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Circular Bioeconomy Systems Institute

ASABE
Engineering a Sustainable Future

SUMMARY REPORT
of the
Farm Production Systems Workshop
a part of the ASABE 2024 Circular Bioeconomy Systems Workshop Series

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We would like to extend our gratitude and appreciation for the valuable insights and contributions from all of the participants during the Summit.

Table of Contents

Agenda

DAY – 1, MONDAY APRIL 1

11:00 am **LUNCH**

11:40 am **Opening Remarks** *(Jim Jones and Brahm Verma, 20 minutes)*
Setting the Stage: Motivation, Goals and Outcomes of this Workshop

Noon **Opening Keynote and Speakers**
Vara Prasad - *Grand Challenges, Concept of Circularity*
Ray Gaesser – *Experience of Using CBS Concepts on the Farm*
Ernie Shea – *Experience of Using CBS Concepts on the Farm*

1:00 pm **Program Overview and Plan of Action** *(Jan Middendorf, 15 minutes)*
- *Why are we here?*
- *What are you being asked to do?*
- *What will be the results from our time together?*
- *Ground rules*

1:15 pm **Guided Facilitation for CBS Farm Production System** *(120 minutes)*
SWOT analysis with participants on this topic:
- *Identifying Strengths*
- *Identifying Weaknesses*
- *Identifying Opportunities*
- *Identifying Threats/Barriers*

3:15 pm **BREAK** *(Tea/Coffee)*

3:30 pm **Clustering Exercise -** *(45 minutes)*
- *Identifying Key Themes*

4:15 pm **Reflections and Wrap-up -** *(45 minutes)*

5.00 pm **Adjourn**

6:00 pm **RECEPTION AND DINNER**

DAY – 2, TUESDAY APRIL 2

7:00 am **BREAKFAST**

9:00 am **Recap of Day 1** *(Organizers, 15 minutes)*

9:15 am **Developing Key Strategies (Deep Dive) for Themes** *(45 minutes)*

- *Plan of Action: What and How?*
    - *Research Questions*
    - *Actions/Activities*
    - *Recommendations*

10:15 am **BREAK** *(Tea/Coffee)*

10:30 am **Developing Key Strategies for Themes** *(90 minutes)*

- *Plan of Action: What and How?*
    - *Research Questions*
    - *Actions/Activities*
    - *Recommendations*

Noon **LUNCH**

1:00 pm **Address Cross-Cutting Areas per Theme** *(120 minutes)*

- *Economics and Life Cycle Analysis*
- *Education and Curriculum Development*
- *Outreach and Communication*
- *Inclusivity and Multidisciplinary*

3:00pm **Final Reflections – Participants**

3:30 pm **Future Plans and Closing Remarks**

4:00 pm **Adjourn**

Introduction

The Farm Production Systems Workshop on Circular Bioeconomy Systems laid groundwork to build a multidisciplinary-stakeholder research partnerships and, potentially, an alliance of members from various professional societies to address the following and other grand challenges facing agrifood systems. The circular bioeconomy aims to decarbonize economic activities, reduce greenhouse gases, regenerate soil health and water resources, produce nearly zero waste, eliminate or significantly reduce environmental degradation, regenerate natural systems, replace fossil carbon sources with biomass, increase food security and resilience, and to increase productivity and economic benefits. With that context for farm production systems, the workshop participants were tasked with two assignments: first, to envision transdisciplinary system-level solutions to modify the current linear systems into a more circular system of systems, and, second, to identify knowledge, techniques and skills needed through important multidisciplinary partnerships and systems approaches. Thirty expert participants (biosketches in Appendix K) spent two days in a facilitated discussion on the current status of these activities in existing agrifood systems.

The CBS-Farm Production Systems Workshop objective was to envision, then develop, an action plan for applying principles of circularity to transition the constituent agrifood and farming systems into sustainable circular bioeconomy systems. Experts were asked to critically assess the ecological, technical, economic and social barriers to advancing principles of circularity in farm production systems, as well as, to assess the degree to which circularity would be achieved in the four main systems in farm production – nitrogen (N) and nutrients, water (H_2O), carbon (C) and biomass, and energy. The key outcomes of this expert convening and assessment are, first, to recommend actions needed to achieve the envisioned circular bioeconomy systems needed for farm production and food systems and to analyze collective needs for new knowledge and research innovations from multidisciplinary stakeholders.

SWOT Analysis

Thirty thought leaders representing a wide range of disciplines and geographic areas in the world gathered in Chicago, Illinois, from April 3-4, 2024 (see appendix K for full list of participants). These leaders were tasked to create strategic plans to tackle gaps in global efforts to develop a circular bioeconomy for farm production systems. Focusing largely on cereal and production agriculture farming systems of the world, these farm production systems research experts conducted a SWOT analysis of the current state of circular bioeconomy systems in farm production globally. A SWOT analysis consists of four categories: strengths, weaknesses, opportunities, and threats. These categories can further be defined as either internal or external factors. Strengths and weaknesses are often internal to an entity. Opportunities and threats tend to be external factors, often beyond the control of the entity/organization, but that impact and/or influence operations.

Strengths

- New image for agriculture (youth)
- Improved economies
- Need for genetic resources/powerful tools for scientific intensification
- Guidelines, roadmaps, development

- More efficiency: reduce waste, lower input cost, increase value and greater ecosystem
- Technological solutions beyond productivity
- Farming system provides application of the one health system
- Optionality
- Social science is important working with communities and trust
- Farmers enjoy it
- Less waste
- Systems integration
- Thinking beyond waste and bi-products
- How health translates from soil to plant to human (efficiency factor CBS schemes)
- Reimagine/Rethink and regulations farming systems
- Delivering solutions to SDGs
- Reduced environmental impact due to lower losses/waste
- Co-develop
- Breadth of expertise interested in farming systems and wide range of technology
- Multidisciplinary engagements
- Opportunities for integration
- Taking a systems view
- Diverse partners
- Better impacts
- Create ecosystems services
- Higher resource use efficiency
- Diversity of sciences; responsibilities, authority to effect change; administration leaders, farmers, etc.
- Collection of systems thinkers from wide range of disciplines
- Additional value for products by-products
- Stimulate agricultural development
- Climate resilience, better impact, multidisciplinary engagement
- Farmer Experimentation
- Improved resiliency while climate is changing
- Problem for one system could be a solution for another system
- Reduced wastage and resource conservation
- Potential greater value to product
- Carbon negative possible
- Science foundation
- Resilience - buffer water scarcity e.g. drought, dry spell (scale-farm to basin aquifer)
- Farming systems is a natural framework for CBS. C, H_2O, nutrients, energy
- Positive environmental impacts
- Higher efficiency through a systems approach
- Circularity possible
- Food + feel + fiber + energy + ecosystem services
- Is major the economic engine for commerce/ economics
- More opportunities
- CBS timely conserving many pressing issues

- CBS potential large and long-term impact it implemented timely and complete
- Scalable to different countries, agriculture produce from systems, economics
- Improve resiliency
- Improve resource management
- Integrating conservation / sustainability with efficiency and profit
- Easy to measure circularity at the farm scale, hence more practical
- Opportunities for maintaining the farmscape
- Diversification of income at the farm-level
- Circularity in farm production systems can tackle almost all challenges of agri-fossil fuel systems all together
- Diversity
- Nutrient use efficiency and recycling
- Reducing waste, loss and pollution
- Positive Impact
- More resilience
- More local relevance; economics; buffered from global events
- Improve local rural economic event social conditions
- Large land areas engaged
- Crops resilient to minor weather, H2O, fertilizer challenges
- Crops with complementary farm ecosystem niches
- Existing innovation in product development tech to enhance seed value chain
- Using waste productivity to displace use of virgin materials and fossil fuels
- Be source for producing feed stock for creating products
- Increase environment health
- Local + regional - Examples providing impact that agricultural productivity improves livelihoods
- Global recognition that farming systems require new innovations
- Potential for reducing waste increasing productivity and contributing to environmental sustainability
- Ability to use natural recourses farm producing for basic human needs - integration systems
- Producers with engage in complex systems (economic, biophysical, social, political, etc.)
- Reduce risks to human health
- System complexity

Weaknesses

- High demands to get the system operating
- Technology/ framework availability emergence engineering
- Siloed science (rewards)
- Overextended. May necessitate privatization of fields / steps in making farm production system more circular
- Complexities of farming systems, diversity = they involve
- Lack of tools and mechanisms to transition
- Lack of policy support
- Finding a win-win situation for all involved actors could be challenging
- High variability in production systems is an embedded challenge

- Mismatch guidelines
- Overlapping indicators
- Data integrity
- Weakness in education in systems concept.
- Lack of integrated, models, data and assessment tools that help farmers, policy make discipline
- Integrating diverse perspectives can be challenging as it often proves difficult to build a consensus
- Current: short term decisions
- Market opportunities
- Tradition - aversion to change
- Aversion to change
- Transformation for adoption requires trust, education and economic returns
- Returns may be difficult to quantify or commodify
- Cost of pollution externalized
- Fear of facing a steep learning curve
- Others working against are more organized
- Access to resources, technology, and knowledge for farmers
- Temporal systems evolve with time
- Context-specific single solutions not always "scalable"
- Lack of data/genetic research
- Reach out to other groups for bi-products
- Lack of agronomic knowledge, adoption and strategies
- Data cycles or LCA
- Lack of policy incentives
- High cost of production/capital
- Acceptance (broadly)
- Models (integrated) crop - livestock - weather - C - energy - nutritional - water
- Difficult to quantify ecosystem non-monetary benefits
- Perspective of age being an exploitive activity; low trust
- Unique systems that prevent broad generalizations
- Gender equity in knowledge transfer
- Transition from short-term to long-term strategies
- Resources to operationalize
- Still at the concept levels. Need more real-life working examples
- Awareness of the impact of downstream workflows from output to input
- Non-aligned or conflicting policies
- Lack of evidence in profitability environmental benefits
- Market for non- commodity crops
- Will require many partners
- Siloed approaches not enough integration
- Incentives farmers resources unfit capital
- Access to capital necessary to argument or change current farming system
- Lack of niche market

- May impose upfront private costs that discourage adoption, though they provide long-term benefits
- Farmers are not being valued as co-creators of solutions
- Each system has inefficiencies are they "addictive?" "use" linearly
- Adoption of complex systems
- Current market does not reward change in the system
- Challenge to quantity short and term impact
- Familiarity/Comfort with linear systems
- Rural out migration lack of rural labor
- More complex ad challenging to research, fund and to sell/promote
- Goes against the grain of established frame works
- Lack of supporting policies at the local and regional levels, regulations
- Lack of new product; Awareness
- Global South/regional; Conflict and Insecurity
- May require higher cost in the beginning
- Cohesive policy @ multiple levels
- There will be multiple solutions for any given farm
- Lack of farm species
- High risk aversion, lack of security + insurance
- Misalignment with dominant commodity/ productivity market system
- Emphasize "total" productivity over profit margins + system-wide productivity
- Single, product, focus
- Siloed commodity groups and policy groups - very difficult to raise funds for support

Opportunities

- Capitalizing, less carbon, intensive product system
- Increasing focus on reusable, reuse and recycle
- Systems thinking (time disciplinary) allows for breaking traditional thoughts
- Transition to stewardship and leading new agriculture do systems
- New business opportunities
- Break throughs: - something new - discovery
- Transform the negative narrative about agriculture
- Integrate farms as part of larger solutions and enterprises
- Emphasize problems solving over disciplines
- Local solutions for global challenges
- Precision conservation
- Improved farm-level management (components/diversification)
- Mitigating climate change with negative carbon solution
- Mesh Ag-based minds with expertise with people from non-agricultural backgrounds and share a common goal
- Integration of AI + entrepreneurship
- Waste reduction, improved efficiency (more profitability)
- At least partially address the human health and environmental health crisis

