C-Quest: Charting a Course for Climate Research in Agriculture

ILSI Research Foundation Workshop Summary Report

ILSI Research Foundation

Mission

The International Life Sciences Institute Research Foundation (ILSI Research Foundation) improves environmental sustainability and human health by advancing science to address real world problems.

The ILSI Research Foundation is internationally recognized as a valuable partner in generating and disseminating scientific information that improves environmental sustainability and human health.

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Contents

Full Session Summary 3
Participation and Polling....4
Top Research Targets Identified for US Agriculture....5
Appendix 6
Breakout Topic I: Soil Health....6
Breakout Topic II: Nitrogen Stewardship....7
Breakout Topic III: Livestock Partnerships 8
Breakout Topic IV: Land Conservation....9
Breakout Topic V: Grazing and Pasture Lands 10
Breakout Topic VI: Integrate Field Research Networks....11
Breakout Topic VII: Grower Adoption of C-Neutral Practices....12
Breakout Topic VIII: C-Neutral Modeling and Verification....13
Breakout Topic IX: Pollinator Health 14

Full Session Summary

There is a growing demand for more nutritious food and for the United States agri-food system to become carbon-neutral. New research suggests these goals are achievable with farming practices that enhance soil health and increase levels of soil carbon. However, important questions still need to be answered, such as the permanence of soil carbon reserves and how to best validate emerging soil carbon protocols. It is essential that the new research agenda for US agriculture includes targets that address such critical information gaps.

It was against this backdrop, and as part of its mission to advance science to address real world problems, that on October 24-25, 2016 the ILSI Research Foundation held *C-Quest: Charting a Course for Climate Research in Agriculture* at Washington University in St. Louis. Eighty scientists, farmers, and other experts attended C-Quest, with the shared goal of developing a prioritized set of research targets for US agriculture that:

- Support achievement of USDA's building blocks for climate smart agriculture;
- Integrate existing US field research networks for climate adaptation;
- Develop a research agenda to achieve a carbon-neutral agri-food system in the US through a focus on soil carbon and soil health, including validation of soil carbon protocols.

C-Quest was co-sponsored by the Foundation for Food and Agriculture Research, the Howard G. Buffett Foundation, Monsanto Company, Soil Health Partnership, USDA, Washington University in St. Louis and the Sustainable Agriculture Research and Education (SARE) program at the University of Missouri. The ILSI Research Foundation took a multi-sectoral, collaborative approach to planning this workshop, by ensuring the C-Quest organizational committee included representatives from the sponsorship groups as well as Field to Market, North American Climate Smart Agriculture Alliance, The Nature Conservancy, and World Wildlife Fund.

A briefing document was circulated to all workshop participants two weeks before C-Quest convened to establish a baseline understanding about climate research in agriculture. The workshop format also included plenary presentations to establish a common level of understanding for all participants and describe the workshop deliverables. Most of the workshop was spent in breakout groups, where individuals were given ample time to collectively brainstorm research targets on Monday and then prioritize these new ideas on Tuesday. A final plenary session was used to share and further refine ideas, which were then voted upon by the entire group using polling software.

The workshop opened with Dr. Himadri Pakrasi and Dr. Barbara Schaal of Washington welcoming participants and acknowledging the timely importance of the topics C-Quest was to explore and the innovative methods by which this group of scientists, farmers, and stakeholders would prioritize research on these issues during this workshop. The opening address featured Dr. Dave Gustafson, ILSI Research Foundation; Dr. Sally Rockey, Foundation for Food and Agriculture Research; Mr. Chris Novak, National Corn Growers Association; and Dr. Mike Lohuis, Monsanto Company.

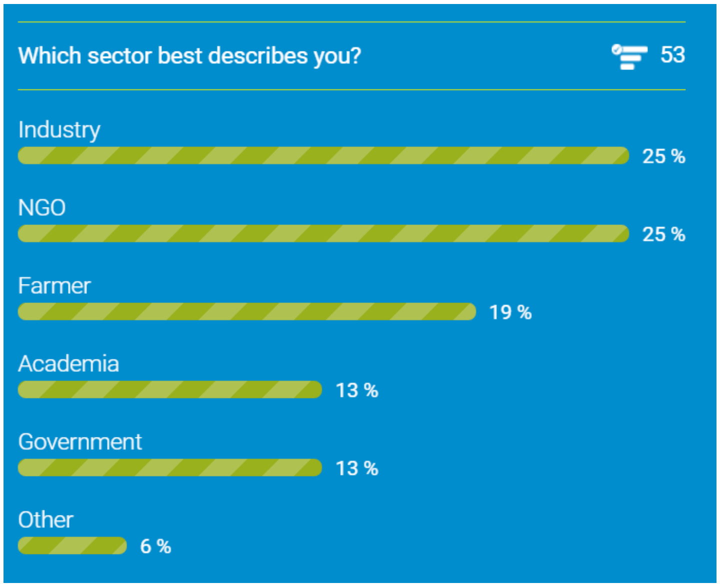
The keynote presentation was provided by Dr. Charles Rice, Kansas State University, who highlighted the climate research challenge for US agriculture, emphasizing the importance of soil health, plant and animal breeding, precision agriculture, modeling, weather forecasting, and risk management. Mr. Bill Hohenstein, USDA, Dr. Nick Goeser, Soil Health Partnership, and Dr. Keith Paustian, Colorado State University, helped set the context of the afternoon discussions with presentations on climate smart agriculture, integrating field research networks, and modeling soil carbon, respectively.

