

July 31, 2020

Mr. Stephen Censky
Deputy Secretary
United States Department of Agriculture.
1400 Independence Avenue SW
Washington, DC 20250

Re: Solicitation of Input From Stakeholders
on Agricultural Innovations
Docket Number: USDA-2020-0003
Federal Register Effective Date: 04/01/2020
Federal Register Page Number: 18185

Dear Deputy Secretary Censky:

Thank you for the opportunity to comment on the U.S. Department of Agriculture's Agriculture Innovation Agenda, a bold goal to increase productivity while reducing agriculture's environmental footprint. We represent a group of scientific societies whose members are engaged in the very research that will enable this goal to become a reality.

The future of American agriculture depends on keeping Americans farming. These farmers of the future will depend on a national community that understands food and farming, they will require economic policies that help farmers remain flexible and embrace new markets, and, above all, they will need products that make agriculture more resilient and sustainable.

The food and agriculture industry should reflect our nation's diversity

The future producers and consumers of food, feed, fiber, and fuels may not have grown up in farming families or farming communities. This makes integrated, K-12 agriculture education essential. USDA should promote and directly support K-12 programs, internships, summer job opportunities, and college and graduate student research scholarships. Extension education programs focused on Native American, Black, Hispanic, and urban populations are needed. The 1890 and 1990 Land Grant universities and colleges should be at the forefront of this effort. USDA should encourage and financially support partnerships between Land Grant universities and non-land grant HBCUs, Hispanic-serving institutions, and Native American-serving institutions to integrate agricultural education into existing STEM programs. Exposing these students to the advanced technologies used in agriculture will not only encourage farming and agriculture research as careers among a population that represents the diversity of the United States, but it will also begin to develop a national community that better understands food and farming.

It is imperative that USDA engage in efforts to improve the public perception of agriculture. A diverse cohort of bright and talented students, including those who grew up in farming families, are turning away from farming and agricultural sciences even as job prospects are opening up. More efforts should be made to collaborate with educators to develop classroom materials, lesson plans, and experiences for teachers that highlight the broad range of jobs available in the food and agriculture industry and the science and technology underpinning it. Agriculture should not be viewed by teachers or students as a

separate subject, but rather incorporated into the science curriculum in primary and secondary schools. USDA should invest heavily in K-12 programs, and the Agriculture and Food Research Initiative (AFRI) should double its budget for direct funding for graduate student research and programs from 1.5 to 3-5 percent, being sure to include underrepresented groups. The training should incorporate not only traditional agricultural subjects but emphasize data science, engineering, and sustainability sciences, which are needed to advance future technological advancements and innovations in agriculture. This funding would act as a magnet for a diversity of talent and raise the profile of agricultural, food, and related industries.

Alongside the research that will enable technological advancements and innovations in agriculture, social science research should also be supported to ensure innovations and interventions are responsive to needs and readily adopted. Outcomes from social science research can improve the delivery of Extension services, inform the design of messaging and marketing, and help policymakers understand the economic incentives and other factors that motivate behavior change and adoption of new technology and practices. Policy interventions should be inclusive of land that is rented, as well as that which is owned, the former making up the majority of farmland in many states.

Create economic opportunities for future farmers by reducing risk and expanding markets

Developing enthusiasm for agriculture as a career is just the first step. Growers need risk management tools like whole-farm crop insurance to handle risk and keep farming an economically viable career choice. Markets for ecosystem services are another essential economic component. Paying growers for using their land wisely, for example sequestering carbon and capturing water, will increase a farmer's bottom line while adding resilience to extreme weather. Research, and translation of research into policy, are critical for positive community and farmer impacts in this area.

USDA will also need to think broadly about the food system and the services it provides to producers. As consumers, physicians, and nutritionists grow to see food selection as a means of preventing or minimizing chronic diseases, demand for the production of specific crop varieties will increase, and consumers are already demanding more locally grown options to reduce the environmental footprint associated with transportation. The U.S. food system has only begun providing consumers with the wide range of products modern shoppers have come to expect, but these demands represent unique opportunities for small farmers, especially those in urban areas. Urban agriculture stands ready to meet many of these new consumer demands, but as this facet of the food supply chain continues to grow, USDA will need to help supply these farmers with the knowledge and services they need.

