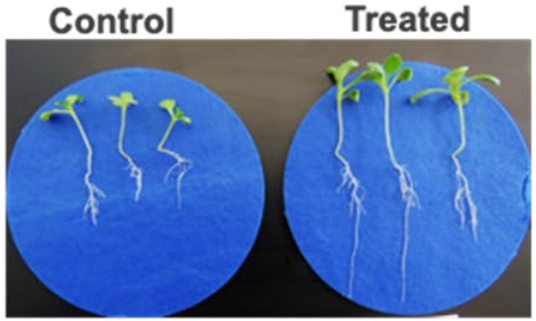
- Endophytes with ability to modulate plant hormones can significantly alter root phenotype
- Selected endophytes were effective in two different Camelina cultivars

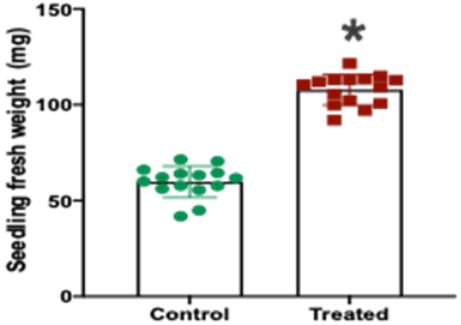
# Proof of concept: Improvement in growth

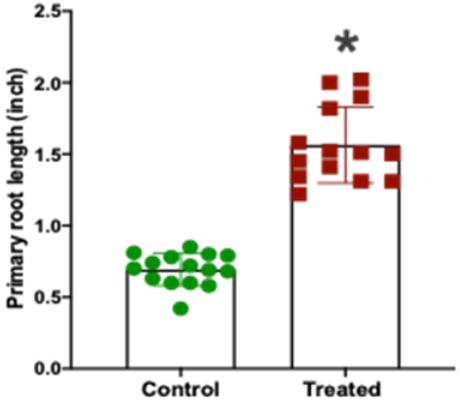
***Beneficial endophyte consortium improved root phenotype and overall seedling growth in Camelina***

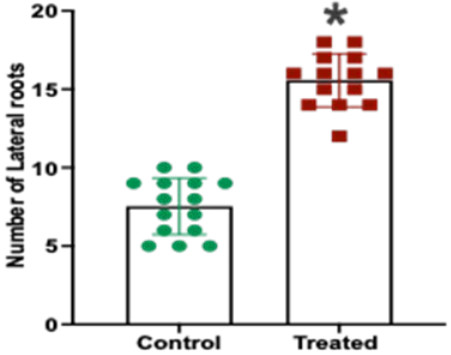


Root Colonization




**The average and SD of 15 seedlings are reported, and significant differences (a Student's t-test determined *) between Control and treated, P < 0.0001. Seedlings were grown on agar plates after seed treatment with endophytes**