- Diversifying agriculture by incorporating premiums and providing ecosystem services, while also reducing reliance on fossil fuels
- Diversification of crops (regionally locally)
- Blur boundaries urban and rural development
- Positioning agriculture as a priority solution pathway to sustainable development attainment
- Motivate development of new engineering paradigms to enable circular as designs emergence engineering
- Relief of economic disparity / poverty as a holistic approach
- Increase biodiversity
- Circularity of energy, mass (N, O2, NH3, C, H20). Information (data, genetics, etc.)
- Allow for entrepreneurship
- Open new revenue + food streams
- Jobs, research and discovery biotechnology etc.. for next generation
- A hopeful roadmap and economic growth for the next generation
- Creation of new business
- Robust cross-boundary collaboration in delivering solutions
- New income streams, new technologies and management system
- Sequences in a circular system
- Connect farm systems with other systems when waste can be used profitably
- Create economic and reward systems
- Opportunity to look holistically at nature rather than looking at climate, water, biodiversity separately
- Greater resilience
- Models all disciplines - work together to integrate theme for different purposes
- Higher consumer - social score benefits
- Education k-12 to create a culture
- Weather/water extremes (crises) force changed practices [status quo not feasible]
- Opportunity to contextualize solutions in scale, time, space
- Whole system utilization e.g. engineering crops for whole plant
- Low cost production, preserve natural resources
- Climate finance for farm / landscape investments
- Data science + AI creating ability to harness complexity in farming systems into insights + decision making
- New business models + incentives for farmer success, profits, economic growth + economy development
- Opportunity to change the linear system novel incentives from the private sector
- Meal, focus, health
- Biodiversity optionality
- Profitability > Climate lout argument
- Reinvigorate small communities/ bridge rural - urban divide
- Attract the younger generation of farmers
- Large interdisciplinary projects can play major roles in advancing circular economy systems
- Social development
- Cost of pollution increase makes CBS more economically viable

- In value chains > unlimited niches to explore
- No shortage of "wastes" to experiment on
- Raising long term farm income and being environmentally sustainable
- Learn from models learn by modeling
- More intergenerational equity in resource use
- Less environmental footprint of farming
- New science and methods to document and analyze systems

Threats (Barriers)

- Data science to move quickly identify gaps + target with specificity + intent (A tool to communicate across sectors + with farms, co-create)
- Institutional norms
- The conservative mentality of farmers needs new trust
- Unknown risks associated with change
- Lack of incentive in use-inspired research
- Increase unused recourses that compete different agriculture production
- Lose momentum, due to... ex. trendiness, politicization, demonetization
- Big agriculture does not favor changes
- Overcome short-term mentality
- Underestimate the need to create meaning that convinces influenceable people and to engage social scientists
- Lack of access to land + high cost of capital for next gen ag
- Transboundary subsidies
- Political unrest/promise without realizing intended outcome
- Aversion to change / organized opposition / fear is a powerful message
- Well-organized efforts that aim to maintain the status quo.
- Non evidence-based policies (need science-based)
- Pavlov's hierarchy of needs (funding, resource, constraint, institutional or social barriers)
- Inability to "read" the future, i.e.: missing the mark on future scenarios, i.e.: targeting one abiotic/biotic stress in liev for another
- Quite-data, research-incentive to become more circular
- Silos: "those who say they have already done that - what is new?"
- Trade
- Government Dysfunction
- Enough time to 'fail fast' and experiment. Failures can lead to mistrust; a bad experience can hinder the diffusion of innovation
- Need networking opportunities to advance-circular agriculture
- Extra-planetary implications
- Nay-sayers say 'It won't work'
- Initial focus or small meets
- Focus on "yield goal" rather than profitability and sustainability
- Market volatility
- Change in geo-political situations, that could reduce funding, and corporate investment
- New technologies that do not deliver as promised

- Lack of patience among funders, society and maybe climate
- Lack of infrastructure
- Change in international trade policy
- Sociopolitical conflicts
- Climate change
- Funding for R&D demonstration, extension incentives
- Intangible social characteristics (cultural values)
- Production oriented view of farming supporting food activities goals
- Limited opportunity to see and assess issues with different lenses
- Potential disruption (economic, productivity, social)
- Linear systems rely on a 'ray' of movement to preserve the status quo
- Struggle to implement social science knowledge into biophysical systems + research
- Lack of investment to transition
- A sound biological solution may not be economical or a business
- Systems thinking teaching/ education
- Lack of equity - at different scales (unequal access to inputs, technology)
- Those of us (who are doing well) are invested in the status quo
- Perceived lack at return on investment
- Potential rise of inequality if opportunities are not provided equally
- Structural gaps (e.g. infrastructure)
- Self-interest of existing interest groups
- Too little too late; Attitude decrease stakeholder buy-in
- Global political shocks, climate shocks
- Extreme weather events
- Economic business eyes - recession can dampen investment in a bioeconomy
- Lack of trust in project benefits
- Low adoption of both known and unknown solutions
- Conflict/insecurity
- Political economy concerns - can influence policies and regulations
- Fear of unknown or failure
- Complex problems > complex solutions > low implementation (no silver bullet)
- Land tenure rental
- Government policies (such as crop insurance) stifle innovation
- Overcrowded Ag - market space - too many efforts pulled in to different directions
- Changes in political will

After completing the SWOT, participants were instructed to identify linkages among all four categories without concentrating on the origin (as a strength, weakness, etc.) to identify research and knowledge gap-opportunity clusters. Participants initially whittled the various strengths, weaknesses, opportunities, and threats into numerous clusters and then further analyzed the small groups to identify seven overarching priorities for development and understanding of circularity in agrifood systems. These are the seven gap-opportunity clusters identified in farm production systems on the second day:

- Economics
- Social Behaviors and Collaboration/Co-creation

- Systems Integration and Complexity
- Policy and Politics
- Resource Efficiency
- Cross-Cutting Themes (Health, Education, Outreach & Communication, Data, Inclusivity, and Multidisciplinarity)
- Climate Change

The facilitators chose to exclude elaboration on climate change because net greenhouse gas emissions reduction or mitigation is a central tenet for increasing circularity in the bioeconomy. Changing net greenhouse gas (GHG) emissions from farm production while understanding the specific impacts of changing GHG levels on agrifood systems' productivity is foundational to all strategies outlined by this working group.

The participant experts agreed with facilitators that the cross-cutting themes should be taken into consideration for all five remaining aspects of CBS and then were divided into five discussion groups tasked to brainstorm research gaps and action items to fill those gaps for the first five categories above, with the details elaborated in their respective appendices (Economics, Appendix A; Social Behaviors and Collaboration/Co-creation, Appendix B; Systems Integration and Complexity, Appendix C; Policy and Politics. Appendix D; Resource Efficiency, Appendix E).

Outcomes and Recommendations

When delving into the research needs for farm production systems, existing research strategies and gaps were further delineated for four primary dimensions of the biophysical farming landscape. In spite of their innumerable linkages, the participants agreed that the first steps to integrating the systems approach will start by outlining our collective knowledge of circularity in these key dimensions of the biophysical farm environment—nitrogen and nutrients, carbon and biomass, water, and energy.

The key assumption behind the recommendations from FPS research community leaders is their hypothesis that a circular bioeconomy starts with increasing circularity in nutrient, biomass, water, and energy generation and expenditures on the farming landscape, even though farming is an open system that often involves significant amounts of biomass removal to concentrated population centers. Acknowledgement that the population size and purchasing power of consumers in urban centers will play a major role in closing circularity gaps in agrifood systems on a global landscape scale, beyond the scope of farm production systems alone, is necessary to note in the context of the group's specific research priorities.

Recognition that the majority of global food, feed, fiber and some fuel demands will always need to be met by farm production systems underlines their unique role in exacerbating or mitigating climate change by anthropogenic activities. Increasing productivity in farm production systems needs to be met with equal progress on all five dimensions of circularity: 1. to increase resource use efficiency; 2. eliminate waste and pollution; 3. Keep products and materials circulating with high use/value; 4. regenerate natural systems; and 5. provide economic benefits. Without consideration of economic benefits, all progress on growing the circular bioeconomy would be halted by farm producers dependent on their farm's net profitability and productivity.

The four key "linear" systems were the strategic focus while listing the multifaceted issues that CBS implementation requires when moving towards circular system of systems. Recommendations include moving to transdisciplinary (i.e. not bound to the traditional confines of your discipline in a multidisciplinary setting) approaches in spite of the majority of technical suggestions falling along "disciplinary" lines (because those are what are currently available to build on). When tasked to develop strategic plans for research on these key resources, participants identified and, in rotating groups, refined the following as actionable priorities for research on these four subjects.

Nitrogen and Nutrients

The major considerations for improving nutrient delivery, productivity and management all center around spatial and temporal factors. The research needs around nutrient and nitrogen delivery are all questions of when, where, and how much? Managing the exact macronutrient needs for optimal biomass production and negligible waste is a complex balancing act, heavily dependent on the lifecycle of the plant(s) and/or animal(s) (and other species' providing ecosystem services like pollination and nodular nitrogen fixation) in the production system. The need for improved fertilizer delivery tools and improved data sets for monitoring nutrient uptake and transport in the plant and on the landscape were emphasized.

Carbon and Biomass

This group identified creativity and redesigning how we think about biomass production as the key to increasing circularity of carbon in farm production and food systems. By creativity, the group, availing from cereal-based production systems primarily, meant diversifying in more ways than just on-farm species and in diversifying the germplasm basis of existing staple species, but also in adding perennials and agroforestry/silvopasture.

The technologies that these experts believe are most currently relevant and promising for improving circularity in the biomass production and removal (i.e. production shifted to urban/consumer centers) activities on the farm are AI/Machine learning for improved modeling of soil carbon change and turnover, as well as multifaceted soil probe systems that groundtruth model assumptions and enhance the accuracy of these carbon models with monitoring over time.

Water

Very similar to nitrogen/nutrient management, the thought leaders emphasized the temporal and spatial relationships of water, plants, animals, and physical barriers to increasing water use efficiency and storage on the farm production landscape. Optimization of amount available (e.g. minimize unnecessary evaporation), the amount used by plants/animals in the system (e.g. minimize waste, luxury consumption in processing) temporally is key to our understanding and improving the water availability and ecosystem health / hydrological system functionality in farm production systems.

Also similar to the carbon and biomass priorities, there is extensive overlap when considering water when quantifying and defining circularity, because like biomass, the technologies that they emphasized also focused on modeling efforts and the improvement of existing measuring and monitoring tools to understand water movement in plants, on the farm and across the landscape. Investment across various existing technologies would be prioritized after the models and metrics are established to evaluate how existing and future practices, like more efficient water-utilizing crops. improved livestock / human gray water recovery, or seasonal rain storage infrastructure, will impact or increase circularity on the farming landscape.

Energy

This group underscored the importance of utilizing and advocating for novel strategies for development of non-carbon-based energy sources on-farm. Furthermore, since the consideration of net GHG emission reductions in the farm production systems is a foundational issue to all system components, participants identified the need to explore these non-carbon sources as sufficiently important enough to decouple the subject of energy production, in general, because it is at the heart of all GHG emissions in the three macronutrient resource cycles on the farm—nutrients/nitrogen, carbon/biomass, and water. Key topics here involve on-farm energy generation and storage through non-fossil fuel energy sources, i.e. via improved batteries and electrification of mechanization and fertilizer / input production processes.

Summary

Defined by the Ellen MacArthur Foundation, the circular economy is a systemic approach to economic development designed to benefit businesses, society, and the environment. In contrast to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims to gradually decouple growth from the consumption of finite resources. Therefore, innovations in circularity naturally demonstrate the central role of the bioeconomy, or for the purposes of this report, the global agrifood production system. Agricultural systems naturally lend themselves to considerations of circularity in many aspects of the system: from production (crop, livestock, biomass), transportation and distribution (market to market linkages, producer to consumer pathways), storage and processing, packaging and marketing, consumer preferences and purchasing patterns, traditional or culturally sensitive food preparation and household consumption habits, down to redefining waste creation and reuse. The circular bioeconomy is about maximizing ecosystem services and net productivity through improved circularity and reduced waste generation throughout every stage in the system.

