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Dr. John Dyer, Research Leader, USDA Agricultural Research Service
Dr. Scott Hutchins, Deputy Undersecretary of USDA Research, Education, and Economics Mission Area
Dr. Sonny Perdue, Secretary, United States Department of Agriculture
Dr. Stephen Censky, Deputy Secretary, United States Department of Agriculture

Dear Drs. Perdue, Censky, Hutchins, and Dyer,

Thank you for the opportunity to submit stakeholder comments on the 2020 Agriculture Innovations Agenda (AIA), announced in the Federal Register on March 26th of this year. On behalf of the Organic Farming Research Foundation (OFRF, https://ofrf.org), we would like to submit the following comments and recommendations.

Introduction and Context

OFRF works nationwide to foster the improvement and widespread adoption of organic farming systems through research, education, and federal policies that bring more farmers and acreage into organic production. The organic method, codified in 2002 in the USDA National Organic Program (NOP) Standards, takes a systems-based approach to management of crops, livestock, soil, water, nutrients, weeds, pests, and diseases toward the goals of optimum production and quality, resource conservation and ecosystem services, and farm economic viability. Because soil health and ecological balance comprise the foundation for successful organic production, organic farmers avoid the use of synthetic fertilizers and crop protection chemicals, genetically engineered organisms, and other environmentally risky technologies.

Since 1992, OFRF has awarded more than 300 small grants to producers, university researchers, and other agricultural professionals to explore and develop new and innovative approaches to crop, livestock, soil, water, nutrient, pest, and weed management within the context of USDA certified organic production systems. Many OFRF-funded projects serve as initial “proof of concept” trials leading to larger research endeavors funded through USDA extramural (NIFA), intramural (ARS), or other sources, and ultimately to valuable practical applications. In addition, OFRF has conducted an in-depth review of USDA funded organic research since 2002, and developed a series of science-based practical guidebooks on soil health management in organic systems (available at https://ofrf.org/research/reports/).

Approximately every five years, OFRF assesses current organic farmer research needs to update its National Organic Research Agenda (NORA). In 2015, surveys and listening sessions with nearly 2,000 certified organic farmers, identified the following top five priorities: soil health (rated “high priority by 74% of respondents), weed management (67%), fertility and nutrient management (66%), nutritional quality and integrity of organic food (55%), and insect management (51%) (Jerkins and Ory, 2016). Respondents also cited climate change as a high (34%) or moderate (42%) priority. Since the report’s publication, extreme weather events have further elevated climate resilience and climate mitigation as urgent research and practical issues for organic producers.

We participated in the May 8th webinar on AIA presented by Drs. Dyer and Hutchins, who invited participants to hold stakeholder workshops to identify innovation opportunities based on the question "what do farmers want?" In response, the National Center for Appropriate Technology, Organic Seed Alliance, and National Sustainable Agriculture Coalition held an on-line listening session on June 30, attended by 186 participants including 40 farmers and ranchers. Several themes emerged in this session:

- Farmers and other participants rated Systems Based Farm Management as highly relevant to their work, while the other three innovation clusters received mixed responses.
- Only a minority of participants rated Genome Design as relevant to their work, yet several farmers expressed a need for regionally adapted cultivars and livestock breeds that perform well in climate-friendly, organic and sustainable systems.
- Research into soil health and optimization of soil-plant microbiomes for resilience and reduced need for inputs is a key innovation priority.
- Mitigation of, and resilience to, climate disruption emerged as a high research priority.
- Innovations should be relevant, accessible, and helpful to small to mid-scale producers.
- Technological developments require oversight and must be assessed for safety, and for unintended environmental and socio-economic impacts.
- Livestock research should include holistic grazing management, organic livestock health practices, and smaller scale decentralized livestock production and meat processing.
- Research should emphasize local food systems, urban agriculture, and strengthening urban-rural connections.
- Research innovations must include human health and social aspects of agriculture and food systems; and should maximize *nutritional value* per acre, not just yield.
- Water use efficiency and water quality in agriculture were cited by several farmers.

It is from this perspective that OFRF offers the following comments and recommendations regarding the USDA Agriculture Innovations Agenda.

<u>Innovation Opportunity:</u>

Optimize organic farming and ranching systems for resilient and profitable production, food quality, and ecosystem services, including soil health and climate mitigation.

1. Commodity and customer base:

This innovation opportunity applies to all agricultural regions, farm commodities, and production systems. While the proposed research is addressed to organic and transitioning-organic producers, anticipated outcomes are relevant to non-organic producers as well.

