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Phytobiomes: Laying the Foundation for Next Generation Agriculture

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Microbiome For Agriculture Virtual Conference
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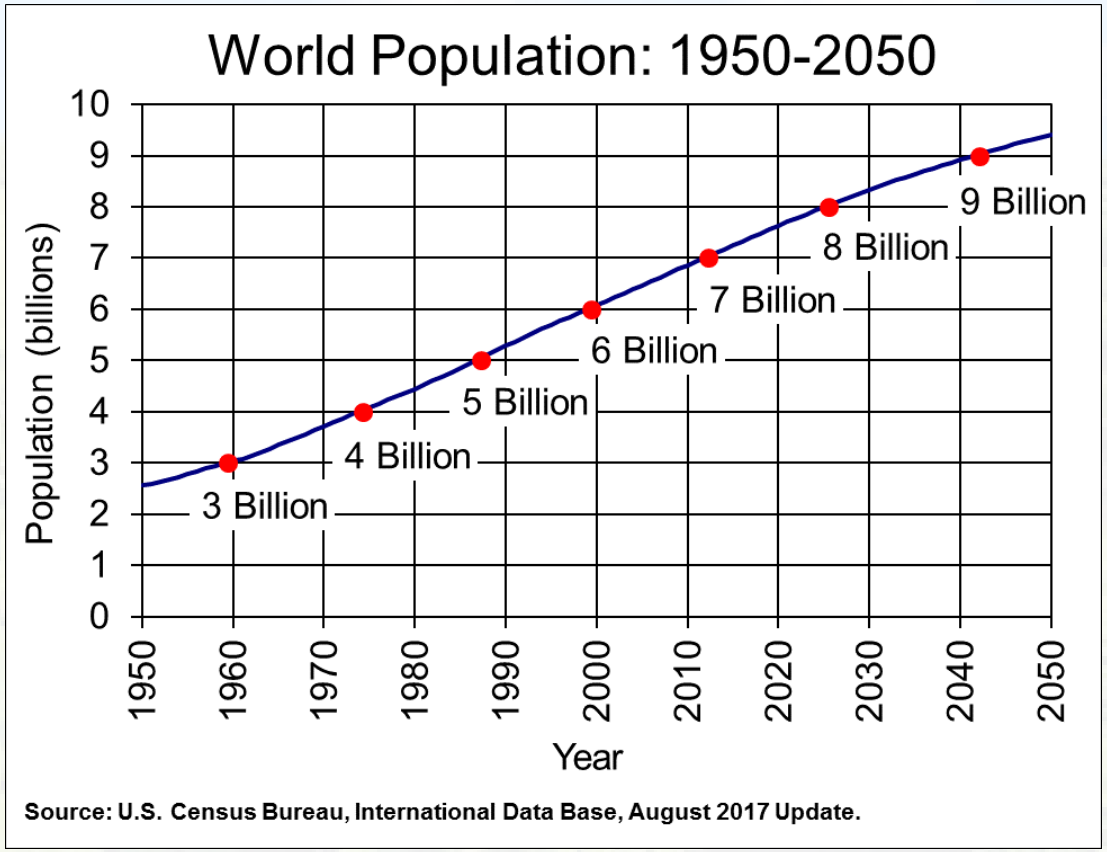
INTERNATIONAL ALLIANCE
FOR PHYTOBIOMES RESEARCH

A nonprofit consortium of industry, academic, and governmental scientists

The Challenge



- Insufficient productivity growth
- Limited land
- 28 Growing Seasons
- Desire for Sustainability

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Moving From Simple to Complex

Traditional science approach

- Reductionist
- World is linear and can be understood by focusing on individual components
  - Soils
  - Plant genetics
  - Microbiomes or
  - Weather

Reality – agriculture is a **complex system**

- non-linear organization
- governed by multiple non-linear interactions and environmental variables
- adaptation via learning or evolution
- it can be influenced