A key takeaway from all of the SWOT clusters was the need for quantifying and defining circularity. The need for developing metrics for assessing and/or measuring circularity returned to the forefront of the conversation regularly. Understanding and quantifying circularity must be followed by developing methods and tools to measure the dimensions of circularity on the farming landscape, and then evaluating if circularity is actually increasing with the implementation of various value-adding schemes and alternative recycling measures. One unsettled question is if circularity can be defined specifically for the nutrient, water, energy or biomass cycles – or if the inherent nature of these systems is too deeply interlinked to definite circularity without consideration of the other resources at all stages in the production cycle.

Two demographics which were regularly mentioned throughout the workshop as "not at the table" often enough in these research and priority setting discussions. Those important groups are farmers and consumers, i.e. our food producers and consumers who in many places are the same party, affected by food price and system changes in a myriad of ways. The two groups that we often envision are at the beginning (the producer) and the end (the consumer) of a linear value-chain, are the two groups most impacted by changing availability and cost of agrifood system inputs and outputs. Essentially, disrupting the linear value-chain and turning it into a more circular bioeconomy will demand placing all kinds of stakeholders, not least of which are food producers and consumers, throughout the cyclical system.

The system of systems approach demands new linkages among more varied stakeholders with greater interconnectivity and intersectional considerations accounted for by individual actors and communities.

Due to that recurring conversation, a related theme emerged and that was using landscape, systems and participatory approaches when establishing new research and development activities. It is fundamental to implementation success to identify the key stakeholders from farmer to consumer that will affect product update and technological changes. Those parties' inputs are necessary while continuously reevaluating which research gaps and opportunities are not being filled or exploited during implementation of the circular bioeconomy principles on the farm landscape. The experts agreed that target populations like women, consumers, and minority populations need to be included for CBS to be effective and inclusive. While all groups recognized that scaling is a major hurdle, it may be that due to the specificity needed for each regional group, a true 'scaling' of specific strategies cannot work. However, the application of the framework and strategies outlined here by the thought leaders *can* be translated across different ecosystems.

The CBS FPS specialists, together devised novel and comprehensive strategies to address the complex issues of circularity that affect various dimensions of the agrifood system and farm landscape. In sum, a combination of the three thematic results here provide a robust strategic approach to the complex nature of SI systems: using a landscape-scale approach, integrating system of systems, and designing authentically transdisciplinary research projects and implementation teams. The need to generate evidence and then have evidence-based policies implemented and supported by key social groups illustrates the interdisciplinary nature of stakeholders at every level. The inherent complexity in circular bioeconomy system development for farm production demands information be sourced from diverse locations and populations, but that improving circularity will be driven at the local level and constantly shaped by unique regional socioeconomic and biophysical constraints. Development of resilient farm production systems utilizing circularity principles will demand broad consideration of the complex interrelationships among various socioeconomic and biophysical issues and creative information dissemination efforts.

Appendix A: Economics

Strengths, weaknesses, opportunities, and threats cluster

- *Fair coops or groups to develop markets for non-commodity crops.*
- *Economics plays a central role in all of the principles of circularity, so ensure that there are unifying concepts that cut across each area and provide realistic opportunities to address the inevitable paradoxes that arise.*
- *Put value on byproducts.*
- *Create reliable standards for ecosystems service markets.*
- *Estimate the ROI of CBE at multiple-levels-farm, system, country.*
- *Need to identify and to create niche for products and/or services associated of CBS.*
- *Need to have more corporate investment to scale practice adaption and develop a harmonized MRV approach.*
- *Explore market opportunities for use of biomass sources as feedstock for new products, and explore biogases.*
- *Maximize ecosystem services.*
- *Reduce behavior to entry for non-commodity crops.*
- *Research climate and green founds potential in this CBS space.*
- *Lots going on so connect with existing projects, think tanks, research.*
- *Ex-ante, forward lowkey analysis, decision support, tools for farmers to assess costs or benefits for their operation.*
- *Enable market, price discovery mechanical, infrastructure support, econometric production or modeling, virtual trade-offs like carbon credit.*
- *Create 21st century CAE cooperatives/collaboratives that facilitate the effective delivery of ecosystems service farm outcomes.*
- *Develop metaverse and standards for ecosystems service delivery that underpin fair markets.*
- *Gap: at the farm production aspect we do not have a clear understanding of the cost of cultivation and how it differs spatially and temporally due to lack of data.*
- *Action: A mega-project, similar to the "Global yield gap" project is necessary for gathering global data to intern where are space of improvements.*
- *Do economic goals point toward profits or well-begin?*
- *Efforts needed that show compromise between profits and biology, which not always go in the same directions.*
- *Increase market demand access, more development for wastes that become resources.*
- *Allocate value/cost of waste to its producer.*
- *Allocate value/cost of biomass benefit to its producer.*
- *Need for intentional economic policies to tackle poverty alleviation, think circular bioeconomic.*
- *Target rapid development of dome big-acre-target systems to incentivize big AG to invest and do tech for deliver to costumers.*
- *Collect farm budgets for farms transitions to circular principles, including cost swings, increased productivity, local benefits and regional water quality.*
- *Need to emphasis the timeline to develop local products that support investment.*
- *Develop tools for determinate the value of ecosystem services.*
- *Evaluate the relative value of alternative technologies in delivery of CBS.*

- *The value of new (not yet discovered) technologies is a critical CBS step as incentive.*
- *Better economics can also come from lower expenses through lower input.*
- *Tradeoffs between profit and environment need to be identified.*
- *Crop-livestock integration is a necessary change for creator profit.*
- *Quantify spatial (local, regional, global) and temporal heterogeneities.*
- *Cost + benefits + analysis.*
- *Increase interdisciplinary cooperation among economics, scientists, engineer to integrate biophysical models for crop, soil, livestock, ecology. Include multiple outposts to consider resource economics, and policy tradeoffs.*
- *Integrated models to enable economics and CBS.*
- *Value decisions include long-terms outcomes/resources sustainability.*
- *Quantify economic of "waste" to the cost.*

Gaps in the Research

- *Integrated economic-biophysical modeling applications to CBE problems (also using this perspective in more than just modeling)*
    - *Applying them for policy design and analysis*
- *Understanding new market (product and byproducts) opportunities*
- *Economic costs and benefits of technology for a CBE relative to linear economy*
- *Evaluating cost effectiveness of achieving desired outcomes of CBE*
- *Quantifying the spatial and temporal heterogeneities in externalities*
- *Understanding trade-offs among impact of CBE on multiple environmental dimensions*
    - *Requires monetizing value of multiple environmental outcomes*
- *Employment impacts, requirements for new skills (workforce development / education needs), social impacts on economy, rural areas*
    - *Potential for distributed manufacturing and economics of it*
- *Prospective analysis of winner and losers from moving to a circular bioeconomy*
- *Cross-scale analysis of the economic costs and benefits of moving to CBE*
    - *Going from local → global → local*
    - *E.g. changes in land, input prices*
- *Evaluating the optimal level of circularity at different stages of production process*
    - *How much waste disposal is economically optimal?*
- *Transition costs, upfront investment, yield impacts, other infrastructure costs*
- *Value of health benefits from CBE*
- *How current farm policies are enabling a CBE? (Analysis of this needed, e.g. subsidies)*
- *Communicating economic and CBS analysis to improve decision making by farmers to provide economic and environmental benefits*
- *Creating markets for ecosystem services and new (crop) commodities*
    - *Water*
    - *Biodiversity*
    - *Carbon*
    - *Agro/ecotourism*
- *Farmer or community-owned collaborative enabling business (coop of the future), i.e. shared digester, processing, etc. or other shared infrastructure to enable economy of scale*

- *Where does it make sense to tweak vs. totally disruptive systems (i.e. we should grow corn in a lot of Iowa, but not all of Iowa)*
- *Ex ante and ex post evaluation for short, medium and long-term to support federal investment decisions*
- *Spatial (local, regional, global) scales*
- *Consensus, framework, criteria to protect agricultural preserves*
- *Metrics and standards*
- *What economic / finance interventions lead to higher equitability? What approaches reduce rural poverty and do not contribute to disparity?*
- *What interventions are specific to smallholders?*
- *What resources are needed and they are available where needed to support profitability? Related to farm-size and cost of technologies?*
- *How can PES (price elasticity of supply?) be improved to be / cause longer term changed practices?*
- *Traceability and certification costs are on the farmer (we need to change that)*
- *Private companies (food and beverage companies) are becoming selective about the way food is produced*
- *CBE could be tokenized as the carbon markets or the sustainable aviation fuel payments (~350$/oe) but requires quantification*

Appendix B: Social Behaviors and Collaboration/Co-Creation

Strengths, weaknesses, opportunities, and threats cluster

- *Behaviors are highly driven by profits, in the context of the agricultural enterprise. And this context is highly influenced by geographical locations, once knowing that, the social studies need to account with this information.*
- *Market circular systems – "kiss the ground" has been influential for regenerative agriculture.*
- *Connect between farmers. Connect between producers and consumers. Connect one health soil – human health.*
- *Organize groups of farmers, industries, groups of commercializing, etc. At a regional or national level with the goal to share experience and recommendations.*
- *Escalate the role of social science in the scaling of practice changes by understanding the behavior and attitude of all actors across the value chain.*
- *Use citizen science approach to engage consumers to accelerate the bottom-up.*
- *Engage young generation in the conversation.*
- *Engage (identify) rural sociologists as individuals or through organizations (such as regional rural development centers) to educate them about CBS and to engage them in developing research in regional/local context.*
- *CBE needs to increase real prosperity.*
- *CBE needs to work for big and small farmers.*
- *Farmers may not always make good decisions and need to accept that.*
- *Use farmers to promote CBE.*
- *Need for understanding what farmers adoption of technologies and practices in different socio-economic contexts.*
- *Need for increased feedback between farmers scientists (i.e., collaborate projects).*
- *Work with farmers and end users to envision the "crop of the future" for info sharing and market (economic theme).*
- *Go beyond theory of change and demonstrate benefits of roles across stakeholders' groups – align on minimum shared outcome.*
- *Great source of CBS; could be via schools, FFA, MANNRS, etc.; could get creatives with contexts, other methods. Examples are powerful at different scales. Precursor to collaborate and co-creation, as well as advocacy and public education.*
- *Research is needed on incentives to invest in CBS by different scales. This can be differentiated by gender/sex, age, geography. But must be for the system and not isolate farmers as the main research subject. Methodologies do not need to be reinvented. Assumes transduce research is funded.*
- *Developing crystal clear socioeconomic impact assessment indicators and metrics.*
- *Threshold of time scale to quantify social impacts.*
- *Mechanisms of co-creating on interface or interjecting boundaries/transection boundaries.*
- *Quantification of opportunity lost for risk reduction.*
- *Education curricular exposed diverse languages and perspectives or disciplines.*
- *Engage social scientists, farmers and prioritizing in farming problems.*
- *Place farmers at renter of CBE discussions to decisions.*

- *Embrace cross-boundary multistate co-creation.*
- *Develop better understanding of urban-rural integration for increasing circularly.*
- *What will drive adaptation for a more circular system: Incentive, values (personal/social), regulations/costs.*
- *More communications to farmers and consumers about benefits of circularity.*
- *More technical assistance.*
- *Label and products based on circularity.*
- *Design incentives that are market based on incorporate social and more human dimensions, i.e. social motivators.*
- *Do not assume that farmers do not want to change, rather that barriers exist to prevent it that could allow change with mitigating risks.*
- *Education transformation to include agriculture, environment, food systems, socio-political-economy systems (yes – systems thinking/training is needed).*
- *Add contributions from local and community-based food systems to address rural/urban integration challenges.*
- *Define the benefit of farmer local innovation in CBS and promote.*
- *Prouder tools for consumers to exercise preferences for CBS. For example, sustainable safety for food products.*
- *Lack of integration between socio-economic and biophysical science discipline.*
- *Be deliberately inclusive while developing proposals or deciding on grants otherwise this will not happen and CBS will not happen in reality.*