2. Challenges and opportunities:

Organic agricultural systems have great potential to build agricultural resilience (yield stability) to climate disruption and other stresses, protect soil and other natural resources, and reduce net greenhouse gas (GHG) emissions through carbon sequestration and improved nutrient cycling (especially nitrogen (N)). Since the beginnings of the organic industry in the mid-20th Century, organic farming and ranching strategies have emphasized healthy living soils as the foundation of crop, livestock, and human health, as well as long-term farm economic viability; and have sought to simulate and collaborate with natural systems and processes to achieve production goals.

Recent research highlights the soil-building and climate-mitigating benefits of organic farming and ranching systems (Schonbeck et al., 2018, 2019, 2020). For example:

- Non-use of synthetic fertilizers, pesticides, herbicides, and fungicides protects mycorrhizal fungi and other vital components of the soil microbiome, which are often harmed by these materials (Druille et al., 2013; Nicolas et al., 2016; Klein, 2019).
- Integrated organic systems that include cover crops, diversified rotations, and judicious use of organic soil amendments, can greatly enhance nutrient cycling and nutrient use efficiency (Bowles et al., 2015; Kloot, 2018).
- Organic cropping systems show enhanced drought resilience and water use efficiency compared to conventional systems (Gaudin et al., 2018; Rodale, 2011).
- Integrated organic systems can enhance soil microbial activity, soil organic matter, and net carbon sequestration (Cavigelli et al., 2013; Wander et al., 1994).

However, much additional research is needed to fully realize the potential benefits of organic practices. Organic producers face several challenges, including:

- Non-use of herbicides leads to greater reliance on tillage and cultivation for weed control, especially in annual crop rotations. Tillage can accelerate loss of soil organic matter, degrade soil structure, and promote erosion.
- Managing pests and diseases without pesticides requires great knowledge and skill.
- Organic nutrient sources such as manure and compost can provide more phosphorus (P) than crops need, especially if these materials are the primary source of nitrogen (N) in organic production. Excess soil P can suppress mycorrhizal fungi, a vital component of a healthy soil microbiome (Douds, 2009; Hamel, 2004).
- Organic N sources are more challenging to manage for optimum match with crop needs. This can result in N-limited production or surplus soluble N that leaches to groundwater or denitrifies into nitrous oxide, a powerful GHG (Li et al., 2009; Muramoto et al., 2015).
- Yields from organic systems average about 20% lower than conventional yields (Ponisio et al., 2014), a yield gap that limits input efficiency and environmental benefits per unit production, as well as farm profitability.
- Most modern crop cultivars and livestock breeds have not been bred and selected for optimum performance in organic production systems, and may suffer declines in yield and quality if grown/raised without conventional inputs (Hultengren et al., 2016).

Perhaps the greatest challenge for organic producers is the long history of under-investment in organic agriculture research, education, extension, and technical assistance, including public plant and animal breeding for organic systems. Prior to 2002, very few USDA research dollars were devoted to organic farming and ranching. Since then, the Organic Research and Extension Initiative (OREI) and Organic

Transitions Program (ORG) have begun to address organic producers' research needs. Yet, even with the 2018 Farm Bill increasing OREI funding to $50 million per year, USDA organic research will still account for less than 2% of total USDA research funding, which lags far behind the ~6% market share of organic products in the US food system. Thus, the 20% "yield gap" represents a research gap (Ponisio et al., 2014), a need to address the challenges noted above, and a major innovation opportunity to optimize the resilience, soil health, resource efficiency, and climate mitigation potential of organic systems. Research outcomes will greatly expand the capacity of Extension and other service providers to deliver relevant information and technical assistance to organic producers.

3a. Outcomes from innovation clusters:

The systems-based approach to farm management reflects the spirit and letter of the National Organic Standards, and plays a fundamental role in successful organic production. Improved understanding of the continuum of soil microbiome, plant, animal, and human nutrition and health will serve the goal of optimizing per-acre output of nutritional value, as well as climate mitigation and other ecosystem services. Improved data management technologies, software tools, and systems models can further help organic producers fine-tune soil, crop, and livestock management practices. For example, refining agricultural GHG models such as COMET-farm, denitrification-decomposition (DNDC), and Greenhouse Gas Reduction through Agriculture Carbon Enhancement Network (GRACEnet) to provide accurate model outputs for organic systems will help organic producers minimize the GHG footprint of their production systems.