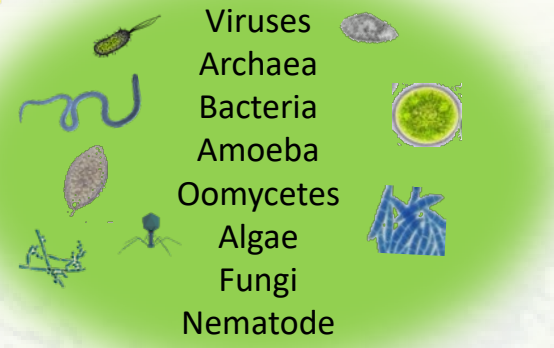
Paradigm shift to a systems approach – the phytobiome

Phytobiomes: Complex Systems of Plant-based Agriculture

“Phyto-” = Plant

“Biomes” = Site specific environments

Climate, Weather, Water



Microbiomes and Macroorganisms/Macrofauna

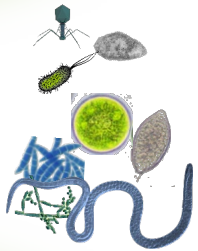
Arthropods, Other Animals and Plants

All influenced by Management Practices

Phytobiomes: Management Context

Crop choices
Species Cultivar
GMO/Non-GMO

Monoculture
Cover crops
Crop rotations



Inputs
Fertilizer type, rate
time & place

Herbicides
Insecticides
Fungicides

Site choices
Irrigation Tile drainage
Livestock Mgt

Till/No-till
Planting time
Harvest time

Holy Grail for Phytobiomes

To understand, predict, and control emergent phenotypes within specific phytobiomes for the sustainable production of food, feed, and fiber

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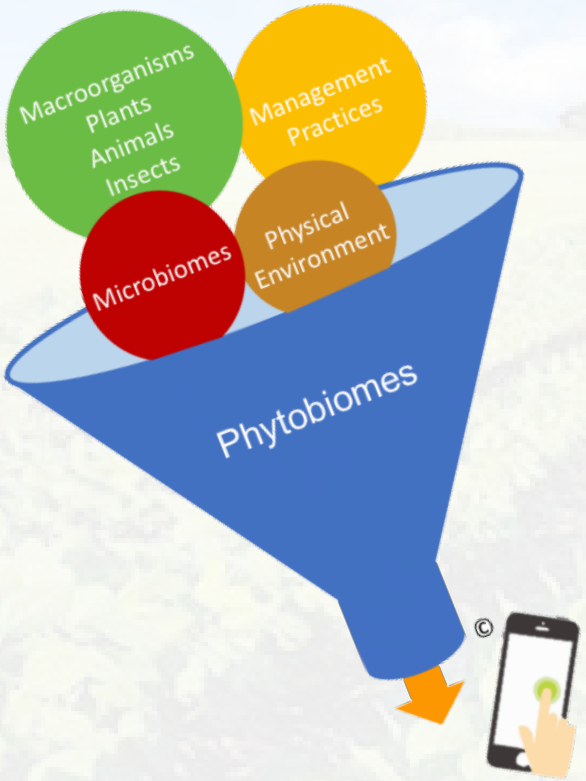
Phytobiomes Alliance Vision



By 2050, all farmers have the ability to use predictive and prescriptive analytics based on geophysical and biological conditions for determining the best combination of crops, management practices, and inputs for a specific field in a given year.