Gaps in the Research

- *What motivates/incentivizes farmers (and other value-chain actors) to invest in and implement new practices?*
    - *What are the constraints?*
    - *How does farm size and revenue affect changes and willingness?*
- *How to communicate across participants / stakeholders?*
    - *Between and among*
    - *Linkages between action/practice/science*
- *How to reduce or offset risks that act as constraints?*
- *Do under-resourced farmers require different approaches to engagement / communications?*
- *Are there non-monetary incentives for actors in systems? What is the role of social capital / social networks?*
- *Trust building? Related to co-creation of knowledge?*
- *Not all or nothing – process, steps, thresholds; what are the benefits to different steps and levels?*
- *What are opportunities for new farm investment?*
- *The gender and "adoption" and youth questions*
- *How to get funding for social science research? How to integrate trans/interdisciplinary research? How to use social science up front to INFORM research needs/knowledge gaps?*
- *How do we identify indicators and metrics for social change impact assessments?*
- *Adversity incentivizes opportunity cost evaluation*
- *Quantification of risks/uncertainties impacts practice changes*
- *Pain to change may be lower than the pain of not changing*

- *Reduce the disconnect among different stakeholders*
- *Reduce timescale of change to transformation*
- *Quantifying the role for peer driven adoption – how to accelerate it?*
- *How to increase relevance of social science, academics and university extension for farmers?*
- *More integration of urban consumer interests into urban and rural decision system*
- *Transferring consumer value for circular products through the supply chain to reward producers on the farm → role for sustainability labeling*
- *Current system for delivery of knowledge (i.e. coop agronomist, sales) doesn't understand / support circular system approaches and benefits*
- *We need farmer-farmer CBS networks*
    - *Local for agronomics*
    - *Not local for markets*
- *"Big ag" – how to make them "nice" (hard) and how to get them interested in new systems that can make them money (easy)*
- *Figures – Definition of co-creation:*

	interest	knowledge	influence
stakeholder a			
stakeholder b			

	farmer	scientist	policy maker
farmer		x	
scientist		x	
policy maker			x

Appendix C: Systems Integration and Complexity

Strengths, weaknesses, opportunities, and threats cluster

- *Common language and data structures for integrating models.*
- *Granting agencies funds for promote programs requiring teams including multiple disciplines for use-inspired research.*
- *Test bed for data collecting.*
- *Grant and research coordination network (NSF-RCN).*
- *Retrial for systems approach.*
- *Develop global standards that can be applied at local for regional levels.*
- *Involve others sectors beyond farm gate to design use for waste as by product.*
- *Strengthen for any mitigated science to develop new models for linkage.*
- *Practical opportunities that fit a diverse agriculture and diverse market opportunity.*
- *What is working in other countries?*
- *Systems have their own identity and characteristics but we need to find ways to link systems. For example, metrics, solution could be different but we should find alignment/overlap.*
- *We should have clear definition and boundary the systems.*
- *The systems need to be defined and the goals other integration need to be clear.*
- *Small-farmers probably run some of the most integrated systems (with the animals and crops) yet they may not be the most profitable.*
- *Articulate systems at varying scales that have sufficient flexibility to allow for central integration.*
- *Guidelines for data security and accessibility for data sharing among different scale of integration.*
- *Understanding metrics and develops prototype metaverse or animated documentary as a manual to follow for futures developments.*
- *Scale neutral data integrations is a must.*
- *Keep non-academic, non-scientists in mind when building/expanding models.*
- *Work on integrating human behavior and practice digital.*
- *Education models.*
- *Integration approaches and practices to achieve multiple solutions to SDG.*
- *Include risk parameters for each integrated system (crop failure/loss, financial, size of ecosystem service).*
- *Integrate system models for analysis of CBS, including trade off (Economy, resource, natural systems).*
- *Digital farm development for adaptation across different farming systems.*
- *Opportunity for collaborate among different disciplines including social secure.*
- *Induce students early in systems perspectives.*
- *Grant funds to support them science.*
- *Increase public and private funding streams for integrating existing data sets and models.*
- *Farm product integrators are part of the systems that reinforces linearity. Product, waste and revenue flows need to be pushed into regenerative frameworks.*
- *Models plus digital twins are the keys tools to quantify CBE benefits.*
- *We need to train the next generation of students and stakeholders to think with a systems approach systems integration needs to return value to farmers.*
- *Develop systems that support specialists, don’t try to train too many generalists.*

- *Gap: we do not know which system integration can work possibly in all situations.*
- *A degree of bioeconomic in the curriculum of the academics to set the next generation scientists on board with taking systems challenges and deploying the research solutions. This curriculum shall focus on learn about approaches in system analysis and tools in disciplines.*
- *Actions: Develop a generic mechanism on tool to provide analysis of benefits with value of system integration.*
- *Provide opportunities, insights, exchange of perspectives, differs groups.*
- *Design totally new systems for producers in specter environments using CBS and all types of inputs.*
- *Define common language in all the sectors with the goal of setting clear boundaries and understanding.*

Gaps in the Research

- *Not Designing system to deal with waste and byproducts (not thinking big enough)*
- *Lack of common language among systems (standards) and modelers (people, discipline) and "refences" (model intercomparison)*
- *Data and metadata to evaluate, train, connect systems and modules and testbeds to evaluate the integrated modules*
- *Lack of training in systems thinking and transdisciplinary science*
- *Lack of incentives for integrative science*
    - *Complexity: hampers mechanistic system integration*
    - *Emergence: demands different modeling approaches to integrate systems operating at disparate spatio-temporal scales*
    - *Complex systems science is under development*
    - *Siloed-linearized science without context*
- *Integration of "subjective" data types (consumers)*
- *Need for super indicators, across systems' boundaries*
- *Need for well-defined "systems" for integration*
- *Define drivers vs. correlated components of a system*
- *Systems need to be viewed in their context (geography – scale – typology of farms)*
- *Can we translate outside the academics (i.e. models)? Who uses it and how?*
- *Does integration of systems always lead to optimal benefits? Are there metrics? What scale to consider*
- *Issues with data privacy, ownership, security, accessibility, and trust*
- *What is the entity in charge of collecting and developing data and systems integration? (private sector, NGOs, public sector, universities…)*
- *The systems need to provide useful answers*
- *How does the system deliver answers, solutions, and quantification of risk to farmers to be useful?*
- *How can trust be built between farmers and system?*
- *Developing a common language and understanding of tools and methods in other disciplines*
    - *Engaging in team science*
    - *Importance of interdisciplinary scientists*
    - *Integrating stakeholders*
- *Education and training in interdisciplinary tools and methods*
- *Developing new types of curricula at undergrad and graduate levels*
- *Developing digital twins that can be tailored to different conditions*
- *Systems need to deliver measurable and multiple ecosystem services*

Appendix D: Policy and Politics

Strengths, weaknesses, opportunities, and threats cluster

- *Develop simple graphics/few talking points about the need for 10+ years funding cycles for research and producer supports.*
- *Develop a few specific examples of circular bio economies to share with policy makers (for all to use).*
- *Public and private sector organize an alliance between farmers and consumers for lobbying/policy and funding recommendation based on CBE principles.*
- *Include different participants within the value chain (farmers – consumers – industries, etc.). While policies are seeing discussed and write.*
- *Expand research on farms, conservation grants.*
- *Ensure crop insurance doesn't discourage research.*
- *Simplify message for broad public + declare economic/jobs benefits.*
- *Develop case for diversity commodity + raise transparency in informal markets.*
- *Do we have a clear idea of what policies would be required to promote CBS.*
- *Action: form a group within the CBS community to look at enabling policies and their prioritization.*
- *Need for institutional structure allowing for science advocacy supporting the homing/concept of circular bio economy and advancing farming production systems that are sustainable in the future.*
- *Creating test beds or demonstrations to showcase the adverse effects resulting from a lack of policy in crop insurance.*
- *Simplify complexities and express in easy-to-understand language for us to explain the need of policy.*
- *Need to have improved integration science into policy and vice-versa.*
- *The amount of public funding should go up for various actions e.g. reserved and innovation, scaling of adaption, market creation.*
- *International trade policy should be considered while developing a policy for specific country.*
- *A process is needed for scientist to be able to advocate for changes in policy. This process cannot be left to the fate of most influential people alone.*
- *Advocacy training for college/university leaders in conjunction with university government relations team.*
- *Distill messages to reflate local impacts of CBS that can be conveyed to policy makers during local events or during hill visits.*
- *Policy monitoring to evaluate the incremental impact/change of proposed/implemented policy.*
- *Develop policy that supports stability and certainty in farm policy and markets.*
- *CBS will benefit from policy roadmap that offers incremental changes and considers unintended consequences.*
- *Farmers should be rewarded for protecting the environment. It is critical to have a quantification method through validate multi-model ensemble to demonstrate the positive impact.*
- *New policies for training farmers on CBS.*
- *Identify allies with interest and influence who can engage with congressional staffers and committees to advocate; understand their perspectives, map the relevant/interested committees, staffers, reps; co-create a strategy both short and long-term for advocacy; allocate resources to efforts; train allies, scientists, and farmers to be advocates.*
- *Clear guidelines.*
- *Incentivization strategies by agencies.*
- *Policy to promote and outreach.*

- *Transboundary tariff support.*
- *Conflict resolution mechanism.*
- *Harmonize inconsistent and conflictions policies.*
- *Transition productive subsidies to payments for ecosystem service delivery.*
- *Increase public CBS investments in research, technical assistance, knowledge sharing, risk management and practice adoption (FA).*
- *Recruit CBS champions (effected officials).*
- *We need new incentive policy to increase adoption of regen ag + climate-smart as they lead to a circular bio economy.*
- *We need new policies to incentive change and create new markets for crops that how do not have a market.*
- *Develop programs for long-term (>10 years) impact (outcomes).*
- *Establish the value of evidence-based policy case studies.*
- *Ensure all policy is influenced by people of CBS (include in policy development framework).*
- *Increase capabilities for evaluating policy adjustments implications in morals models that include CBS and tradeoffs.*
- *Increase funding for public research.*
- *Certainty of funding for practice incentives.*
- *Education related to incentivizing forward financing in circular economy practices.*
- *Education, engagement; slow case; advocacy work; champions; white papers; demonstrative; testimonial; certification; engage local businesses.*

Gaps in the Research

- *Political champion (State, federal, global)*
- *Reliable Markets*
- *Crop Insurance (fair, validated outside U.S.?)*
- *Policy to incentivize ecosystem services (transition from production subsidies)*
- *Harmonize policies (working at cross purpose within and across countries)*
- *Investment (shift or increase) in circular system*
    - *Technical planning*
    - *Financial*
    - *Research*
    - *Technical/Knowledge sharing*
- *Include farmer and consumer stakeholder voices in policy decisions (new alliance between farmer and consumer) – at national level?*
- *Longer term planning and funding cycles (not 4 years) (non-political?)*
- *Impact: policymakers and consumers value proposition of the investment*
    - *Tax dollars*
    - *Predictability of the system*
    - *Time to see changes – modeling*
- *Messaging: written documents and demonstration testbeds*
- *Don't wait for the dust bowl or climate change (…already happening!)*
    - *Highlight and demonstrate threat of no action*
    - *Complexity (e.g. citrus greening ->devastation of an industry)*

  - *Diversify commodity markets*
- *How to advocate at different scales – local drivers?*
- *How to institutionalize science communication? By academic scientists? (policy makers)*
- *Show me the money*
- *Mismatch in policy guidelines at different scales/agencies/state*
- *Filling forms for incentive application is cumbersome (full-time job) – many farmers do not want to deal with it*
- *Uncertainties in NRCS and other agencies funding availability*
- *Evidence-based policy -> case studies of the benefits of evidence-based policy*
- *Frameworks to evaluate policy effectiveness in CBE context*
- *Unintended consequences of policy*
- *Winners and losers from a policy (political economy effects)*