Advanced field sensing technologies will greatly enhance the capacity of researchers to develop practical guidelines for best organic management for soil health, crop nutrition, and non-chemical management of crop pathogens and pests. Real-time field sensors can also help farmers optimize both production and agroecosystem health. For example, a number of weed management tools and strategies have shown promise for reducing intensity of soil disturbance while maintaining satisfactory weed control (Schonbeck et al., 2017a), but improved real-time assessments of soil conditions and weed populations are needed to help organic producers select the best tools and take timely action. Field sensors can also pinpoint nutrient needs and help organic producers to apply optimum amounts of nutrient sources where needed.

Finally, some of the tools of genomic analysis and advanced plant breeding can help improve crop genetics for organic systems, leading to development and release of regionally adapted, public cultivars that perform optimally in integrated organic production systems.

3b: Research gaps, regulatory barriers, and other hurdles

The main hurdle to successful and economically viable organic production is the under-investment in research and development of improved organic farming and ranching systems, based on an apparent lack of appreciation of their potential to enhance long term sustainability and resilience, climate mitigation, and food quality. Assertions that the main purpose of the USDA Organic Standards and certification is to offer consumer choice based on "perceived risks" of conventional production (National Academies, 2019, pages 87 and 98) places the organic method in far too narrow a context, especially in a time of climate crisis when the multiple benefits of sustainable organic systems are needed more urgently than ever.

Some of the technologies cited in the AIA – notably gene editing and synthetic biology – are not allowable for USDA certified organic production. Many are not appropriate or accessible for small diversified farms, which include many organic operations that develop unique, place-based production and resource stewardship systems utilizing locally-available resources and low-cost methods. We are concerned that the AIA bypasses the research needs of organic producers, and thereby misses a major innovation opportunity to further the AIA stated goals of resilience, sustainability, and production. Furthermore, farmers should play a central role in the design of new sensing, data management, and genetic technologies, to ensure that these tools actually meet their needs and empower them to make better management decisions.

Additional organic research should address knowledge gaps including but not limited to:

- Understanding and optimizing crop nutrient cycling and delivery, disease suppression, and other soil microbiome functions in organically managed soils.
- Understanding and optimizing soil carbon and nitrogen dynamics for climate mitigation and resilience in organic systems.
- Integrating organic strategies (cover crops, diverse rotations, organic amendments, low-impact tillage, crop-livestock integration) to enhance soil health, climate mitigation, resilience, and optimum production.
- Region- and site-specific adaptation of integrated organic approaches to these goals.
- Integrated organic weed management strategies including reduced-impact tillage tools and methods that protect soil health and provide adequate weed control.
- NOP-compatible and soil-enhancing alternatives to conventional crop protection chemicals for tough weed, disease, and pest problems.
- Improved, NOP-compatible, grass-based livestock production and health care systems for organic producers

Innovation Opportunity:

Optimize crop genetics and indigenous soil-plant microbiome interactions for crop vigor, disease resistance, water and nutrient efficiency, and climate resilience in organic systems, utilizing existing genetic resources and NOP-compliant methods.

1. Commodity and customer base:

This innovation opportunity applies to all agricultural regions, farm commodities, and production systems. While the proposed research is addressed to organic and transitioning-organic producers, anticipated outcomes are relevant to non-organic producers as well.

2. Challenges and opportunities:

One of the leading constraints on successful organic production is the lack of crop cultivars that are well-adapted to organic production systems (Hultengren et al., 2016; Ponisio et al., 2014). Over the past 75 years, most plant breeding and cultivar development efforts have been conducted within the context of high-input conventional systems, resulting in selection for responsiveness to soluble fertilizers and dependence on synthetic agrochemicals for protection against pests, weeds, and plant pathogens.

One outcome of such selection has been a weakened capacity of modern cultivars to partner with beneficial soil microbes for enhanced nutrient and moisture uptake, disease-resistance, and overall plant resilience and vigor. For example, open pollinated land races of sorghum form much stronger associations with arbuscular mycorrhizal fungi (AMF) than modern hybrids, and the land races greatly outperform the hybrids on lower-fertility soils (Cobb et al., 2016). Similarly, Mexican and Central American land races of corn host endophytic and rhizosphere N-fixing bacteria that provide up to 50% of the crop's N requirement, while modern corn hybrids selected in and for high N-input conventional systems host strains of *Fusarium* fungi that inhibit N fixing microbes (Goldstein, 2016, 2018). *Trichoderma* fungi in the tomato rhizosphere induce systemic resistance to late blight (*Phytopthora infestans*) and leaf mold (*Botrytis cinerea*), more effectively in land races than in modern hybrids (Hoagland, 2018).