Discussions were advanced in breakout sessions where participants first brainstormed and then prioritized relevant research topics across nine areas: 1. Soil Health, 2. Nitrogen Stewardship, 3. Livestock Partnerships, 4. Land Conservation, 5. Grazing and Pasture Lands, 6. Integrate Field Research Networks, 7. Grower Adoption of C-Neutral Practices, 8. C-Neutral Modeling and Verification, and 9. Pollinator Health.

On October 24, two additional plenary presentations were provided by Dr. Bob Reiter, Monsanto Company, who emphasized the need for climate change response and mitigation from the private sector, and Dr. Suzanne Lutfalla, INRA (French National Institute for Agricultural Research), who described "4 per 1000", a new international, multi-stakeholder initiative to improve levels of soil organic matter and foster carbon sequestration in soils. After these additional perspectives were shared, the breakout groups reconvened to refine their lists of research ideas, and used group voting to prioritize the most relevant topics. These lists were then prioritized by the entire group of workshop participants in a final plenary session. *To view the agenda, presentations, news releases and briefing document from C-Quest, please visit http://bit.ly/ILSIRF_CQuest2016.*

Participation and Polling

For the first two polls at C-Quest, participants were asked to select their sector and how many years they have worked in this area. As shown below, the 53 respondents represent a broad mix of industry, non-governmental organizations (NGOs), farmers, academia and government. There was also good diversity in terms of years of experience, with 28% very early in their careers (0-5 years) and 59% having at least 10 to more than 30 years of experience.



Participants included a broad mix of all relevant sectors and had good diversity in terms of years of experience.

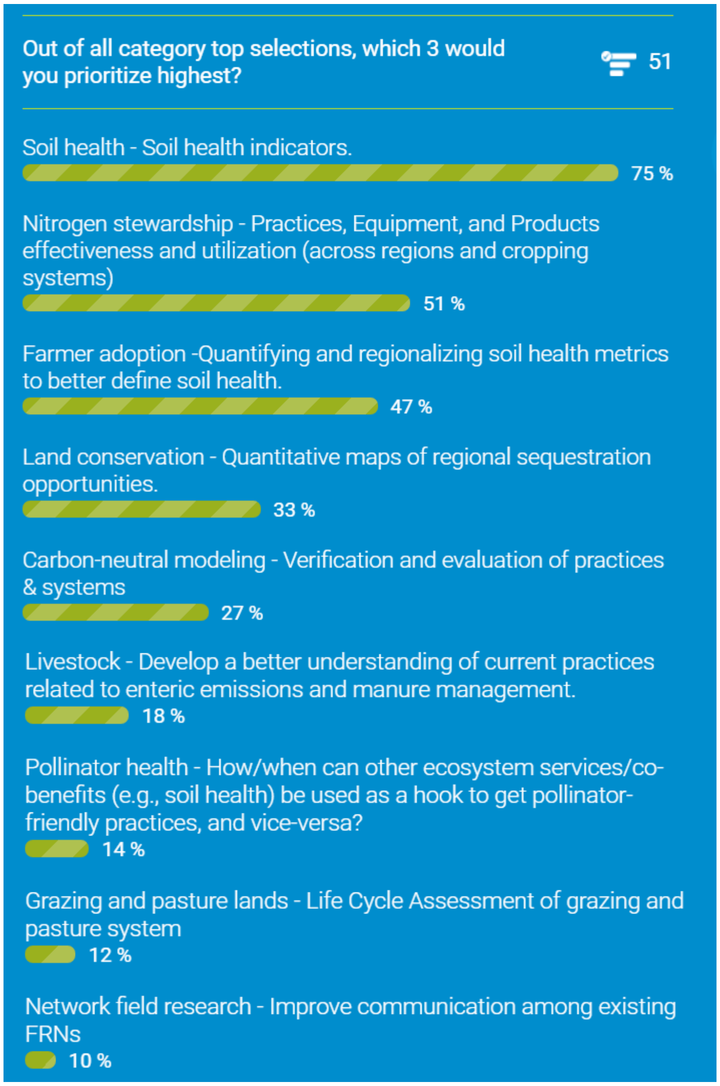
Note: For all questions regarding research prioritization, participants were asked to select up to three responses from the options provided. Results for those questions are contained in the Appendix and show the percentage of voters who selected that response among their three selections. Those totals are therefore greater than 100%.

Top Research Targets Identified for US Agriculture

C-Quest participants identified the following research targets to support USDA's climate smart agriculture initiative, integrate existing US field research networks, and achieve a carbon-neutral agri-food system in the United States.

1. *Soil Health: Development of Quantitative Indicators*
2. *Nitrogen Stewardship: Effectiveness of Practices, Equipment & Products*
3. *Grower Adoption of C-Neutral Practices: Quantifying and Regionalizing Soil Health Metrics to Better Define Soil Health*
4. *C-Neutral Modeling & Verification: Verification & Evaluation of Practices & Systems*
5. *Land Conversation: Quantitative Maps of Regional Sequestration Opportunities*
6. *Livestock Partnerships: Better Understanding of Effectiveness of Current Practices on Enteric Emissions and Manure Management*
7. *Pollinator Health: How/When can other Ecosystem Services/Co-benefits Be Used*
8. *Integrating Field Research Networks: Improve Communication among Existing Networks*
9. *Grazing & Pasture Lands: Life Cycle Assessment of Grazing & Pasture Systems*

After selecting these top priorities from the lists developed by the breakout session groups, the top overall result for each topic was used to populate a new poll that prioritized between the different top results.



The overall top priority identified by the participants is to develop reliable indicators and metrics for quantifying soil health.

This reflects the surging commercial and research interest in promoting robust soil microbial communities, improving cover crop cultivars, and characterizing soil health-related ecosystem services. Other highly ranked research targets included the effectiveness of practices, equipment, and products for nitrogen stewardship, as well as the use of soil health indicators to help drive farmer/grower adoption of carbon-neutral farming practices. A common theme that emerged from all the C-Quest discussions is that growers will respond in positive ways when given access to reliable data on practices that are profitable and achieve better, long-term outcomes.