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Phytobiomes Vision for Agriculture

- Sustainability index for a specific farm, forest, or grassland
- Adaptive, data-driven, on-farm systems for managing phytobiomes for optimal sustainability and productivity
- Plants that select for beneficial communities
- Biologicals as indicators/predictors of crop and soil health
- Novel and improved management practices
- Biological information ranging from plant genetics to microbial communities incorporated into the next generation of precision/digital agriculture technologies
- Crops with increased resilience to abiotic and biotic stress

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Phytobiomes Vision for Agriculture

- Full integration of biologicals into site-specific crop management
- Crop variety/hybrid, microbial communities, nutrient stewardship, and pest control practices that are best suited for sustainable agricultural production of a particular site
- Degraded and depleted lands effectively rehabilitated globally through optimization of microbiomes for soil health and appropriate plant selection
- Rapid, inexpensive diagnostic tools available for growers to empower real-time management decisions and concurrently increase the depth of data for predictive analytics
- Increased profitability of sustainable food production

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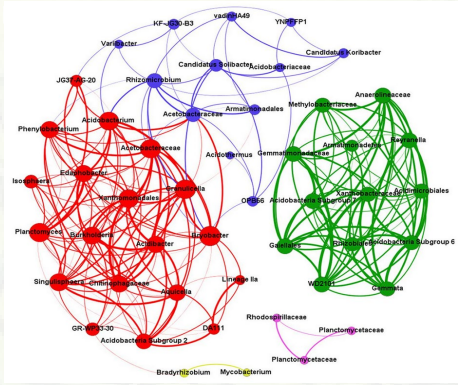
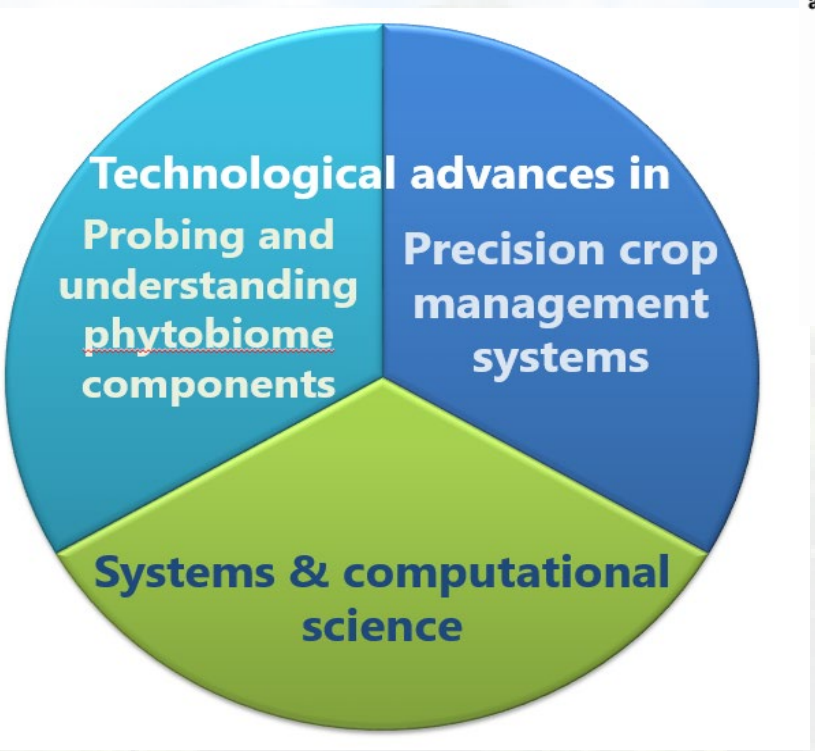
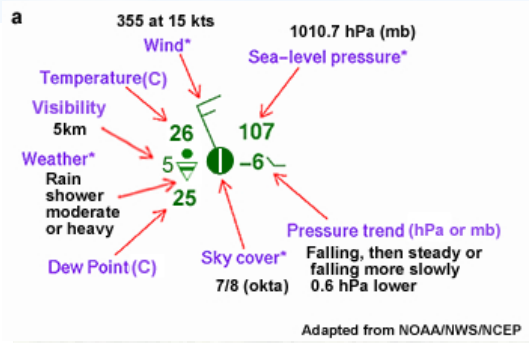
Why Now?