Yet, opportunities exist to reverse these trends through improved soil health management combined with in-field plant breeding and selection in organically managed soils. During the past 15 years, the USDA Organic Research and Extension Initiative (OREI) has funded several farmer-participatory plant breeding networks that have developed several dozen new public cultivars and hundreds of advanced breeding lines of tomato, carrot, and other vegetable crops; barley, rice, quinoa, and other grains; dry beans and soybeans; and winter legume cover crops (Hoagland, 2018; Mirsky et al., 2019; Murphy, 2018; Schonbeck et al., 2017b; Simon, 2019; Zhou, 2018; Zubieta and Hoagland, 2017). Farmer-identified breeding objectives include ability to thrive and yield under organic management, nutrient efficiency, N fixation (legumes), competitiveness against weeds, resilience to drought and other stresses, and resistance to pathogens and parasitic nematodes, and desired market traits. For example, the Carrot Improvement for Organic Agriculture network is developing new carrot cultivars with large, weed-suppressive canopy, resistance to leaf blight and nematodes, and color, flavor, and nutritional value characteristics demanded by organic consumers (Simon, 2019).

Public cultivars offer another key advantage, in that farmers can further adapt them to local conditions through on-farm seed saving and selection, or utilize them for on-farm breeding. Maryland organic vegetable producer Brett Grosgal has used recurrent mass selection (RMS) at his farm to develop new cultivars of tomato, pepper, arugula, and other cool-season greens with horizontal (multi-trait) resistance to several major disease and greatly enhanced resilience to weather extremes related to climate disruption (Grosgal, 2019). His experience shows that RMS can be a powerful and farmer-accessible tool for improving an existing favorite cultivar or for developing new cultivars from an initial cross of selected lines. Virginia organic grower and plant breeder Edmund Frost has used other in-field plant breeding and selection techniques to develop new cucumber varieties with enhanced horizontal resistance to downy mildew (*Pseudoperonospora cubensis*) (Frost, 2020).

Genetic variations in both plant and microbial symbiont modulate N-fixing efficacy in legumes (Drinkwater and Grossman, 2018; Hardarson and Atkins, 2003) and AMF symbiotic efficacy of various crops (Douds, 2009; Hamel, 2004; Silva, 2016; Simon, 2019), showing that careful matching of crop cultivar with microbial strain may be important for optimizing nutrient efficiency. Substantial cultivar differences in root depth, biomass and architecture, suggest an opportunity to select crops for enhanced nutrient and water uptake, as well as carbon sequestration deep in the soil profile (Kell, 2011).

Soil management practices have substantial impacts on soil and plant microbiomes. Organically grown carrots showed a greater capacity than conventionally grown carrots to host beneficial root endophytic microbes that induce systemic resistance to *Alternaria dauci* leaf blight (Abdelrazek, 2018). In California, organically grown lettuce sustained much less damage from corky root (caused by the bacterium *Rhizorhapis suberifaciens*) than conventionally grown lettuce, because N fertilizer and herbicide applied to the latter reduced the disease-suppressive activity of the soil microbiome (Ariena et al., 2015). Tightly-coupled nitrogen cycling in organic tomato, in which the crop obtains sufficient N from soils low in nitrate-N (~5 ppm) depends on a combination of optimum soil and nutrient management, soil microbiome, and plant gene expression (Bowles et al., 2015; Jackson, 2013). Other studies have shown that organic soil management enhances AMF activity and associated carbon sequestration only when care is taken to avoid buildup of excess P through compost and other amendment applications (Rillig, 2004).

Overall, these findings illustrate a tremendous opportunity to enhance the productivity, resilience, carbon sequestration, and other ecosystem services of organic cropping systems through a combination of plant breeding and improved understanding and utilization of indigenous soil and plant microbiomes. Farmer-participatory breeding endeavors will develop public cultivars with enhanced capacity for plant-soil-microbiome relationships that underpin traits including water and nutrient efficiency, disease and pest resistance, weed-competitiveness, overall resilience and vigor, and high quality and nutritional value. Modern tools for genomic analysis will be utilized to help farmer-scientist teams to select germplasm for farmer-identified breeding priorities, evaluate breeding lines, and enhance efficiency of cultivar development. Additional research will develop practical guidelines for soil health practices to optimize plant-soil microbiome function and thereby realize the full potential of new and existing cultivars.