Note: Due to a first-place tie in responses to the "Farmer adoption" research ideas, a later version of the poll included an option of "Determine Key factors that drive farmer decision making", which came in fourth at 37%. Although not enough responses were garnered for the later poll to include it here, both grower adoption strategies were clearly high priorities for many participants.

Appendix

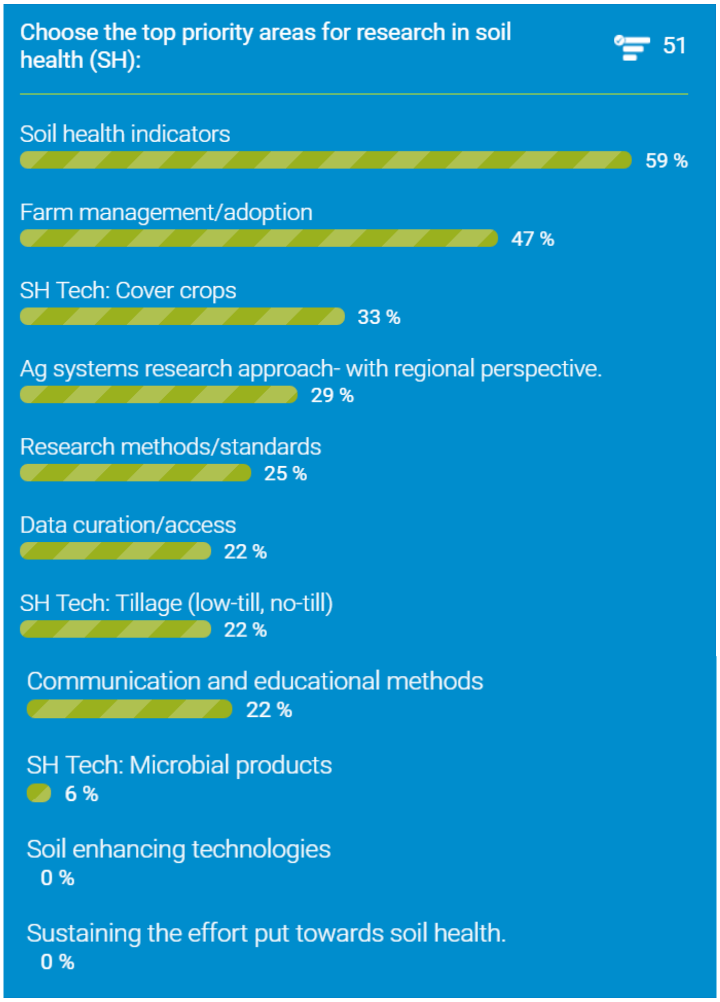
This appendix contains research needs, discussion notes and polling results for each of the breakout topics discussed at *C-Quest*: Charting a Course for Climate Research in Agriculture (October 2016).

Breakout Topic I: Soil Health

Land use and management can build or reduce soil carbon depending on the specific management practices used. Thus, opportunities for greenhouse gas (GHG) mitigation in agriculture include encouraging practices that increase soil carbon or discouraging those that reduce soil carbon. Management practices that improve soil health decrease erosion of carbon-rich top soil and increase soil organic matter. These practices result in organic matter stabilization and carbon sequestration. Additionally, improved soil health status can reduce net carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions, both directly and indirectly, for example through reductions in inputs and fuel usage.

Participants from Breakout Topic I were asked to the rank the following areas for research in soil health:

- Indicators (theory of soil health)
- Functional relationships and systems boundaries/linkages
- Research methods and standardization (e.g. Farmer compensation, timeframe, reference/benchmark soil samples, and cross discipline methods)
- Farm management/adoption (e.g. Economics and systems interactions such as weeds and insects)
- Data curation and access (e.g. Privacy and compensation)
- Modeling
- Understanding carbon pools, sequestration, and capacities
- Communication and education– multifaceted translation
- Benchmarking
- National survey data – practices/systems
- Farmer innovation and validation
- Technologies/sensors
- Climate change impacts on soil health indicators
- Defining, standardizing classifications
- Funding/incentives
- Social science – opportunities/barriers to behavioral change
- Policy connections to soil health



Development of reliable soil health indicators (metrics) was ranked as the top priority area for Breakout Topic I: Soil Health.