Appendix E: Resource Use and Efficiency

Strengths, weaknesses, opportunities, and threats cluster

- *Combine sensors, models, tools to quantify resource balance of farm systems for CBS for N, E, H_2O, C.*
- *Develop metrics for quantifying circularity of resources at a farm scale.*
- *Creating and publishing standards for measuring and reporting circularity*
- *Developing tools for identifying resource losses and wastes at the farm scale*
- *Understanding solution options, developing new options for increasing circularity of resources at farm scale, small and large.*
- *Working with farmers to evaluate and demonstrate new methods for increasing resource efficiency through test beds*
- *Incorporates resources balance outputs from farm enterprise models for ECA, N balance.*
- *Need the knowledge of how practices, individually, produce incremental benefits in efficiencies so that practitioners can choose the most contextual ones for their circumstances.*
- *Action: research programs (additive or omission) to understand practice vs efficiency at various scenes and context.*
- *Perform on farm research to parametrize system models.*
- *Quantify the risks to productivity through resource efficiency.*
- *Develop models that at time points in the season when growers can make management changes.*
- *Design new systems practices that can delivery CBS outcomes at all scales.*
- *Need for key metrics/indicates for measuring efficiency and understanding trade-offs when one or more parts of an agricultural system becomes efficient.*
- *Need to accurate for potential externalities of resource efficiency efforts – do efficiency really solve problems at great spatial scales?*
- *Advance research and commercialization of new, cleaner N sources faster.*
- *Take final steps in tech for cellulosic.*
- *Infrastructure and marketing opportunities need be established.*
- *Water, nitrogen, energy, carbon use efficiency needs to be evolved together and not in isolation.*
- *We need to use models that are validated to evaluate practices that increase resource use efficiency.*
- *Map resource locations and resource needs to link them.*
- *Quantification of C, H2O, energy, nutrient cycles at farm scale.*
- *Interconnect farms within a landscape (cattle, crops, biodiversity), for efficiency.*
- *Maximize "biology" for efficiency: plant-root microbiome.*
- *Dissemination a knowledge and technical assistance on methods of productive to increase resource efficiency.*
- *In-field nutrient resource and more efficiency measures can improve farm level management and further increase circular framework.*
- *Create incentives for farmers willing to make transformation changes that will have direct positive impact on the environment, but those ideas (practices) are not proved.*
- *Connect world that bring new ideas and tech with the operators that will be the users of that tech.*
- *Create linkages beyond farm use cases to improve economic benefit.*
- *Clearly articulate tradeoffs that drive clarity [be that system B more resource intensive to achieve economic return].*
- *Determine a $ value of "wasted" resources by connect to venture capital.*

- *Identify the pathways to practices.*
- *Marketable practices to products for enhancing resource use efficiency.*
- *Create contextual frame worlds that are adaptable for local/regional applications to avoid a one-sure-fit-all mentality.*
- *Determine measures of circulants (at all levels).*
- *Promote whole system utilization e.g. whole plant utilization in crops with multiple products.*
- *Fundamental research for more innovation to identify model solutions.*
- *Generate credible evidence to bridge information gap that will lead to scaling of existing solution adoption.*
- *Quantification of resource efficiency benefits through on farm demonstration and models.*
- *Efficiencies need to be defined and contextualized.*
- *Since not everything can be optimized/maximized at the same time, the topic of "allowable" or thresholds for inefficiencies need to be introduced.*

Gaps in the Research

- *Identify suites of practices (their economic costs and benefits) currently available (and new tools and practices need to achieve even more circularity)*
- *Understand and evaluate their performance (field-based and modeling) with metrics and indicators and their potential market benefits and policy support / incentives*
- *Build decision support systems to make more informed decisions by capturing GxExMxSocio-economic behavior, climate series (historical 30 years), projected climate*
- *Developing tools for quantification and measurement of resource efficiency (e.g. models, sensors, hardware and software)*
- *Trade-offs and synergies between resource efficiency and profitability*
- *Quantifying resource use balance on the farm → what is taken up, lost, wasted?*
- *Potential for on-farm energy generation and use*
- *Understanding behavioral and economic barriers to adoption of resource efficient technologies*
- *Need for on-farm sensors and tools to inform decision support systems*
- *Scale of operations needed for resource efficiency → what is optimal at farm, regional or larger scale?*
- *Improved technologies for managing reuse and recycling on-farm → integrating crop and animal agriculture*
- *Opportunities for using residual and waste on farm*
    - *Optimal level of residue reuse*
    - *Trade-offs in residue use*
- *Upfront costs of increasing resource efficiency and long-term benefits of input savings and profits*
- *Demonstrating and communicating the gains in resource efficiency, having demonstration farms and testbeds*
- *Bridge new technologies and practical implementation on farm. How to deploy new technologies in new farming systems?*
- *Criteria, framework, metrics to quantify and design systems at landscape level including farming operation, processors, etc.*
- *Efficiency includes metrics about diversity, input/output (farm → watershed/basin/aquifer)*
- *Increased system complexity will require using complex systems thinking and may switch from prediction to management*

- *Define thresholds for inefficiencies for specific contexts (trade-offs) (ranges vs. absolutes)*
- *Resource efficiency paradox (Recognize and address)*

Appendix F: Carbon / Biomass Circularity

Research Questions for Farm Production Systems

- *How do we create intensify carbon (C) inputs?*
  - *Go beyond corn and soy*
  - *How do you add perennials / wheat / more roots*
- *How to redesign corps – more efficient allocation of resources (e.g., seed, plant canopy and root systems, above and below)?*
  - *Plant breeders need to think below ground*
- *How to redesign the farm → diversified fields?*
- *How to move to relay cropping, diversified rotations, perennial cover crops?*
  - *Include agroforestry / silvopastoral*
- *Stabilize biomass in building materials / textiles*
- *Firebreaking / residue burning – how to manage air quality and forest management for fires including policy levers to produce residue burning.*
  - *Develops ways to harvest a use residue instead?*
- *Utilize and manage carbon stock in invasive species.*
- *How can marginal lands be managed for carbon removal/sequestration?*
- *Clarify value model of carbon markets – model of carbon sequestration potential of different soils? (1 dot)*
- *How to convert "above ground" crop byproducts to utilize carbon? (so… it's not a loss)*
- *What more is needed to strengthen/enhance soil carbon sequestration… using sustainable bio-products?*
- *How can we improve soil carbon measurement (monitoring, reporting, verification)?*
- *What type/form of carbon should be in soils? What are the impacts of different carbon forms on crops, etc.? Interaction with soil biome?*
- *How can carbon markets be more accessible and equitable to benefit smallholders in fragile ecosystems?*
- *Appropriate biomass processing systems (to make biochar) – bring processing to biomass sources.*

Existing Technologies

- *AI – Machine learning for remote sensing with C models to estimate soil C change / turnover (11 dots)*
- *Mobile soil probes/spectroscopy - multiple model ensembles (11 dots)*
- *Biochar production, biomass stabilization, carbon durability (3 dots)*
- *Laminate / building materials / steel replacement*
- *Enhanced rock weathering, inorganic carbon cycling removal (1 dot)*
- *Remote sensing / Landscape scale carbon inventories (2 dots)*
- *Digesters, CH_4 (Methane) capture (3 dots)*
- *Plant Breeding (5 dots)*
- *Microbial cover crops (4 dots)*

Appendix G: Nitrogen and Nutrient Circularity

Research Questions Farm Production Systems

- *(Biological soil) x Biostimulant amendment to increase nutrient use efficiency*
- *On-farm, systems-level quantification and characterization of nutrient loss*
- *Better utilization and understanding of livestock and crops' interaction for nutrient management*
- *Improve and advance models to quantify nutrient cycles and loss (how to model multi-crop systems to optimize nutrient use)*
- *Distributed green nitrogen fertilizer will decarbonize nitrogen production and make it more locally available (technology is there, needs commercialization)*
- *Better technology / cultivars / recommendations for cover cropping/no till*
- *Long-term: Nitrogen fixing grass and better nitrogen use-efficiency within plants and through root architecture*
- *Improve current management technology (to do better on the 5 R's—refuse, reduce, reuse, repurpose, and recycle)*
- *Better slow-release fertilizer*
- *How to do testing / sensing for nutrient levels?*
- *Can we manipulate soil microbiome to improve nutrient use efficiency?*
- *How can the results (of nutrient testing/sensing) be used for decisions on farm?*
- *Post-quantification / characterization – How to enhance uptake and reduce nutrient loss?*
- *Can the nitrogen cycle in (broader) system be optimized? (Use run off / leached nitrogen)*
- *How to extract nitrogen / nitrogen fixation from biological organism? Other methods?*
- *Capturing and quantifying impact of spatial variability in nitrogen use-efficiency*
- *How to deliver nutrients in a synchronized way with plant needs → matching supply and demand*
- *Understand relationship between yield variability and nitrogen-use efficiency?*
- *(Technologies)*
- *Develop data sets on the farm and transport of nutrients (region → region) in products*
- *Extract phosphorous / nutrients from current waste streams*
- *Develop decision-support tools for nutrient management at the field level, regionally specific*
    - *Multi-factor optimization*
    - *Train implementation partners*
- *Slow-release fertilizer without plastic / with bioplastic*
- *Improved precision equipment*
- *Which fossil energy sources can be replaced?*
- *What are effective routes to distribute and store the product energy? (conversion to ethanol, routes to capture cellulosic biomass – high density vs. low density)*
- *Will energy production influence food prices?*
- *Are there other energy sources beyond biomass?*
- *How will farm equipment changes influence energy use? (Autonomous, large vs. small equipment)*
- *What is the energy portfolio of the food systems? What is the measure of efficiency?*
- *What is the viability of new farm technology?*
- *Ammonia stewardship / capture for energy management*
- *Manure management for energy as a model for other farm systems (biogas)*
- *Technology to optimize light capture by crops (mono, relay, double crop systems)*

- *Vertical farm → use renewable energy and optimize system*
- *Agrovoltaics – improve crop varieties and management recommendations*
- *Renewable/local energy for machinery/dryer/buildings*
- *On-farm preprocessing of biomass for energy crops to resources transportation energy costs*
- *Advance technologies for wind/solar/biodigester (technology needs development and commercialization – scale)*
- *Engineer for smaller, more local "energy grid"*
- *Water are more energy efficient methods for drying grains?*
- *Increasing energy efficiency of irrigation / water lifting? How to incentivize industry / farm to change?*
- *What are and how to manage trade-offs between replacing human energy vs. mechanized equipment?*
- *Reducing inputs in areas of low response*
- *Increase energy efficiency*

Existing Technologies

- *Electric tractors*
- *No till*
- *Robotics and spraying drone*
- *Agrovoltaics*
- *Generate energy from low power hydropower*
- *Slow release N fertilizers*
- *Better weather projections*
- *Phosphorous recovery*
- *Decision Support Systems (DSS) (models and digital tools) - (10 dots)*
- *Crop models (2 dots)*
- *Landscape models*
- *Some biological additives / stimulants (most promising category) (5 dots)*
- *Slow release / stabilizers (1 dot)*
- *Green nitrogen (10 dots)*
- *H_2O / soil N sensors*
- *Breeding tech whole genome prediction (WGP) editing, GxE (xM) and NF*
    - *For plants (biological Nitrogen Fixation)*
    - *For microbes (biological Nitrogen Fixation)*
- *Precision application equipment on farm and remote sensing (7 dots)*
- *Remote sensing for R&D (1 dot)*
- *Digital opportunity for farer feedback / metrics (tools, sensors)*
- *Technology to reduce / conserve nutrients*
- *Sensors to trace loss through tile system (not just terminally) (1 dot)*
- *Variable rate tech/UBA application*
- *Microbiome management technology (1 dot)*
- *Manure and biosolid management (2 dots)*
- *Inoculants (N, P, micorrhizae)*