3a. Outcomes from innovation clusters:

Anticipated outcomes from this innovation opportunity include:

- A systems approach that integrates crop genetics and soil management to optimize the crop-soil-microbiome continuum to meet production, produce quality, resilience, and environmental stewardship goals.
- Enhanced overall climate resilience and soil carbon sequestration through co-selection of crop genetics and soil microbiome function.
- Practical information on region- or site-specific best organic practices to optimize indigenous microbiome functions.

- Utilization of existing germplasm banks and modern genomics, metabolomics, and phenomics technologies to inform in-field, farmer-participatory plant breeding efforts will lead to new public cultivars with:
  - Enhanced capacity to associate with AMF, N-fixing bacteria, and other soil microbes that enhance nutrient cycling and uptake, thereby reducing fertilizer input costs and nutrient-related environmental impacts.
  - Enhanced water uptake and use efficiency mediated through root depth and architecture, and microbial associations, resulting in reduced need for irrigation and greater drought resilience.
  - Enhanced resilience to pathogens, pest nematodes, and other biotic stresses, based on horizontal (multigene) resistance and capacity to host microbes that induce systemic resistance or suppress pathogens directly.
  - Enhanced competitiveness towards weeds, thus lessening the need for cultivation or other weed control measures.
  - Good yields, yield stability in "bad" weather years, high nutritional value, and other desired market traits.
- Advanced field sensor technologies will provide tools to monitor soil nutrient cycling, plant-available moisture, and carbon sequestration dynamics, thus informing producer management decisions to realize the full benefits of improved plant genetics and soil microbiome management. Field sensors can also facilitate rapid and accurate evaluation of accessions during breeding and cultivar development trials.
- Cutting edge data technology will play an important role in managing the great volume of data entailed in developing optimum plant genetics—soil microbiome combinations for organic production of a wide range of crops in different agro-ecoregions.

These outcomes will benefit both organic and non-organic conservation agriculture systems in which farmers seek to reduce input costs, optimize production, and mitigate environmental and climate impacts.

3b: Research gaps, regulatory barriers, and other hurdles

The current focus on genome design and microbiomes appears to emphasize gene editing, synthetic biology, and other technologies to engineer new or modified crops and micro-organisms, yet modern genomic and phenomic analysis can also be utilized to inform and facilitate cultivar development and microbiome management using NOP-allowed methods (USDA, 2020b; National Academies, 2019, page 7). While engineering crops, microbes, and entire agroecosystems for precision management of crops, nutrients, soil, water, and other resources to meet AIA production and environmental goals appears attractive, this approach raises several concerns:

- The release of novel, engineered life forms into agricultural fields entails potential environmental risks which organic producers seek to avoid.
- Engineered organisms are not allowed in USDA certified organic production. Their widespread use limits advancement of organic production systems and increases the probability of cross contamination.

- Introduction of microbial inoculants from off-site sources is often ineffective because indigenous soil microbiomes usually overwhelm the inoculant (Kleinhenz, 2018).
- At the same time, however, there is a risk of an introduced microbial inoculant being *too* effective, becoming an invasive exotic species that upsets or supplants indigenous soil, plant, or animal microbiomes.
- The process of developing new engineered organisms entails massive investments of time and funds, largely excludes producers from the vital work of crop genetic improvement, and misses opportunities for simpler, safer solutions that utilize existing local resources.
- Because of the cost of development, engineered crop cultivars are generally subject to utility patents, which prohibit farmers from adapting cultivars to their locales, soils, and production systems through seed saving and selection.

All of these problems can be mitigated by utilizing the tremendously diverse existing "library" of indigenous microbiomes, crop cultivars and land races, livestock breeds, and beneficial organisms to achieve the AIA goals of sustainability, resilience, and efficiency. Genomics and other "omics" technologies offer powerful tools to enhance understanding of what is already at hand, and can greatly facilitate in-field traditional breeding efforts to develop improved cultivars for organic and other low-input, resource-conserving, and climate-mitigating production systems; and to optimize management of indigenous soil and plant microbiomes.

Research gaps include myriad as-yet unexplored opportunities to increase understanding and optimize plant genetics and soil-plant microbiomes utilizing existing resources and safe, affordable, NOP-compliant methodologies. For example, the plant genes involved in tight N cycling in organic tomato trials in California are present in most plant species; hence a great potential exists to develop and refine organic soil management practices and cultivar selection to achieve tight N cycling in a wide range of crops in all U.S. agro-ecoregions (Jackson, 2013).