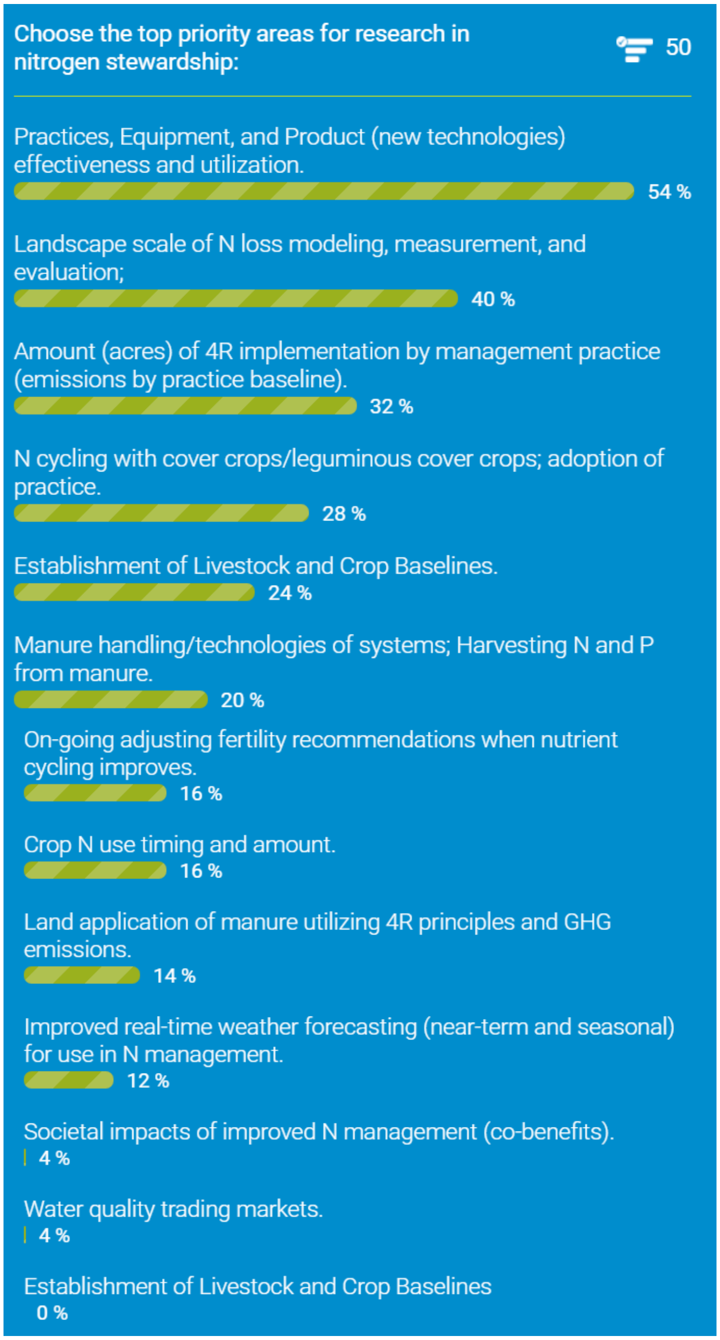
Breakout Topic II: Nitrogen Stewardship

Within the United States, agriculture is a significant source of N_2O emissions, a GHG that is over 250 times more potent than CO_2, on a per-molecule basis. N_2O emissions from synthetic nitrogen fertilizers and organic sources represent a major source of GHG emissions from U.S. agricultural production. N_2O emissions from synthetic fertilizer and organic amendments account for more than 50 percent of cropland agriculture N_2O emissions. Management of nitrogen application can reduce these emissions, such as practicing the "4Rs" (right source, right source, right time, right place). N_2O emissions from cropping practices depend on many factors, but several key factors are the timing, source, placement, and quantity of nitrogen (both from organic sources and synthetic sources) applied. Weather and soil health also influence nitrogen losses and the resulting efficiency with which it is taken up by crops. Taking these factors into account, GHG emissions can be reduced substantially through improved nitrogen management practices and increased nitrogen use efficiency on crop and pasturelands. In addition to reducing N_2O emissions, these practices can also significantly reduce nitrate leaching, improving local and regional water quality, and reduce on-farm input costs.

Participants from Breakout Topic II were asked to the rank the following areas for research in nitrogen stewardship:

- Practices, equipment, and products effectiveness and utilization across regions and cropping systems
- Amount in acres of "4Rs" (right source, right source, right time, right place) implementation by management practice
- Establishment of livestock and crop baselines
- Landscape scale of nitrogen (N)loss modeling, measurement, and evaluation; Moving beyond small-scale chamber projects to larger scale or farm scale/ watershed scale
- On-going adjusting fertility recommendations when nutrient cycling improves (for example, general improvements in nitrogen (N) cycling, conservation tillage, and cover crops)
- Nitrogen cycling with cover crops/leguminous cover crops and the adoption of practice
- Improved real-time forecasting for use in nitrogen (N) management
- Manure handling/technologies of systems; Manure hauling costs versus nitrogen and phosphorus (N and P) content value of the manure; Harvesting N and P from manure
- Land application of manure utilizing 4R principles and GHG emissions
- Societal impacts of improved nitrogen (N) management (co-benefits)
- Crop nitrogen (N) use, timing and amount

Practices, equipment and product (new technologies) effectiveness and utilization was ranked as the top priority area for Breakout Topic II: Nitrogen Stewardship.