https://discovr.labworks.org/

# High throughput, imaging, and ‘omics tools

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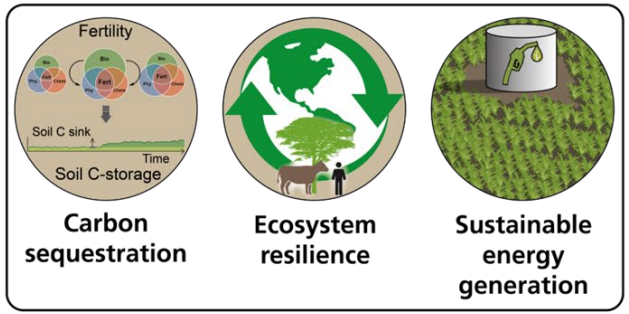
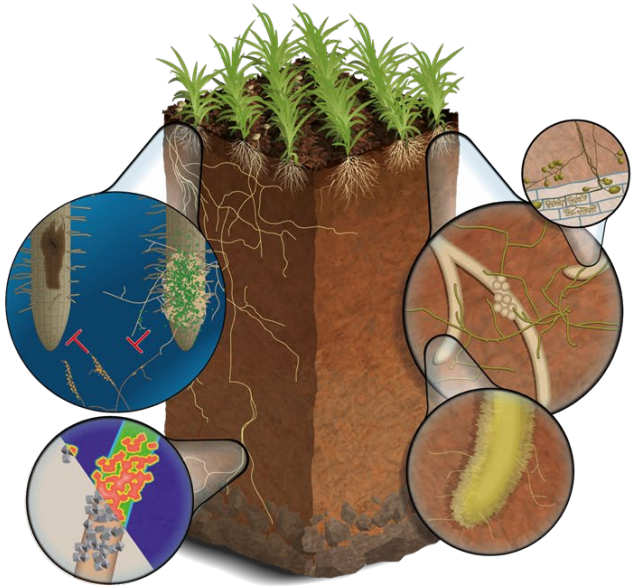
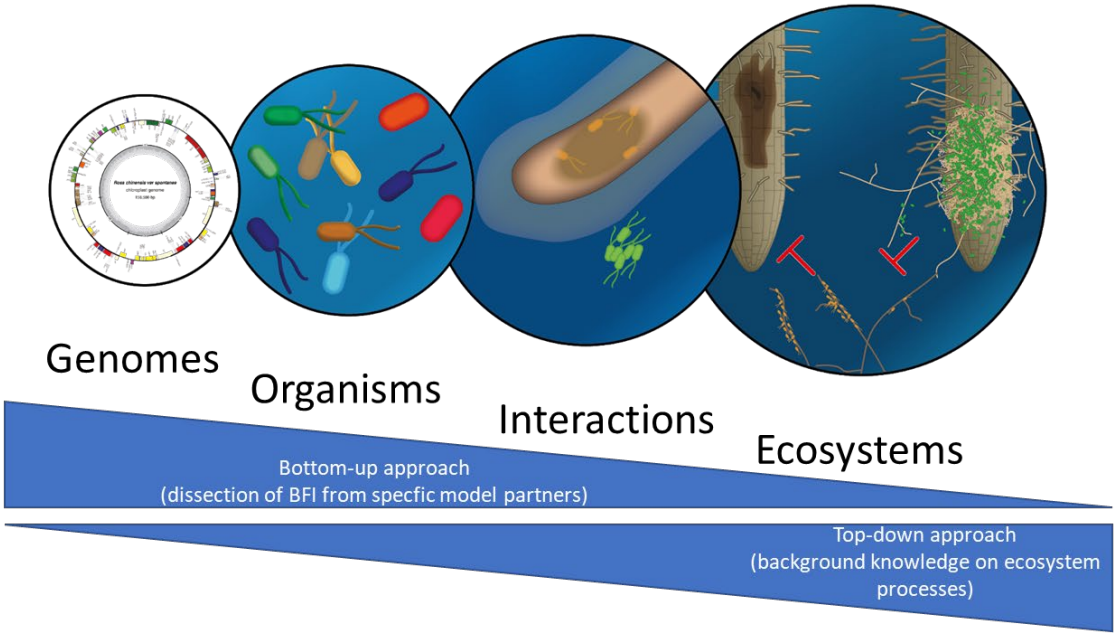
Tim Widmer USDA visit, November 17th, 2022