<u>Additional Recommendations on the USDA Agriculture Innovation Agenda</u>

Shift the emphasis of the AIA from *maximizing* production to *optimizing* production, and from "feeding the world" to meeting nutritional needs of the U.S. population in a way that allows and empowers other nations and regions to feed their own populations.

The Federal Register notice (USDA, 2020a) cites USDA goals to "increase[e] agricultural production by 40 percent to meet the needs of the global population in 2050 while cutting the environmental footprint of U.S. agriculture in half." Considering that intensive production already exceeds the long-term carrying capacity of many U.S. agricultural lands, these two goals will be extremely difficult if not impossible to achieve simultaneously. Experienced organic farmers understand the intimate connection between the health of agricultural lands and ecosystems, and human nutrition and health. They understand that U.S. agricultural production must be optimized in relation to soil health, resource condition, and ecosystem services, as well as food security and nutritional value for the nation's population. In addition, the urgency of the global climate crisis mandates a goal of reducing agriculture's greenhouse gas (GHG) footprint to *zero or less* (net carbon sequestration) by 2050. Instead of "feeding the world" with surplus U.S. commodities, the Agriculture Innovations Agenda must prioritize development of adaptable models for truly sustainable agricultural systems.

Organic agriculture is one such model that has already proven itself highly effective in food-insecure regions around the world. In 2008, United Nations published findings of a study of 114 organic agriculture projects in 24 African countries that engaged a total of 1.9 million small-scale farmers (mean 2.6 acres per farm). Projects trained producers in organic or sustainable methods that relied largely on locally available natural resources and low-cost technologies. Adoption of organic practices led to an average yield increase of 116% and improved farmer household income so that families could afford basic medical care, send their children to school, and purchase food during lean times (United Nations, 2008). These initiatives not only improved soil health but also built social capital, including stronger farmer coops and social organizations, community cohesion, and collaboration in protecting and improving local natural resources.

With a stronger focus on quality, optimum production and long term ecological sustainability, a modified AIA can help inform and support this kind of effort in food insecure communities across the U.S. and overseas. In addition, by reducing its GHG footprint to zero by 2050 as proposed in the 2020 Agriculture Resilience Act (H.R. 5861), U.S. agriculture can help stabilize global climate, and thereby benefit worldwide food production and food security.

Ensure that publicly funded agricultural research serves the public good.

The Federal Register notice states that "Stakeholder input will inform the Department as it works to develop a comprehensive strategy to guide public-sector research objectives and inform private-sector product development in order to maximize the U.S. Agriculture sector's continued ability to meet future demands." This raises concerns about a possible conflict of interest. While the goal of the private sector is to maximize profits for the company and its shareholders, the USDA's mission is to serve the *public* interest – to empower farmers and ranchers to provide nutritious food and other vital products to the US population; to protect and enhance our soils, resources, environment, and climate; and to make a good living and quality of life in so doing. While private-sector research can play an important complementary role and yield valuable products for producers, it can also lead to outcomes that undermine environmental and social goals. Examples include high fertilizer rate recommendations that lead to water pollution and GHG emissions, pesticide products and protocols that endanger human and environmental health, and utility patents on crop seeds that deny producers the right to save and select seed.

Similarly, private-sector research and development of NOP-allowable amendments, pest controls, and microbial inoculants also serve private interests first. As a result, organic producers constantly face the challenge of ascertaining whether a given product will actually benefit their operations. All producers depend on sound, impartial, publicly-funded research to inform their decisions as to what practices and inputs best serve their business, environmental, and quality of life goals. The AIA must prioritize serving the public good in terms of farm and ranch economic viability, rural community wellbeing, stewardship of soil and other resources, climate mitigation and resilience, and food security and quality for all. Benefits to private interests may also accrue from USDA-funded research, but private sector goals must not be allowed to modify or steer the AIA.

Support innovative research and development of advanced grazing management systems and integration of crops with pastured livestock production.

Advanced grazing management systems, including management-intensive rotational grazing (MIG), adaptive multi-paddock grazing, mob grazing, multispecies grazing, and silvopasture show great promise for promoting soil, forage, and livestock health; resilience to drought and other stresses; carbon sequestration; and net reduction in GHG emissions per unit of meat or dairy production. These systems distribute manure across grazing paddocks at rates that minimize adverse impacts on water resources, air quality, and climate. Operations that integrate crop production with rotationally grazed livestock have additional opportunities to optimize nutrient cycling and greatly reduce reliance on off-farm nutrient inputs.