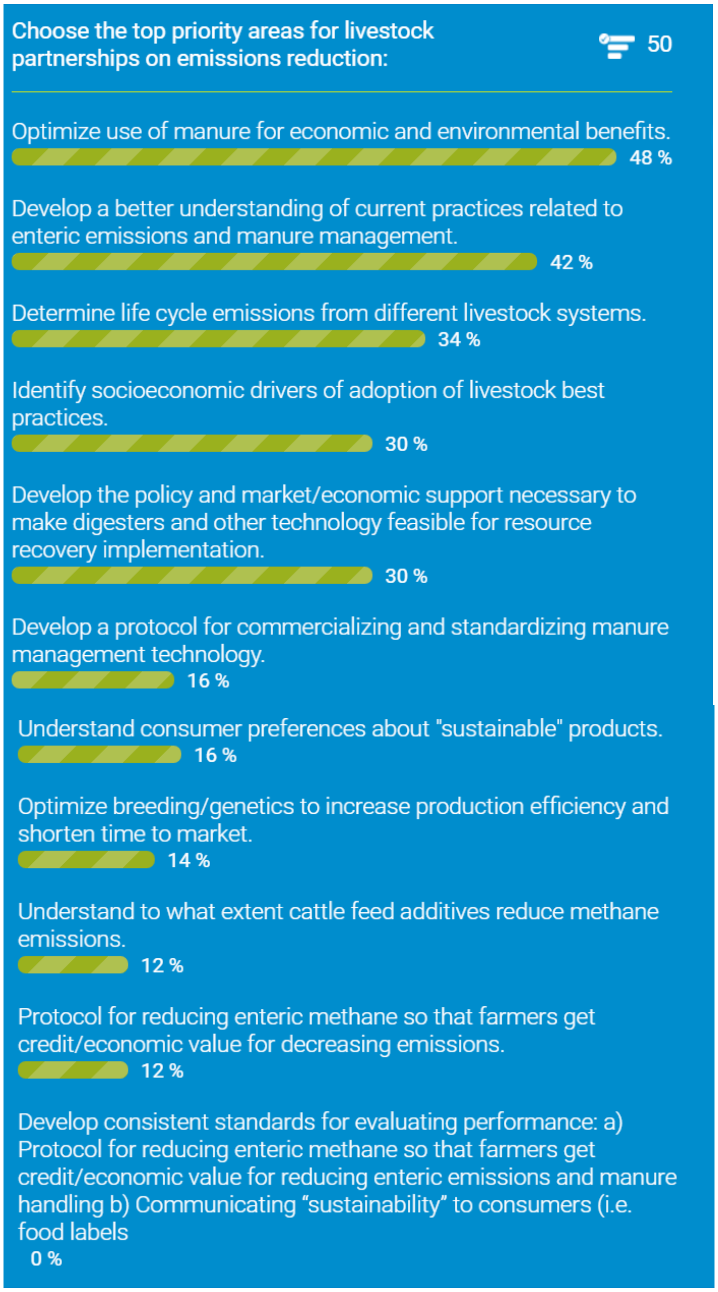


Breakout Topic III: Livestock Partnerships

When livestock manure is treated and stored in anaerobic conditions (e.g., as a liquid/slurry in lagoons, ponds, tanks, or pits), decomposition results in large emissions of methane (CH_4), a GHG that is more potent than CO_2 with higher short-term impacts on the atmosphere. Livestock manure management accounts for almost 10% of GHG emissions from agriculture globally, and contributes an equal proportion to the US methane emission inventory. Managing manure to either encourage aerobic decomposition, which produces little to no methane, or capturing the methane through digester technologies or covers with flaring, can greatly reduce the GHG emissions from livestock production. Livestock are significant contributors to methane total emissions, with emissions coming from enteric fermentation by ruminants and management of liquid manure.

Participants from Breakout Topic III were asked to the rank the following areas for research in livestock partnerships:

- Establish baseline of current practices and related emissions to enable targets and measurement Determine the total life cycle emissions associated with different systems for raising livestock (e.g., grass-fed and grain-fed)
- Conduct a comparison of socioeconomic impacts of different livestock systems and understand what drives adoption of best practices
- Optimize breeding/genetics to continue to increase efficiency in production and shorten time to get cattle to market
- Understand to what extent can feed additives help reduce methane emissions
- Optimize use of manure
- Develop consistent standards for evaluating performance (eg. Protocol for reducing enteric methane so that farmers get credit/economic value for reducing enteric emissions and manure handling; Communicating "sustainability" to consumers (i.e. food labels)
- Develop a protocol for commercializing and standardizing manure management technology
- Develop the policy and market/economic support necessary to make digesters and other technology feasible for resource recovery implementation



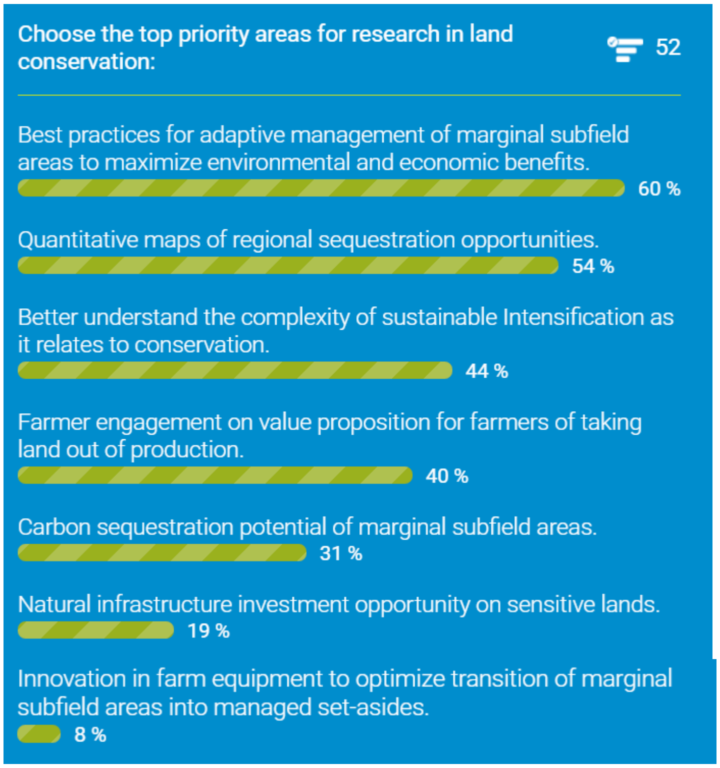
Optimize use of manure for economic and environmental benefits was ranked as the top priority for Breakout Topic III: Livestock Partnerships.

Breakout Topic IV: Land Conservation

The term "sensitive lands" denotes soils and landscapes that are valuable due to properties (e.g., high organic matter, wet hydrology) and/or function (e.g., wildlife habitat, filtration, and hydrologic storage). Typical examples of these soils are organic rich histosols, floodplains, or wetlands along riparian areas. Properties and functions of these soils are easily disrupted from agricultural or urban land use. Sensitive lands that are used for agricultural production can be protected by changes in land use (long-term cover). This reduction in land use intensity can provide multiple environmental benefits, including substantial GHG mitigation that occurs as carbon is sequestered or preserved in soils and vegetation. When land is removed from crop production, several activities—including tillage, nitrogen fertilization, and energy use—are substantially reduced or eliminated, generating additional GHG mitigation.