Appendix H: Water Circularity

Research Questions in Farm Production Systems

- *Can we match water availability with locating production systems? Adapt system to where suitable? (better match)*
- *How do we address drainage of seasonal excess and re-integrate when/where needed?*
- *How to implement conjunctive use of tech to manage water → from farm to landscape to basin/aquifer? (precision water management) (include competitive use cities vs. farms of the southwest?*
- *How to minimize evaporation?*
- *How to do equitable water allocation for climate resilient diversified farm system? (regional, local)*
- *Water harvesting / storage – how and where? (nature-based solutions, gray water, green water) – to manage seasonal drought*
- *Water – nutrient management at multiple scales in various weather / climate (unpredictable), at landscape level, matching water availability and crop types*
- *How do we get synergies of increasing carbon? → more water–retention → more transpiration and more water infiltration with better soil structure*
- *How do we create crops to be more water efficient / salt-tolerant?*
- *How do we better understand spatial variability in water availability and match input supply?*
- *Develop incentives that ensure that water efficiency metrics don't lead to more water use*
- *Build management scenarios*
- *Scenario preparation / risk identification so that disasters or attacks have limited impact on water quality, resilience*
- *Increase use of technology to improve water quality (have tech, need to validate and increase use of models and scale)*

Existing Technologies

- *Microirrigation – drip, irrigation zones, Variable-Rate Technology (VRT) irrigation*
- *Tile drainage – capturing and recycling*
- *Precision agriculture, sensors, drones, remote sensing*
- *Economics, computer science, data analysis, ABE, soil science, hydrology, agronomy*
- *Optimize (with models) system by understanding water needs in all crops in system, including cover crops – include risk estimates*

Measure/monitor/plan:

- *Satellite / Remote Sensing / Thermal (6 dots)*
- *Moisture probes / sensors (5 dots)*
- *Towers*
- *Handheld / thermal (1 dot)*
- *Drones*
- *Robotics*
- *Decision Support System → with improved information on crop water requirements (1 dot)*
- *Weather forecasting*
- *Wifi-based field sensors*

- *Apps to monitor data and control irrigation systems*
- *Digital twins for water shed characterization of water quantity AND quality with machine learning / artificial Intelligence (1 dot)*
- *Stress response / biochemistry (8 dots)*
- *Crowd sourcing to deploy sensors*

Do:

- *Tile drainage methods (1 dot)*
- *Water lifting / pumps (1 dot)*
- *Distribution on field*
- *Low till / no till*
- *Diversions / canals*
- *Storage – nature-based infrastructure (5 dots)*
- *Covers for surface water to evaporate*
- *Soil amendments (2 dots)*
- *Crop models / relay crops (4 dots)*
- *Plant breeding for WUE (water use efficiency) (1 dot)*
- *Landscape models / hydrological models (2 dots)*
- *Riparian / Streambank Management*
- *Irrigation telemetry (1 dot)*
- *Water quality monitors (nutrients and contaminants) (3 dots)*
- *Manure water recovery (2 dots)*
- *Water reuse/gray water (1 dot)*

Appendix I: Energy Circularity

Research Questions in Farm Production Systems

- *Which fossil energy sources can be replaced?*
- *What are effective routes to distribute and store the produced energy?*
    - *Conversion to ethanol*
    - *Routes to capture cellulosic biomass*
    - *High density vs. low density conversion*
- *Will energy production influence food prices?*
- *Are there other energy sources beyond biomass?*
- *How will farm equipment changes influence energy use? (e.g. autonomous, large vs. small)*
- *What is the energy portfolio of the food system? What is the measure of efficiency?*
- *What is the visibility of new farm technology?*
- *Ammonia stewardship and capture research for energy management*
- *Manure management for energy as a model for on-farm systems*
- *Technology to optimize light capture by crops (mono, relay, double crop)*
- *Vertical farm: use renewable energy and optimize system*
- *Improve crop varieties and management recommendations for agrovoltaic systems*
- *Renewable/local energy for machinery/dryers/buildings*
- *On-farm preprocessing of biomass for energy crops to reduce transportation energy costs?*
    - *What are more energy efficient methods for drying grains?*
- *Advance technological solutions for wind/solar/biodigester energy production (i.e. the technology needs to be developed, commercialized, then scaled)*
- *Engineering for smaller, more local energy grids*
- *Increasing the energy efficiency of irrigation/water lifting? How to incentivize industry/on-farm to change?*
- *What trade-offs between replacing human energy with mechanized equipment? How to manage this?*
- *Reducing inputs in areas of low response*

Existing Technologies

- *Digester (7 dots)*
    - *Anaerobic*
    - *Enzymatic*
    - *Thermochemical conversion*
- *Solar powered equipment, electric tractors, pumps, high efficiency electricals (8 dots)*
- *Solar, wind, geothermal electricity (0 dots)*
- *Biofuel conversion (8 dots)*
    - *Ethanol (starch vs. ethanol)*
    - *Diesel*
    - *Aviation fuel*
    - *Marine fuel*
- *Small-scale hydropower (1 dot)*
- *Crop and landscape models (3 dots)*

- *Breeding technology (1 dot)*
- *Robotics to improve energy efficiency (1 dot)*
- *Digital / remote sensing / sensors / wifi / satellite communications*
- *Energy storage (local) – batteries, etc. (4 dots)*
- *No till*
- *Electric tractors*
- *Robotics and spraying drones*
- *Agrovoltaics*
- *Low-power hydropower*

Measure:

- *Regarding digester technology:*
  - *Energy produced vs. biomass loading*
  - *Gas Quality (1 dot)*
  - *Solids Quality*
  - *Water use*
  - *Energy use*
  - *Application efficiency*
  - *Landfill use reduction (food waste)*
  - *Decision support systems built on tech/models*
- *Regarding solar/wind/geothermal electricity:*
  - *Energy offset, fraction of on-site energy (5 dots)*
- *Regarding biofuel conversion:*
  - *Reduce energy requirement for inputs and processing, e.g. conversion, automation, small-scale/human-scale equipment (5 dots)*

Appendix J: Transdisciplinary Suggestions

- Address education/curriculum gaps.
- Identify the systems/CBS boundary.
- Develop/ research roadmap.
- Identify missing disciplines.
- Increase share of farmer voice and perspective.
- Distinguish benefits of CBS for all audiences.
- Retain circular focus.
- Continue to look for diverse technological solutions.
- Think global.
- Farmers collaboration is essential.
- More representation for others participants of the value chain.
- Define roadmap to start making need it changes.
- Increased communication.
- Share the information with the researcher and stockholder community.
- Don't waste much time in conversations and strategy development, rather start doing the work.
- Bring in corporate partners on a pre-competitive platform.
- Show specific example, a real one, that circular bioeconomic is possible in the context of farming systems.
- Developing a coalition of farmers that showcase and demonstrate advantages of circular systems and need for policy support.
- Advocacy for policies to support on farm CBS. Enabling institutions and policies to support market opportunities for circular products.
- Thank you for the opportunity to participate and meet new colleagues and share our fresh ideas.
- Address how the circular bioeconomic relates to the concepts of sustainability.
- Engage broader communities in AG and for systems on creating a local, national and international alliance that advance CBS using interslice R and D.
- Develop outreach articles that communicate farming systems CBS examples.
- Keep the momentum going.
- Get food and sewerage companies.
- Raise funding for CBS.
- Synthesize these two great days for a perspective or policy forum paper.
- Identify the highest scoring "solution"
- Find the best researchers and models.
- Do on-farm testing of the results, utilize the results on this workshop.
- Come to a common understanding of bioeconomic, circulatory system.
- Keep up this good work.
- Find ways (funding) to build the multi discipline partners engaged in innovations that transform the circular systems.
- It's never too soon to ramp up communication and advocacy.
- Let us develop CBS manual for farming system.
- Identify intermediate success metrics.
- Promote farmer experimentation to accelerate adaption cycles.

- Include smallholder geographic under the CBS framework as it will open up research questions and action points.
- Integrate more farmers into the conversation
- Co-create solutions.
- Engage broadly using the robust resources that are in our universities, stakeholders, government agonies.
- Look deeply beyond the usual suspects.
- Create roadmap document that scalable strategies with economic strategies of countries with bioeconomic.
- A CBS week-ling intention on research.
- Crisp, focused message

Appendix K: Participant Bios

ORGANIZERS AND SPEAKERS

Bruno Basso

Dr. Bruno Basso is a Distinguished Professor at Michigan State University, specializing in sustainable agriculture. His research integrates various disciplines such as Biophysics, Climatology, Hydrology, Genetics, Agronomy, and Soil Science to enhance decision-making across agricultural systems. With a focus on row-crop production ecosystems, Dr. Bruno Basso aims to address sustainability concerns associated with chemically intensive practices. His research emphasizes providing sustainable ecosystem services, including crop production, carbon sequestration, and nitrogen conservation. Key aspects of his research include developing and applying advanced crop system models, utilizing remote sensing technologies to understand nutrient and water uptake, and assessing the impact of climate variability on agricultural systems. Dr. Bruno Basso is dedicated to developing new technologies and knowledge transfer to empower farmers in managing spatial and temporal variability effectively, thereby optimizing economic and environmental outcomes.
https://msu.edu/honoredfaculty/directory/basso-bruno.html

Ignacio A. Ciampitti

Dr. Ignacio Ciampitti is a Professor of Agronomy at Kansas State University, the Director of the USAID-funded Digital Tool consortium, and the Director of the Institute for Digital Agriculture and Advanced Analytics. Dr. Ciampitti's research integrates fieldwork, statistics, remote sensing, and modeling to comprehend plant responses. With over 200 refereed journal articles in the last decade, his expertise spans corn, soybean, sorghum, and canola crops. Notable accolades include Early Career Awards from Agronomy and Crop Science societies and recognition for outstanding editorial contributions. Currently, Dr. Ciampitti serves as Associate Editor-in-Chief for the European Journal of Agronomy and is on the editorial boards of esteemed journals like Remote Sensing and Field Crops Research. He also holds a board membership at the Crop Science Society of America. He received the Werner L. Nelson Award for Diagnosis of Yield-Limiting Factors (2023) and Fellow (2022) of American Society of Agronomy (2023).

https://www.agronomy.k-state.edu/about/people/faculty/ciampitti-ignacio

Ray Gaesser

Ray Gaesser, raised on a small, diversified farm in southern Indiana, embodies the essence of responsible farming. With a deep-rooted belief in the privilege of farming, Ray founded Gaesser Farms in Corning, Iowa, in 1977. What began as a modest venture has flourished into a 6,000-acre operation, comprising 620 owned acres and an additional 5,400 rented or custom farmed acres. Gaesser Farms prioritizes sustainability, employing cutting-edge technology and innovative practices to conserve and enhance resources. The farm has been 100 percent no-till since 1991, and cover crops have been integral since 2010. Corn and soybeans are cultivated for local ethanol production and Stine Seed Company, respectively. Beyond the farm, Ray is an esteemed figure in the agriculture community. He holds executive roles in prominent associations like the American Soybean Association and the North American Climate Smart Agriculture Alliance. Ray's contributions have been recognized through various accolades, including the Iowa Master Farmer Award in 2012 and a tribute in the Congressional Record by Iowa Congressman Tom Latham in 2013. Ray Gaesser's dedication to sustainable agriculture and his leadership in promoting international relationships and trade underscore his profound impact on the farming industry.