The AIA white paper lists “practices to improve fertilizer and manure management, capturing biogas, [and] improving livestock production efficiency” among strategies to sequester carbon and reduce GHG emissions (USDA, 2020b, p 4). The National Academies of Science, Engineering, and Medicine report chapter on livestock production focuses on precision livestock farming, “intensive rearing systems,” and advanced sensing technologies to monitor animal stress levels (National Academies, 2019, pp 57 – 82). Grassfed systems are criticized for higher GHG emissions, despite multiple studies of MIG systems and silvopasture across the US showing improved forage quality that reduces enteric methane emissions and greatly enhanced carbon sequestration (>1 ton C per acre) that can reduce net GHG footprint from livestock production to virtually nil (Brown, 2018; Feliciano et al., 2018; Machmuller et al., 2015; Ominksi et al, 2001; Stanley et al., 2018; Teague et al., 2016; Wang et al., 2015).

The NOP Standards require organic livestock producers to give their animals access to pasture, with at least 30% of dietary needs met through grazing for cattle and other ruminants. Additional research into regionally-adapted advanced grazing systems is essential for both organic and non-organic ranchers and farmers to realize the potential for optimum production, resilience, and climate mitigation. Research priorities include livestock breeding and selection for advanced grazing systems and organic management, regionally adapted forage mixes, NOP-compatible livestock health practices, and lifecycle analyses of alternative livestock production systems. Because of its great potential to enhance the sustainability, resilience, productivity, and quality of livestock systems, advanced grazing management research merits top priority in the livestock-related innovations agenda.

Ensure that advanced technologies in data management, automation, and genetics are used in service of soil health, climate mitigation, farm and community economic vitality, and other sustainability goals, and do not become ends in themselves.

The 2019 National Academies of Science, Engineering, and Medicine report, on which the AIA is based, highlights several research goals: soil conservation and soil health, nutrient and water use efficiency, improving crop and livestock genetics, precision livestock production, early detection and prevention of crop and livestock diseases, early detection of foodborne pathogens, and minimizing food waste (National Academies, 2019, pages 2-3). The report devotes entire chapters to soils, water efficiency, crops, livestock, and food science, and identified five “breakthrough opportunities,” consisting of methodological strategies to achieve research goals:

- Transdisciplinary research and systems approach
- Advanced sensing and monitoring technologies
- Data science, software tools and agri-food informatics
- Genomics and precision breeding
- Soil, plant, animal, and human microbiomes

The Federal Register (FR) notice calls for stakeholder input on research objectives and opportunities framed within the following four "innovation clusters":

- Genome Design, including gene editing and precision breeding.
- Digital / Automation, utilizing field sensors.
- Prescriptive Intervention using data sciences, software tools
- Systems Based Farm Management for efficiency, resilience, and sustainability

The National Academies of Science, Engineering, and Medicine report presents advanced sensor, data management, and genetic technologies *as tools for advancing soil health and other research objectives* (National Academies, 2019). In contrast, the FR notice focuses on the technologies themselves, omits microbiomes from the list of innovation clusters, and makes no mention of soil, water, or other vital resources (USDA, 2020a). Similarly, the AIA white paper addresses soil and water only briefly (USDA, 2020b), and microbiome research has apparently been subsumed under Genome Design (Hutchins and Dyer, 2020).

We are concerned that this reframing could lead proposal reviewers to prioritize elaborate technologies over practical outcomes. As a result, USDA may invest billions of dollars in with limited benefit to farmers, food systems, natural resources, or the climate. In addition, advanced technologies may not be accessible and affordable to small-scale and limited resource producers, who benefit most from simple, affordable, practical, and scalable solutions, such as the organic practices implemented so successfully in Africa (United Nations, 2008).

We urge the USDA to develop an Agriculture Innovations Agenda that keeps priority goals clearly in focus: soil health, water and nutrient efficiency, resilience and yield stability, economically viable farms and rural communities, climate stabilization and other ecosystem services, and food security. The AIA must prioritize innovations that serve family farmers and ranchers, the public good, and environmental health, and not simply "high tech" for its own sake or ever greater degrees of automation demanded by the largest scale agribusiness operations.

Conduct impartial, science-based assessments of potential unintended consequences of technological innovations.