# Addressing DOE priorities studying bacterial-fungal interactions (BFI) – DOE Science Focus Area

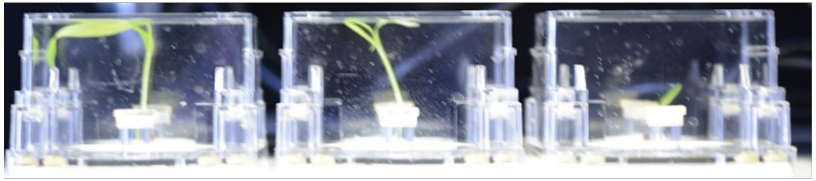


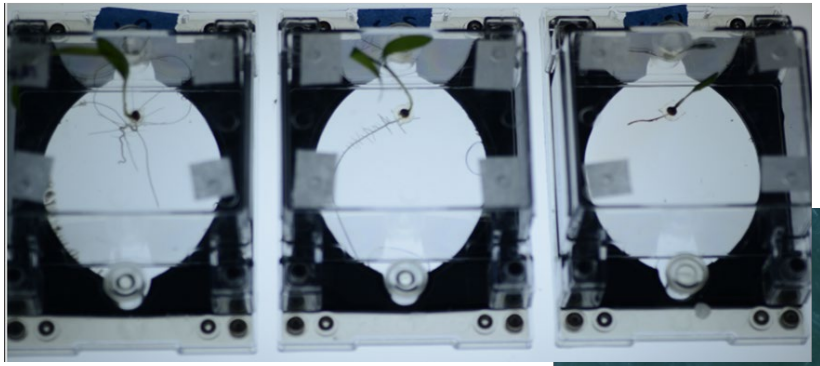





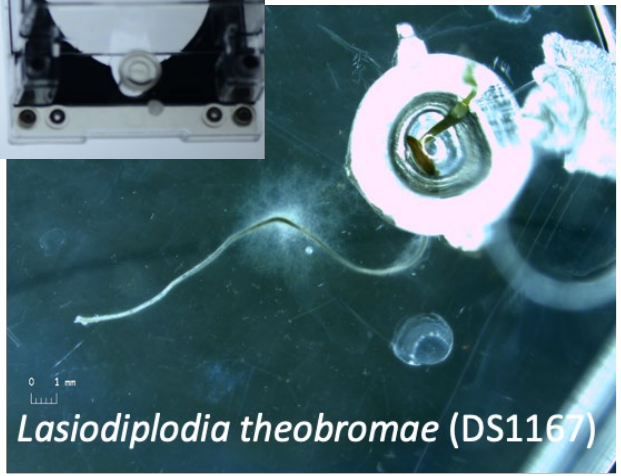
# High throughput tools for phenotyping and imaging

Quantifiable plant phenotypes under stress conditions in EcoFABs





Visualizing spatiotemporal plant-microbe interactions using isolates and defined consortia




Sevilleta LTER
lternet.edu/site/sevilleta-lter/

Experimental system for arid and marginal lands.

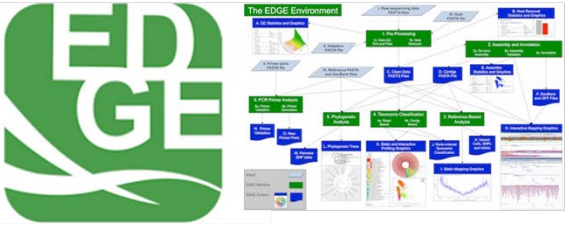
Blue grama as model grass for heat and drought tolerance.

# Bioinformatics tools with standardized workflows

User-friendly and publicly accessible

nmdc National Microbiome Data Collaborative

microbemetadata.org




edgebioinformatics.org

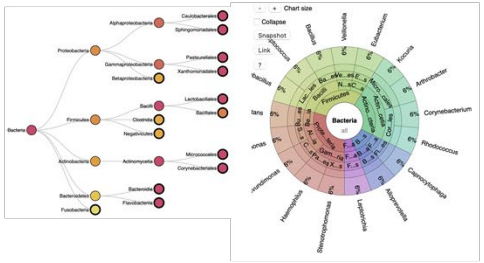

sfa-bfi.edgebioinformatics.org

Establishing and promoting standardized methods for microbiome research

- developing best practice algorithms for microbiome data analytics
- bridges with national facilities (e.g., JGI, EMSL), harmonize workflows, metadata, and -omics data management
- working with a broad array of partners such as funding agencies and societies (NSF, NASA, ASM) and institutions (NCBI, ICTV, SeqCode, GSC, IMMSA, etc.) to establish concrete metadata and analysis standards

EDGE: Empowering the Development of Genomics Expertise

- fully integrated web-based bioinformatics platform
- user-friendly and interactive interface accessible to the larger scientific community
- established pipelines and spearheading quality control in COVID-19 genome analyses, transitioning and poised for biosurveillance of future pandemics




- publicly available repository of known fungal-bacterial associations
- input sourced from fungal genome SRA data
- interactive, publication-linked

# Emerging efforts

- Moving GPGMs into EcoFabs and greenhouse
- Coupling EcoFabs to downstream HT screening tools
- Use of hyperspectral data to track microbial applications and nutrient use
- Biochar, alone and coupled to microbial applications, with an emphasis on arid and semi-arid soils
- Application of epidemiological models and decision support tools to plant disease spread