Participants from Breakout Topic IV were asked to the rank the following areas for research in land conservation:

- Best practices for adaptive management of marginal subfield areas to maximize environmental and economic benefits
- Quantitative maps of regional sequestration opportunities
- Better understanding of the complexities of sustainable intensification as it relates to conservation
- Farmer engagement on value proposition for farmers of taking landing out of production
- Carbon sequestration potential of marginal subfield areas
- Natural infrastructure investment opportunity on sensitive lands
- Innovation in farm equipment to optimize transition of marginal subfield areas into managed set-asides



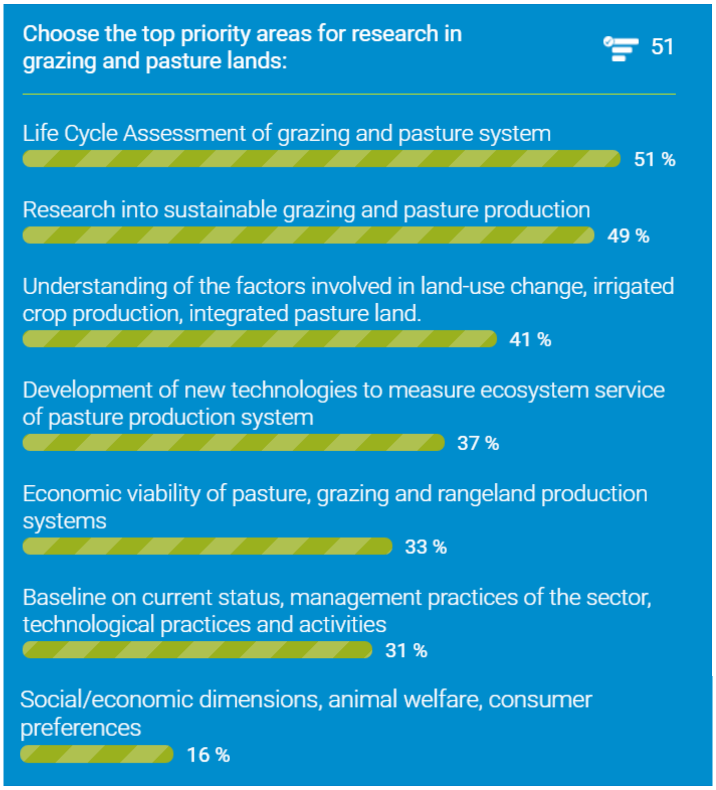
Best practices for adaptive management of marginal subfield areas to maximize environmental and economic benefits was ranked as the top priority area for Breakout Topic IV: Land Conservation.

Breakout Topic V: Grazing and Pasture Lands

The proper management of grazing lands (range and pasture) can both meet individual farm and ranch livestock production goals and play a role in nationwide efforts to increase soil carbon sequestration. Atmospheric carbon fixed by growing forage plants is translocated to roots and incorporated into the soil carbon pool via humification. By far, the most important factor governing the direction and rate of carbon flux in grazing lands is short-term climate variability, particularly rainfall and temperature. Planning to sequester carbon in arid rangelands is particularly challenging because of the low productivity and high year-to-year variability. In regions where annual rainfall is higher and more reliable, there is a higher probability that plains will sequester larger amounts of carbon.

Participants from Breakout Topic V were asked to the rank the following areas for research in grazing and pasture lands:

- Research into sustainable grazing and pasture production (including sustainable forage management strategies; optimize the grazing/pasture system; carbon neutral grazing practices; biodiversity)
- Life Cycle Assessment of grazing and pasture system (including life cycle inventory for grazing and pasture production systems (GHG, land use); need consistent survey information to conduct LCA; need more research on GHG (including carbon sequestration); optimize the age of animal in the context of improving GHG profile).
- Baseline on current status and management practices of the sector, research and data that needed to collect, technological practices and activities
- Social economic dimensions, animal welfare, consumer preferences
- Economic viability of pasture, grazing and rangeland production systems
- Development of new technologies to measure ecosystem service of pasture production system



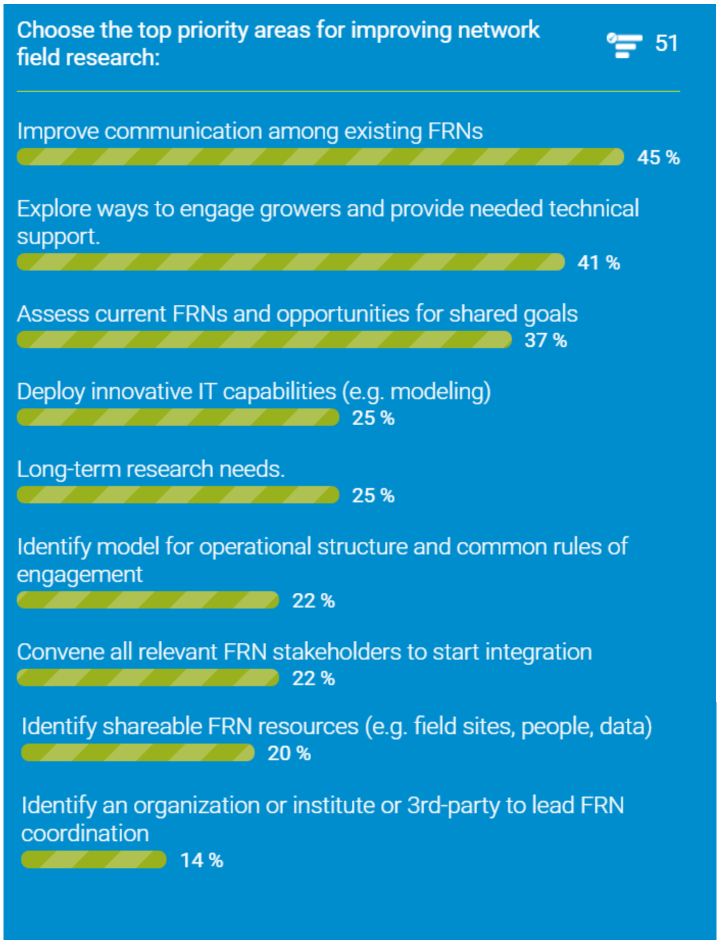
Life Cycle Assessment of grazing and pasture systems was ranked as the top priority area for Breakout Topic V: Grazing and Pasture Lands.