Neither the FR notice nor the National Academies of Science, Engineering, and Medicine report addresses potential unintended agroecological, economic, and social consequences of some of the unfolding and proposed technological innovations, such as:

- Gene editing and CRISPR technologies for crops, livestock, and soil organisms
- Synthetic biology, nanotechnology, and engineered plant microbiomes
- Introduction of gene-edited or exotic microbes into agroecosystems
- *In-planta* "biosensors" to track crop condition
- Automation of decision making

The following statements illustrate this blind spot:

- "We will also continue working to modernize our regulatory framework so America's producers will have the benefit of modern technologies, such as biotechnology, necessary to meet these challenges." (USDA 2020b, page 1)
- "Encouraging the acceptance and adoption of some of these breakthrough [genetic] technologies requires insights gained from social science and related education and communication efforts with producers and the public." (National Academies, 2019, p 7 and p 191).
- "Ignoring the need to better understand and anticipate consumer food behaviors, drivers, and trade-offs may limit consumer acceptance of new products, technologies, and market innovations. The need to better account for consumers' perceptions of risk around new technologies also underpins the need for education and strategies to best communicate the nature of food production, processing technologies, and the science involved …" (National Academies, 2019, p 102).

These statements imply that it is only the inaccurate *perception* of risk that limits adoption of new technologies. However, the risks are unknown and potentially substantial, and their full and impartial assessment must be completed before technological innovations are released for widespread adoption. In particular, novel technologies that fundamentally alter or "engineer" complex ecosystem processes developed through 450 million years of co-evolution among land plants, animals, microbiomes, and their physical environments must be approached with utmost caution. For example, just as kudzu and several other exotic plant species imported for erosion control early in the 20th Century have become invasive weeds, introduction of novel microbes or microbiomes into cropland to improve crop nutrition, resilience, or yield could upset or displace key components of indigenous microbiomes, leading to losses in other key functions.

It is for this reason that organic farmers have always avoided the use synthetic chemicals and genetically engineered organisms, and that USDA National Organic Standards exclude their use on certified organic operations. Organic producers work with natural ecosystem processes to build and maintain soil, crop, and livestock health, resilience, and productivity   Judicious application of advanced genomic, field sensing, and data management technologies to better understand agroecosystem processes can play a vital role in helping organic and non-organic producers alike achieve the AIA goals of sustainability, resilience, and efficiency – without introduction of engineered organisms and other risky technologies.

National Academies of Science, Engineering, and Medicine scientists recognize that "unintended consequences are not immediately recognizable;" that such risks may arise with interventions such as "altering photosynthesis routes, manipulation of the soil microbiome [and] widescale deployment of autonomous data-collecting sensors"; and that systems thinking across agriculture and food systems research can help identify and mitigate these risks (National Academies, 2019, pp 174-5). We are pleased to see this recognition, and strongly urge USDA to reflect and apply this caution in development and implementation of the AIA. For each advanced technological innovation, a systems based approach would ask not only "*can this be done?*" but also "*should this be done, and if so how?*"

Pursue innovations that empower farmers and ranchers – not put them out of a job.

The National Academies of Science, Engineering, and Medicine report promotes sensing technologies and data science primarily as means to *facilitate human decision making*, and mentions automatic responses only with regard to certain aspects of crop irrigation and confined animal systems management. For example, field-deployable sensor and bio-sensor technologies would be used to alert the producer that particular parts of a field need irrigation, supplemental nutrients, or pest/disease control measures to maintain optimum production (National Academies, 2019, p 5). In contrast, the FR notice frames this innovation area as "digital / automation," utilizing sensor data to "respond automatically with interventions that reduce … losses and maximize productivity."

Advances in sensing technologies and data science can help translate the huge and rapidly growing body of agri-food system data into practical applications, and create an information commons that facilitates interdisciplinary research and the sharing of vital information amongst stakeholders (National Academies, 2019, pp 5-6). However, application of some aspects of these advances, especially artificial intelligence and machine learning, to agricultural operations raises serious socio-economic and human questions, such as, "*What are people for?*" (Berry, 2010).

Turning more and more of the farming and ranching professions over to automated decision making could foreclose employment opportunities in rural America, limit opportunities for human creativity in agriculture and food system work, and even take human land stewards out of the process altogether. The impacts of these technologies on employment opportunities, rural economic viability, social capital, and quality of life must be thoroughly assessed. Again, in addition to asking "*can this be done?*" we must ask: "*should this be done, and if so how?*"

We appreciate the opportunity to provide these comments to USDA and thank you for considering these recommendations. We look forward to continuing to work with you in the development and implementation of an Agricultural Innovations Agenda that supports a sustainable, climate-friendly, resilient, and efficient future in our food and farming systems.

Sincerely,

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