https://www.solutionsfromtheland.org/directory/name/ray-gaesser

Jim Jones

Dr. Jim Jones is a Distinguished Professor Emeritus in the Agricultural and Biological Engineering Department, at the University of Florida, retiring from the department in 2010. He continued to work on many research projects until 2016 when he accepted an invitation to serve as a Program Director at the National Science Foundation (NSF) and co-lead the major funding multidisciplinary and multi-agency programs (e.g., Innovations at the Nexus of Food, Energy, and Water Systems, jointly funded by NSF and USDA-National Institute of Food and Agriculture). While at NSF, he led the development of a new multidisciplinary research initiative called Signals in the Soil (SitS). He completed his responsibilities at NSF in 2019, and he now works part time at the University of Florida on various initiatives locally, nationally, and internationally. He developed a remarkable career based on mathematical modeling and computer simulation to integrate scientific knowledge from different disciplines for use in agricultural decision-making. His work has been acknowledged through his advanced rank at the university, through numerous awards and honors, and through the careers of many scientists he has trained. Dr. Jones was elected to the National Academy of Engineering in 2012.

https://abe.ufl.edu/people/fculty/james-jones/

Carlos Messina

Dr. Carlos Messina is a distinguished professor specializing in predictive breeding within the Department of Horticultural Sciences. His pioneering work revolves around enhancing the nutritional content of Florida's produce and leveraging agriculture as a potent tool in mitigating climate change impacts. At the forefront of innovation, Dr. Messina focuses on integrating artificial intelligence (AI) into plant breeding methodologies. He envisions AI as a transformative force, facilitating the synchronization of crop enhancement endeavors. His ultimate goal is to foster regenerative agricultural systems that not only enhance human health but also ensure nutrient security and bolster resilience against climate change. With a passion for advancing agricultural technologies, Dr. Messina's endeavors represent a crucial step towards a sustainable and nourished future.

https://hos.ifas.ufl.edu/people/on-campus-faculty/carlos-d-messina

Ernie Shea

Ernie Shea serves as the President of Solutions from the Land (SfL), a nonprofit organization dedicated to incubating and supporting farmer-led, multi-stakeholder platforms. These platforms inspire, educate, and equip agricultural partners to innovate and lead efforts toward sustainable development, climate resilience, and enhanced productivity in the food system. With over 40 years of experience spanning global, national, state, and local levels, Shea has been instrumental in designing and facilitating initiatives to enhance agricultural landscapes. His work focuses on carbon sequestration, water quality protection, public health improvement, and the promotion of resilient food systems. Previously, Shea held senior leadership positions in the State of Maryland, including Assistant Secretary of Agriculture for Agricultural Development and Resource Conservation. He also served as the Chief Executive Officer of the National Association of Conservation Districts (NACD) from

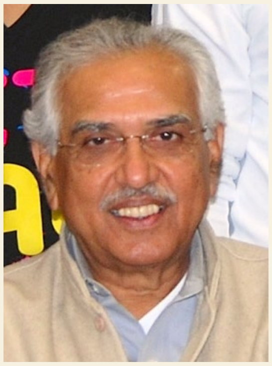
1986 to 2004. In addition to his role at SfL, Shea facilitates the 25x'25 and North American Climate Smart Agriculture Alliances and coordinates state-level climate smart agriculture initiatives. He is actively involved in the Chesapeake Bay cleanup effort and serves on the Board of the Harry R. Hughes Center for Agro-Ecology. Furthermore, Shea is the Founder and Principal of Natural Resource Solutions (NRS), LLC, a consultancy specializing in conservation and natural resource policy and programs.

https://www.solutionsfromtheland.org/about/name/ernest-shea/

Vara Prasad

Dr. P.V. Vara Prasad is a University Distinguished Professor and the R.O. Kruse Professor of Agriculture at Kansas State University. He serves as the Director of the Feed the Future Sustainable Intensification Innovation Lab (SIIL). He obtained his B.S. and M.S. degrees from Andhra Pradesh Agricultural University in India, followed by a Ph.D. from the University of Reading in the United Kingdom. His research focuses on comprehending how crops respond to changing environments and management practices. His work extends to developing optimal management strategies to enhance and safeguard yields. Passionate about education and outreach, he actively builds human and institutional capacity. His impactful programs in Africa and Asia focus on innovative solutions for food, nutrition, and climate security, and ultimately are improving the lives of smallholder farmers. He was the former President of the Crop Science Society of America; member of International Commission on Sustainable Agricultural Intensification; and current chair of the Plant Working Group of the Council for Agricultural Science and Technology.

https://www.k-state.edu/siil/about/people/index.html



Brahm Verma

Dr. Brahm Verma is Professor Emeritus and Associate Director Emeritus of the Faculty of Engineering which was officially organized as College of Engineering at the University of Georgia (UGA). Since the mid-1980's he has championed for the emerging discipline of biological engineering and served as the founding president of the Institute of Biological Engineering (IBE) – A Society for Advancing *Biology-Inspired* Engineering. He also created the Faculty of Engineering at the UGA. He has published on similitude in engineering; mechanization/automation of greenhouse and nursery; modeling using artificial intelligence techniques; and information systems and decision methodology. Dr. Verma received his B.S. from University of Allahabad (India), M.S. from University of Kentucky, and Ph.D. from Auburn University. He has received numerous awards including IBE Lifetime Visionary Award. He is a Fellow of the American Society of Agricultural and Biological Engineers (ASABE) and the IBE. Recently he has been leading efforts on "Circular Bioeconomy Systems" at the ASABE to address many key challenges in our agri-food systems.

https://engineering.uga.edu/team_member/brahm-verma

Facilitators

Ana Carcedo

Dr. Ana Carcedo is a postdoctoral researcher fellow at the Ciampitti Lab in the Department of Agronomy at Kansas State University. She obtained her degrees from the National University of Rosario in Argentina. Specializing in modeling and crop simulations, her research aims to develop frameworks that optimize farmers' labor and enhance crop management practices. With a keen interest in crop ecophysiology and management, Dr. Carcedo actively contributes to the agricultural community. She serves as the chair of the Field Model Applications American Society of Agronomy community and as the chair of the Kansas Postdoctoral Association, showcasing her dedication to advancing agricultural research and fostering collaboration within the scientific community.
https://ciampittilab.wixsite.com/ciampitti-lab/post-doctoral-researchers

Jan Middendorf

Dr. Jan Middendorf serves as the Associate Director of the USAID Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) at Kansas State University (KSU). With over 30 years of experience, she spearheads research, impact assessment, and monitoring and evaluation efforts for SIIL's $75 million portfolio funded by the U.S. Agency for International Development (USAID). Her expertise lies in establishing and nurturing partnerships with U.S. and international institutions, industry stakeholders, and developmental partners. Dr. Middendorf holds a B.S. in business administration from the University of Rhode Island, an M.A. in international affairs from Ohio University, and a Ph.D. in curriculum and instruction and evaluation practice from Kansas State University. Dr. Middendorf is committed to institutional and program improvement through strategic planning, change management, and evaluation, making significant contributions to multi-institutional, interdisciplinary projects worldwide. https://www.k-state.edu/siil/about/people/index.html

Emma Flemmig

Emma Flemmig serves as a Program Manager for the Feed the Future Innovation Lab for Sustainable Intensification (SIIL) at Kansas State University. Flemmig provides administrative support for the SIIL portfolio's associate awards and manages the Activity Tracker. Her experiences include the World Food Prize's global youth programs, serving as a former president of the International Association of Students in Agriculture and Related Sciences, as well as completing a USAID Borlaug Global Food Security graduate research fellowship in Haiti, and a Fulbright-Nehru student research fellowship at Punjab Agricultural University in India. She has most recently worked in grants management and business development with Quisqueya University in Port-au-Prince, Haiti, and The Land Institute in Salina, Kansas. https://www.k-state.edu/siil/about/people/index.html

INVITED PARTICIPANTS

Gbola Adesogan

Dr. Gbola Adesogan is a Distinguished Professor of Ruminant Nutrition, serving as the Director of the Food Systems Institute and the Director of Strategic Partnerships for the Feed the Future Innovation Lab for Livestock Systems. With a focus on sustainably enhancing animal-source food production and consumption, Dr. Adesogan's research delves into improving forage production, quality, and preservation. He is renowned for his work on utilizing feed additives, forages, and byproducts to enhance animal production and health in a sustainable manner. His contributions are pivotal in addressing the global challenge of food security and ensuring the resilience of livestock systems to meet the growing demands of a burgeoning population. https://animal.ifas.ufl.edu/people/adegbola-adesogan/

Miguel Castillo

Dr. Miguel Castillo is a prominent figure in the Forage & Grassland Program at North Carolina State University (NCSU), serving as the Grassland Science Specialist. With a focus on improving ecosystem services in agricultural and pasture-based livestock systems globally, he collaborates across tropical, sub-tropical, and temperate environments. Dr. Castillo facilitates international partnerships to enhance resource management and system resilience. Originally from Loja, Ecuador, he earned his undergraduate degree in Plant and Animal Sciences from Zamorano University, Honduras. He later obtained M.S. and Ph.D. degrees in Agronomy from the University of Florida, followed by an MBA from NCSU. His research spans from Brachiaria cultivar evaluation for pasture-based livestock systems to innovative practices like biosolid utilization for forage fertilization and strip-planting techniques for rhizoma peanut introduction into perennial pastures. He is driven by a strong commitment to sustainable agriculture and global impact. https://cals.ncsu.edu/crop-and-soil-sciences/people/mscastil

Robert Henry

Professor Henry is a distinguished scholar with a vast academic background, holding degrees from the University of Queensland (B Sc, Hons), Macquarie University (M.Sc. Hons), and La Trobe University (Ph. D). In recognition of his exceptional contributions to plant analysis, he was awarded a higher doctorate (D. Sc) by the University of Queensland in 2000. Currently serving as Professor of Innovation in Agriculture, Professor Henry previously held key leadership roles, including Director of the Centre for Plant Conservation Genetics at Southern Cross University and Research Director of the Grain Foods Cooperative Research Centre. His expertise lies in utilizing molecular tools to study agricultural crops, with a focus on Australian flora and economically significant plants. Professor Henry's groundbreaking research in genome sequencing has paved the way for the diversification of food crops, leading to the development of enhanced food products. https://qaafi.uq.edu.au/profile/180/robert-henry

Prakash Kumar Jha

Dr. Prakash Kumar Jha is an Assistant Professor of Agricultural Climatology at Mississippi State University. His research focuses on integrating advanced modeling techniques, in-situ remote sensing, and advanced climate information for decision support in agriculture and water management. Utilizing agricultural models, data science, simulation, and optimization techniques, he strives to understand the complex processes of agricultural production systems at various scales. Recently, Dr. Jha was honored with the prestigious Foreign Fellow Award from the Society for Science of Climate Change and Sustainable Environment (SSCE), an Indian-based organization dedicated to addressing climate change and environmental sustainability. This accolade recognizes his work in mitigating climate change's impact on agricultural systems, developing novel agricultural practices for food security, and fostering collaboration between researchers and policymakers.
https://www.pss.msstate.edu/associate.php?id=248

David Jones

Dr. David Jones is a distinguished professor of Biological Systems Engineering and a courtesy professor in the Food Science & Technology Department at the University of Nebraska-Lincoln (UNL). With a Ph.D. in Agricultural Engineering from Oklahoma State University-Stillwater, he has been an integral part of UNL's academic leadership. Jones served as the department head for Biological Systems Engineering from 2017 to 2023, following his role as associate dean for Undergraduate Programs in the College of Engineering from 2011 to 2017. During his tenure, he oversaw undergraduate studies, curriculum development, and student services, earning recognition with a Presidential Citation from the Institute of Biological Engineers. Jones is renowned for his expertise in transport processes, mathematical modeling, and senior capstone engineering design. He has been honored with multiple awards from UNL, reflecting his dedication to teaching, advising, and mentoring. Passionate about fostering innovation in engineering education, Jones participated in a prestigious National Science Foundation program aimed at boosting innovation and entrepreneurship in undergraduate engineering education. He also led UNL's Strengthening Transitions to Engineering Programs (S.T.E.P.) initiative, enhancing pathways for students transferring to the College of Engineering.
https://bse.unl.edu/faculty/david-jones