Breakout Topic VI: Integrate Field Research Networks

The imperative of adaptation to climate change and other environmental challenges confronting the US agri-food system calls for integration of current field research networks, to assemble large datasets on the performance of current and future crops and cropping systems and farm level management practices. For efficiency and continuity with current activities, existing public agriculture research infrastructures should form the core of the new integrated network, which would include both public- and private-sector collaborators. Such an integrated network would provide the set of experimental facilities needed to explore and test adaptation and mitigation strategies.

Participants from Breakout Topic VI were asked to the rank the following areas for integrating network field research:

- Improve communication among existing field research networks (FRNs)
- Explore ways to engage growers and provide needed technical support
- Assess current FRNs and opportunities for shared goals
- Deploy innovative IT capability (e.g. modeling)
- Long-term research needs
- Identify model for operational structure and common rules of engagement
- Convene all relevant FRN stakeholders to start integration
- Identify shareable FRN resources (e.g. Field sites, people, data)
- Identify an organization or institute or 3rd party to lead FRN coordination



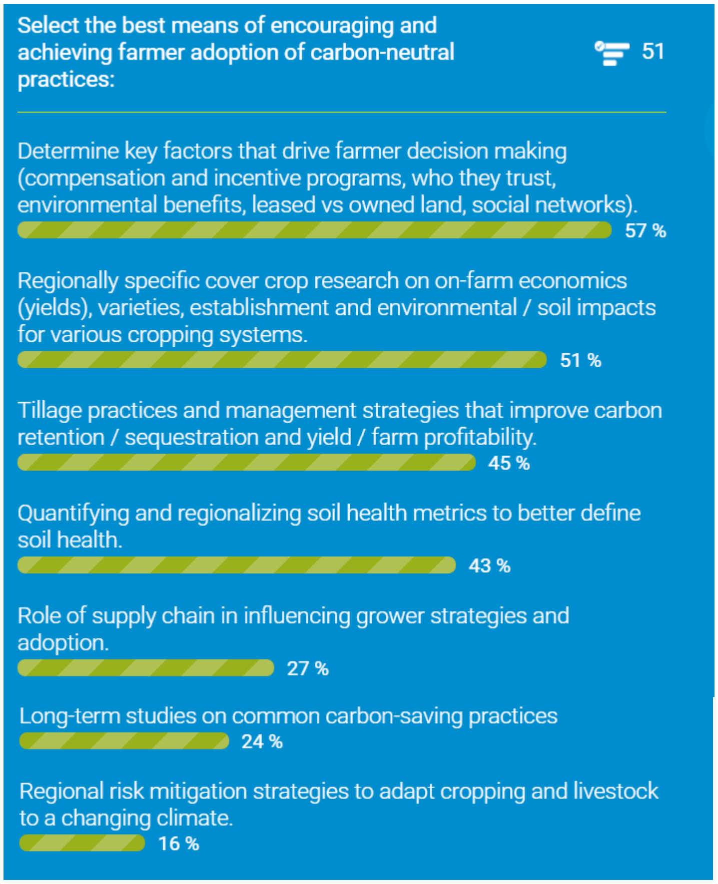
Improve communication among existing networks was ranked as the top priority area for Breakout Topic VI: Integrate Network Field Research.

Breakout Topic VII: Grower Adoption of C-Neutral Practices

America's farm, ranch and forest managers are stewards of the land, and have long recognized the significance of managing soil health, plant productivity and animal nutrition. A number of new tools can help them adopt the new and evolving sustainability practices that can improve both economic and environmental outcomes.

Participants from Breakout Topic VII were asked to the rank the following areas for grower adoption of C-neutral practices:

- Role of supply chain in influencing grower strategies and adoption
- Long-term studies on common carbon-saving practices
- Regional risk mitigation strategies to adapt cropping and livestock to a changing climate
- Tillage practices and management strategies that improve carbon retention/sequestration and yield/farm profitability
- Determine key factors that drive farmer decision making (e.g. compensation and incentive programs, who they trust, environmental benefits, leased vs. owned land, and social networks)
- Regionally specific cover crop research on on-farm economics (e.g. yields), varieties, establishment and environmental/soil impacts for various cropping systems
- Quantifying and regionalizing soil health metrics to better define soil health



Determine key factors that drive farmer decision making was ranked as the top priority area for Breakout Topic VII: Grower Adoption of C-Neutral Practices.

Breakout Topic VIII: C-Neutral Modeling and Verification

Conservation practices and other management changes can reduce GHG emissions and increase carbon storage while improving soil health, crop or livestock productivity, and resilience to drought and other extreme weather. However, it is not possible to monitor every field and measure net GHG emissions directly. Models are needed to understand the connection between management practices and the resulting GHG outcomes. Monitoring of the adoption of those practices (e.g. conservation tillage, cover crops, advanced nutrient management, etc.,) can then make it possible to infer GHG emissions.