For example, urban farms offer new and exciting opportunities to leverage population density for a more efficient, circular economy of waste and re-use while also providing jobs and agricultural education opportunities in city centers. Carbon dioxide, greywater, heat, and compost from urban environments can be utilized by nearby urban farms, and these farms could then provide increased carbon sequestration, cleaner air, mitigation of the "heat island" effect, greenspace, and a reduced risk of flooding through improved water retention in soil. USDA should work with urban growers to make sure regulations designed for large monocultures make sense in a small, urban environment, and support for Extension will be vital.

Invest in systems designed to be resilient

Resiliency should be broadly considered to include not only the ability of cropping systems to produce under environmental stress, but also the ability of crops, markets, and management systems to adapt to all variety of stresses. Labor shortages due to pandemics or immigration policy changes or loss of markets for social or political reasons can be just as disruptive to the agricultural sector as extreme weather, pests, or plant diseases.

A variety of opportunities to promote resilient agriculture exist, for example in soil health, covered further below, but USDA must also consider opportunities for agricultural resiliency within the water sector. Better ground and surface water management would benefit from tools for monitoring and reporting on-farm water consumption and withdrawals. Water management would also be well-served by information-sharing partnerships between the USDA, USGS, and local water conservation districts.

Water resources rarely align with geopolitical boundaries, and competing interests often result in conflict and inefficiencies. USDA programs should encourage multi-agency and interdepartmental collaborations and prioritize projects that enhance such collaborations. Tools to support decision making, for example strategic water supply-demand matching, could promote safe and appropriate reuse of municipal and agricultural waste waters. Technology transfer and intellectual exchanges from countries outside the United States, especially those with long-term experience in mitigating drought and desertification, would enable the United States to build upon existing knowledge. Foreign expertise in desalination, high-efficiency irrigation technologies, water harvesting techniques, and evaluation of the long-term effects of water reuse in agriculture from countries in the Mediterranean, Middle East, and North Africa could prove valuable to areas of the United States struggling with water availability.

Future farmers need tools and products that make agriculture more resilient and sustainable

Sustainability models

True sustainability modeling is an indispensable tool for farmers of the future. Models can help farmers optimize their land management for increased productivity and sustainability while reducing environmental footprint and risk. Substantial research and technological and sociological development are needed for these models to be data-driven and outcome-oriented.

But models are only as good as the data they use, and their effects only as good as their user. Extension and training on relevant databases and the process of data collection and submission will also be key. Also, diverse systems, including urban or vertical systems and systems with perennials, diverse cover crop mixtures, and animals need to be included.

Data repository

Complex models that steer farmers towards optimized land management solutions rely on the collection and availability of data. USDA needs to lead the creation and management of a data repository for agriculture data. This effort needs to be far more sophisticated than the USDA-ARS Ag Data Commons,

and it must be integrated across “One-USDA,” as opposed to separated by agency or outsourced to the private sector. The private sector has been unable to respond in the face of a simply overwhelming need, and the federal government is the logical choice for housing this crucial national resource. For the data to be useful, however, the data repository must be created and maintained using FAIR (findable, accessible, interoperable, reusable) standards, and there needs to be universal agriculture data standards for data collection and formatting.

USDA, in cooperation with the scientific community, is the most logical source for these standards, which would need to include, for example, crop rating scales for breeders, metrics for soil traits, and formatting for data collected from sensors. The leadership exhibited by the National Institute of Health in its development of the National Center for Biotechnology Information (NCBI) for genetic data could serve as one model; this data infrastructure has led to countless important discoveries and sparked new businesses transforming human, animal and plant health. The private sector has realized that their data and the decision this enables are their most important asset after people; it is time USDA took a similar view.

Soil testing 2.0

Farmer decisions need to balance short- and long-term outcomes for optimized crop productivity, soil carbon sequestration, reduction in nutrient loss, and increased resilience to stressors. These decisions will be based on models that require data from across a wide spectrum of geographies and cropping systems. Collecting this data and processing it for easy use will take a large and sustained investment. What is needed is a new generation of soil testing – “Soil Testing 2.0.”