Madhu Khanna

Dr. Madhu Khanna is a Distinguished Professor in Environmental Economics at the University of Illinois. With a diverse research portfolio, she has contributed significantly to various fields, including technology adoption, agro-environmental policy analysis, and the implications of biofuels. Throughout her career, she has delved into topics such as technology adoption, conservation payments, and voluntary pollution control programs, aiming to improve environmental protection and sustainability in agriculture. She has also conducted interdisciplinary research on the economic and land use implications of biofuel production, particularly focusing on next-generation bioenergy crops. In addition to her academic roles, Dr. Madhu Khanna serves as the Director of the Institute for Sustainability, Energy, and Environment and holds multiple professorial positions across various departments, reflecting her interdisciplinary approach to research.
https://ace.illinois.edu/directory/khanna1

Peter Kyveryga

Dr. Peter Kyveryga is an Agronomist at John Deer. He is dedicated to advancing methodologies for conducting and analyzing on-farm agronomic and environmental studies. His research aims to enhance agronomic decision-making by developing online interactive tools for farmers and agronomists. Additionally, Peter serves as an Affiliate Associate Professor at the Department of Agronomy, Iowa State University. In this role, he collaborates with faculty and students on projects related to precision agriculture, remote sensing, data science, and soil health. Recognized for his contributions to the field, Peter is a Fellow of the American Society of Agronomy (ASA). He has also served twice as the Technical Editor-Precision Agriculture for the Agronomy Journal and served as ASA Program Chair. https://www.researchgate.net/profile/P-Kyveryga-2

Nicole Lefore

Dr. Nicole Lefore currently serves as the Director of the Feed the Future Innovation Lab for Irrigation and Mechanization Systems at University of Nebraska. She is committed to advancing equitable and sustainable outcomes through agricultural water management and intensification. She leads initiatives aimed at accessing and managing water for sustainable agriculture, particularly for smallholder farmers worldwide. With over 30 years of international experience in research for development, policy advocacy, and project implementation, Nicole has worked extensively in Sub-Saharan Africa and the developing world. She previously served as Director of the Feed the Future Innovation Lab for Small Scale Irrigation at Texas A&M University. Nicole's expertise spans water and land institutions, governance, markets, finance in small-scale irrigation, equity in development, and gender issues. Her dedication to supporting smallholder farmers globally stems from her family's farm in Oregon. Nicole holds a Ph.D. in Government from the University of Virginia and an M.Sc. in Development from the School of Oriental and African Studies at the University of London. https://waterforfood.nebraska.edu/meet-our-people/nicole-lefore

Sara Lira

Dr. Sara holds a Bachelor's degree in Ecology and Master's and Ph.D. degrees in Plant Breeding from Iowa State University. With 15 years of experience in corn breeding at Corteva, Sara brings a wealth of knowledge and expertise to her work. Beyond her professional accomplishments, Sara and her husband actively manage a cow-calf herd on his family farm in Appanoose County. Committed to community service, Sara serves on the board of Susan G. Komen of Iowa, where she focuses on reducing breast cancer deaths in underserved rural areas. Passionate about improving the lives of farmers and rural Iowans, Sara is dedicated to enhancing the health of Iowa's lands. She is thrilled to represent Corteva's renewed commitment to sustainable agricultural research, products, and services.
https://www.corteva.com/

Kaushik Majumdar

Dr. Kaushik Majumdar serves as the Director General for the African Plant Nutrition Institute (APNI), based in Morocco at the Benguérir headquarters. With a diverse background, Kaushik obtained his M.Sc. in Agricultural Chemistry and Soil Science from BCKV University, India, and earned his Ph.D. in Soil Mineralogy/Soil Chemistry from Rutgers University, USA. Throughout his career, Dr. Majumdar has held significant roles in various organizations, including as a Soil Mineralogist at the Potash Research Institute of India (PRII), Deputy Director of Eastern India and Bangladesh for the Potash & Phosphate Institute of Canada-India Programme, and Director of the South Asia Program of the International Plant Nutrition Institute (IPNI). As IPNI Vice President for Asia and Africa Programs, Dr. Majumdar led plant nutrient management research and education initiatives, fostering partnerships and resource mobilization to advance the fertilizer sector through research, extension, and capacity building. He has also contributed significantly to developing fertilizer decision support tools, technical bulletins, training aids, and scientific publications. https://www.apni.net/team/kaushik-majumdar/

Lauren Maul

As the Sustainability Director at the United Soybean Board, Lauren Maul spearheads sustainability research and education initiatives funded by the board under the leadership of US soybean farmers through their checkoff program. With a strong dedication to promoting sustainable agriculture, she supports various sustainability projects aimed at enhancing value for farmers and improving overall sustainability performance. Bringing a wealth of experience as an environmental scientist and program director, she has worked extensively in sustainable agriculture, natural resource management, food systems, water quality, soil health, conservation, renewable energy, infrastructure, capital projects, regulatory compliance, environmental science, and policy for public, private, and non-profit organizations. She holds a Master of Science (M.S.) degree in Natural Resources and Conservation from Oregon State University. https://www.unitedsoybean.org/

Dan Northrup

Dr. Dan Northrup is a technology development leader with extensive experience in genetics, agriculture, and sustainability. Throughout his career, he has successfully designed, managed, and executed transformative research portfolios impacting various sectors, including food production, human and animal nutrition, renewable energy, and soil health. Dr. Northrup specializes in reducing emissions from agriculture and enhancing farm profitability through agronomic interventions. Currently serving as a Principal at Galvanize Climate Solutions, Dr. Northrup provides technical diligence on agriculture and life science companies. He is a member of the United Soybean Board's Sustainability Advisory Council and an independent board member of Dryland Genetics. Previously, he held the position of Director of Special Projects at Benson Hill, focusing on novel protein sources for animal nutrition and plant-based meats. With a Ph.D. in immunology from the University of Pennsylvania and a biomedical engineering degree from Duke University, Dr. Northrup brings a unique blend of expertise to his work.

https://galvanizeclimate.com/team/dan-northrup

Joaquin Olivero

Joaquin Olivero is a Vice President at Fall Line Capital, based in Little Rock, AR, where he plays a key role in underwriting new farm acquisitions, conducting data analysis across the Fall Line portfolio, and managing farms within the Mississippi Delta region. With over a decade of professional farm management experience, Joaquin brings extensive expertise to his role. His background includes managing farms spanning thousands of acres in Arkansas, Louisiana, Mississippi, and Argentina, cultivating various crops such as rice, corn, soybeans, wheat, cotton, and milo. Joaquin holds a degree in Agricultural Engineering from the University of Buenos Aires, where his passion for soil conservation was cultivated. A dedicated advocate for innovative erosion control practices, Joaquin remains committed to implementing sustainable agricultural techniques, including optimal no-till practices, cover crops, and field terracing. https://www.fall-line-capital.com/team/joaquin-oliverio

Partha Ray

Dr. Partha Ray is a Dairy Scientist and Veterinarian with over a decade of experience collaborating with stakeholders in dairy production to develop innovative on-farm and system-level solutions aimed at enhancing the sustainability of dairy production. With a background in Veterinary Science and Animal Husbandry (B.S.) and Animal Nutrition (M.S.) from India, he earned his Ph.D. in Animal Sciences, Dairy from Virginia Tech. Throughout his career, Dr. Ray has been dedicated to advancing dairy production sustainability, leveraging his expertise to address key challenges in the industry. His research and collaborative efforts focus on implementing practices that improve efficiency, reduce environmental impact, and promote animal welfare. Dr. Ray is committed to driving positive change in the dairy sector, contributing valuable insights and solutions to enhance its sustainability and resilience. He is currently the Science Lead, Sustainable Dairy Production at The Nature Conservancy.
https://www.linkedin.com/?trk=public_profile_nav-header-logo

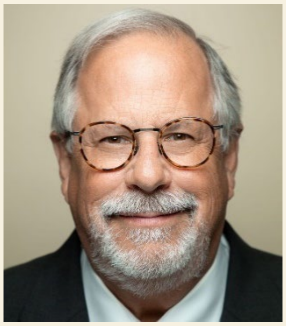
Charles Rice

Dr. Charles Rice is as University Distinguished Professor and Mary Vanier Endowed Professor in the Department of Agronomy at Kansas State University. He is passionate about environmental stewardship. He obtained his B.S. from Northern Illinois University, advanced degrees in Agronomy from the University of Kentucky, where he found his calling in soil microbiology, carbon cycling, and climate change research. Dr. Rice has garnered international recognition, including being a co-winner of the 2007 Nobel Peace Prize for his contributions to the United Nations' Intergovernmental Panel on Climate Change. His research spans soil quality, microbiology, and climate change, aiming to improve and protect the environment. Dr. Rice served as President of Soil Science Society of America. He also contributes to national initiatives like the National Academies Board on Agriculture and the U.S. Department of Agriculture's Agricultural Air Quality Task Force.
https://www.agronomy.k-state.edu/about/people/faculty/rice-charles

Stella Salvo

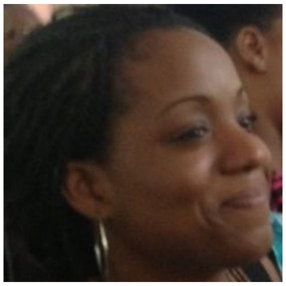
Dr. Stella Salvo is the Head of Development & Deployment in Analytics & Pipeline Design for Bayer's Crop Science division. She leads efforts to introduce new technologies to global plant breeding programs, leveraging innovations in data science, genomics, phenomics, and analytics. Dr. Salvo has over 20 years of experiences in plant breeding, leading discovery, deployment, and projects focused on capacity building and development in Asia and Africa With a Ph.D. in Plant Breeding and Genetics from the University of Wisconsin, an M.S. from Colorado State University, and a B.S. in International Agronomy from Purdue University, Stella brings a wealth of expertise to her role. She manages a collaborative breeding project with the Gates Foundation and the International Institute for Tropical Agriculture, aiming to enhance agricultural practices in developing regions. Stella's dedication extends to volunteering in Sub-Saharan Africa with USAID, where she shares her knowledge of plant breeding and genomics in countries like Mali and Ethiopia.
https://www.researchgate.net/profile/Stella-Salvo

Gary Thompson



Dr. Gary Thompson is the Executive Director of the Southern Association of Agricultural Experiment Station Directors, where he spearheads national and regional efforts to advance agricultural and natural resources research. With a wealth of experience, Thompson has served as an adviser for federal and international funding organizations and is recognized as a Fellow in the APLU-sponsored Food Systems Leadership Institute. Having held esteemed positions such as associate dean for research and graduate education at Pennsylvania State University and head of the Department of Biochemistry and Molecular Biology at Oklahoma State University, Thompson brings a wealth of leadership experience to his role. He has also contributed significantly to academia, serving as a professor and program director for Plant-Biotic Interactions at the National Science Foundation. Thompson received his Ph.D. from Purdue University and has been actively involved in academia, with appointments at various prestigious institutions including the University of Nebraska and the University of Arizona.
https://economics.arizona.edu/person/gary-thompson

Taisha Venort



Dr. Taisha Venort, born in the U.S. and raised in Haiti, embarked on her academic journey at Purdue University, earning a B.S. degree in Environmental and Ecological Engineering. Her passion for ecological sciences led her to pursue a M.S. degree in the same field at Purdue, where she was honored with a Borlaug Fellowship for her research on Farm Biogas in Kenya. Continuing her academic pursuits, Taisha earned a Ph.D. in Agricultural and Biological Engineering from the University of Florida, supported by a prestigious McKnight Fellowship. Under the guidance of Dr. Cheryl Palm and Dr. Rafael Muñoz-Carpena, her research focused on agricultural intensification and natural-human systems, particularly in smallholder contexts. Taisha's outstanding contributions have been recognized with the Corteva Delta Research Grant and the U.S. Borlaug Fellow in Food Security. Currently, she serves as a research investigator at Corteva Agriscience.
https://www.researchgate.net/profile/Taisha-Venort