Convergence of need & opportunity







Advances in assessing microbiome components

Genome-enabled technologies

Amplicon sequencing

Metagenome sequencing

Meta-transcriptome sequencing

Meta-proteome analysis

Metabolome analysis

Species (taxa) number, abundance, composition

Community function

Community activity

"Who is there?"

"What can they do?"

"What are they doing?"

Phytobiomes: Major Research Gaps

Microbiomes

Climate, Weather, Water

Arthropods, Other Animals and Plants

Management Practices: Precision Agriculture

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Research Priorities

- Enhanced understanding of the interactions between plants, microbiomes, and other components of phytobiome systems
- Cost-effective in-field sequencing platforms and weather sensors
- Databases that support correlation and network studies of site-specific and temporal geophysical and biological data
- Cryopreservation methods for entire microbial communities
- Stabilization methods for Gram-negative bacteria for large quantities of seed with on-seed stability of 120 days
- Effective microbiome transplant methods for field use and controlled environment systems

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Research Priorities

- Simple, simulation models that are functionally accurate to real world complex conditions
- Trait- and gene-based microbial genomics datasets
- Integration of microbial data with databases and equipment used in precision agriculture
- Artificial intelligence methods for microbial and microbiome annotation and gene prediction
- Machine learning and deep learning tools for understanding networks
- Systems level predictive and prescriptive analytics for on-farm implementation

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Short-term Regulatory Science Priorities

- Research that supports streamlined regulatory pathways
- Consensus risk assessment methods to establish the safety and efficacy of microorganisms
- Microbial genome sequence-based classification & risk prediction systems
- Databases of public & private microbial genome and metagenomic sequences (WGS, 16S, ITS)
- Standards, protocols, check-lists (minimum information, sampling, reference datasets, regulatory requirements, WGS quality…)
- Census of microbes by state, province, region, and country
- Machine learning methods (e.g., NLP) for scientific literature (biology, mode of action, stability, related studies….)

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Longer-Term Priorities

- Science to support commercialization of microbial communities that include uncultured microbes and genetically engineered microbes
- Artificial intelligence, machine learning, and deep learning approaches which could support research, regulatory review, and commercialization of microbes, microbial communities, and genetically engineered microbes
  - ✓ E.g., Predictability of diseases and product performance
- Complex models that can be used to substitute field trials while taking into consideration the effect of the entire phytobiome

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Success Depends Upon

- Efficacious delivery, storage, and monitoring of microbial products
- Clear descriptions of where, when, and how to utilize microbial products
- Standards, protocols, check-lists….
- Sequence-based microbial classification systems
- Clear regulatory pathways for microbial-based biostimulants, biopesticides/biocontrol agents, biofertilizers, and plant varieties/hybrids
- Decreased time and requirements for regulatory approvals
- Transdisciplinary, public-private collaborations

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Areas of Progress

- Increased understanding of the various components of phytobiomes, especially within the plant/soil microbiome, plant/microbe interactions, and within and between the plant, microbiome, and environment
- Genome sequence-based classification system and risk prediction classification system for microbes
- Microbe sequence database that includes phenotypic data
- Draft standards, protocols, check-lists (minimum information, sampling, reference datasets, regulatory requirements…)

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Phytobiomes Conference 2022

September 2022

Denver, CO, USA

www.phytobiomesconference.org

Main Scientific topics

- Climate/weather
- Environmental Data Set
- Plant fitness
- Microbial community assembly and function
- Network analyses within the phytobiome system
- Modeling
- Data – framework, tools and resources, big data
- Genetic linkages
- Carbon sequestration
- Interactions within phytobiomes for abiotic stress
- Engineering microbes and microbial communities
- Precision agriculture/digital Ag
- Fertilizer, nutrient, and chemical input efficiency
- Product development
- Regulatory requirements
- Greenhouse & Field trials
- Industry research needs

International Alliance of Phytobiomes Research Sponsors

Thank you for your attention.

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