Participants from Breakout Topic VIII were asked to the rank the following areas for C-neutral modeling and verification:

- Dissemination of research outcomes and tools
- Model improvement
- Model validation to understand utility for society
- Data needs and data access
- Model verification and evaluation of GHG outcomes
- Verification and evaluation of practices and systems

Verification and evaluation of practices and systems was ranked as the top priority area for Breakout Topic VIII: C-Neutral Modeling and Verification.

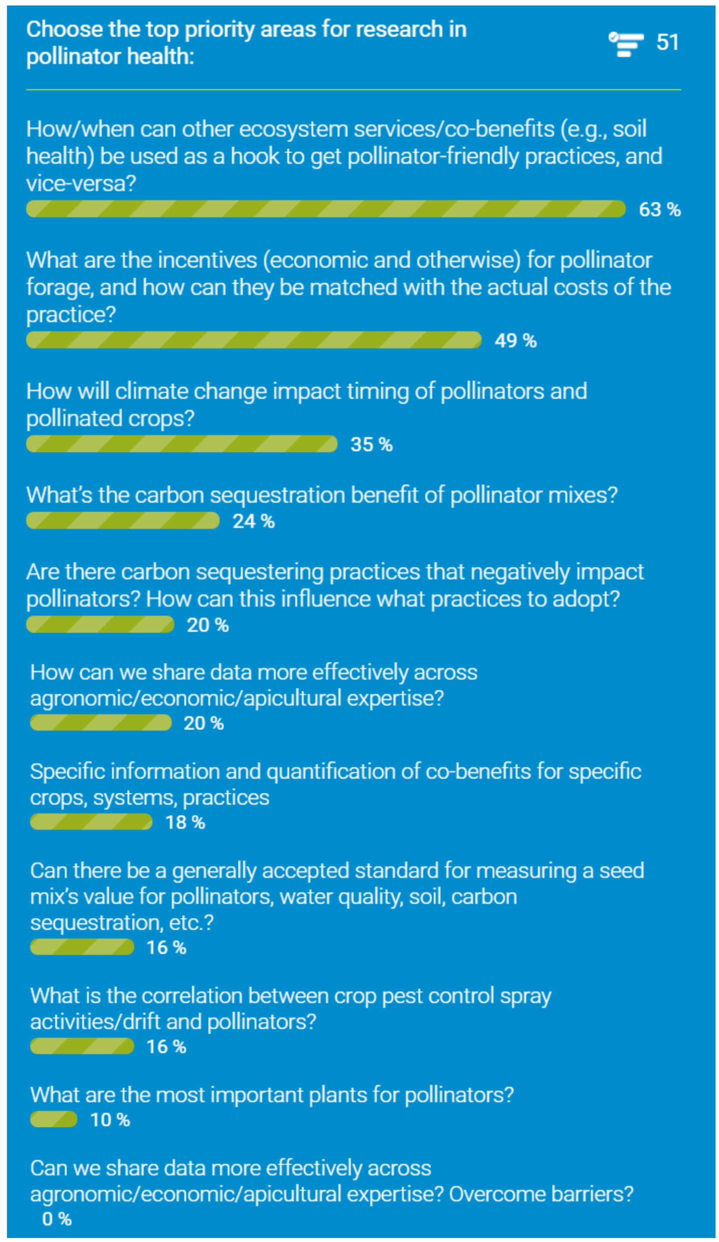
Breakout Topic IX: Pollinator Health

Pollinator health is critical to managed and native landscapes as well as to our food security. National strategies are underway to protect pollinator health and to promote climate-smart agriculture. These strategies can be mutually reinforced by encouraging high quality pollinator habitats on agricultural lands that provides a variety of ecosystem benefits. Existing research has explored the benefits of pollinator forage for crop production as well as the potential impact of climate change to pollinator forage and pollination services. The intersection of climate-smart agriculture and pollinator-friendly practices has also been explored in specific contexts such as cover crops and agroforestry practices. Beyond benefits to pollinators and pollination services, pollinator-friendly conservation plantings also have the potential provide multiple benefits for other wildlife, water quality, soil health, integrated pest management, and even carbon sequestration. Additional research is needed to quantify these co-benefits for particular cropping systems, including the carbon sequestration benefits of pollinator forage, cover crops and pollinator-dependent food crops. Exploration of the benefits of pollinator forage for climate mitigation, climate adaption, and a host of other ecosystem services can aid in the identification and implementation of win-win management for pollinator-friendly, climate-smart agriculture.

Participants from Breakout Topic IX were asked to the rank the following areas for pollinator health:

- What is the correlation between weed spray activities/drift and pollinators?
- What are the most important plants for pollinators?
- How can we share data more effectively across agronomic/economic/apicultural expertise?
- Can there be a generally accepted standard for measuring a seed mix's value for pollinators, water quality, soil, carbon sequestration, etc.?
- What specific information and quantification of co-benefits for specific crops, systems, practices are needed?
- Are there carbon sequestering practices that negatively impact pollinators? How can this influence what practices to adopt?
- What's the carbon sequestration benefit of pollinator mixes?
- How will climate change impact timing of pollinators and pollinated crops?
- What are the incentives (e.g. economic and otherwise) for pollinator forage, and how can they be matched with the actual costs of the practice?
- How/when can other ecosystem services/co-benefits (e.g. soil health) be used as a hook to get pollinator-friendly practices?

Determine how other ecosystem services can be used to induce pollinator-friendly practices was ranked as the top priority area for Breakout Topic IX: Pollinator Health.



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