Next generation soil testing will include high-throughput methods to quantify multiple fractions of soil organic matter. This will be used for evaluating crop productivity and validating performance-based ecosystem service markets. Also needed are updated soil nutrient testing methods that integrate the influence of plants, soil biology, and the microbiome on nutrient retention and recycling. This testing, which requires improved lab-based methods that are inexpensive and rapid, will need to be paired with an investment in low-cost, scale-neutral technologies and in-field sensors to monitor water, nutrients, and carbon through time and space.

As researchers and others collect data with these improved tests and sensors, they can upload them into the open-source, data-sharing platform described above. This is needed to catalyze continuous evaluation and improvement of methods and to link soil measurements to crop productivity and environmental outcomes over time.

Ubiquitous sensors

Researchers will likely be the first users of inexpensive, real-time, biodegradable sensors, and the data they produce will power models for decision support tools. But once the decision support tools are in place, growers can also use these sensors. Sensors will be embedded into plant tissue or in the soil nearby and powered sustainably, for example with miniature solar panels. These sensors will detect the presence of stressors or beneficials in real-time and could deploy or signal the deployment of precisely applied inputs. Indeed, such technology, when integrated with satellite maps, data management software, decision support tools, and precision farming equipment, would reduce inputs of all kinds, from pesticides and water to time spent on site. It is not practical to remove densely deployed sensor

arrays several times a year, but because normal farming operations, such as tillage and harvesting, will destroy them, the sensors need to be low-cost, disposable, and biodegradable.

It is important that the design of these crucial sensors go hand-in-hand with the development of a unified ag data repository, as outlined above. Sensors capable of correctly and securely collecting, formatting, and directly uploading their data will reduce user error and the need for extra training. USDA needs to be out front with its data repository and standardization guidelines to enable sensor manufacturers clarity and universal data compatibility in their designs. U.S. agriculture needs data to be standardized and manufacturer agnostic, like the “power take off” (PTO; e.g. 540 rpm class I,II, III) to avoid the interface problems that plague users of various computer and mobile phones models.

Breeding toolbox

Farmers will benefit from crops that thrive with reduced water and fewer inputs, crops that defend themselves against pests and pathogens, and crops with increased photosynthetic efficiency. These traits will impact global carbon sequestration and the production of renewable energy feedstocks while improving nutrient use efficiency and the quality of natural bodies of water. Advanced crops like these would increase productivity, sustainability, and resilience, but their development depends on the availability of an advanced breeding “toolbox.” Such a toolbox would be equipped with properly maintained and indexed global germplasm collections and tools for genomics, transcriptomics, phenomics, bioinformatics, and machine learning to inform breeding decisions, and it would empower genome design across crop species and across geography and season. In addition to understanding interactions between a crop’s genotype, environment, and management, there is even the potential for “custom” or “dynamic” crops, which display traits tailored to their specific environment and can adjust to variable weather conditions within and among seasons in response to a pest, pathogen, or weather condition.

Innovative breeding tools to achieve these ambitious goals are emerging rapidly. They include more efficient phenotyping and genotyping combined with optimized and on-target genome editing reagents that enable the creation of site-specific mutations or insertions. The innovations also include the development of data-driven computational models for improved genomic prediction.

Large investments in this kind of breeding toolbox have been made in major crops, with close coordination between the public and private sectors, and it has transformed breeding decision-making. The investments produced vast knowledge of genome sequence, gene expression, predicted gene function, and functional sequence variants that produce useful phenotypes. This knowledge can be integrated with systems analysis made possible by continual advancements in computational and machine learning pipelines.

Expanding these tools to minor agronomic and specialty crops that provide food, feed, fiber, ground cover, and fuel, including cover crops and perennials, will be essential to enable more efficient precision breeding. These are investments that the private sector may find difficult to prioritize, but investments in breeding tools for minor crops will afford benefits for all crops. For example, tools that enable combining knowledge of allelic diversity in germplasm with innovative breeding methods will introduce that diversity to elite lines, and this will enable all breeders to initiate rapid responses to new challenges, including emerging pests and diseases, while remaining aligned with sustainability initiatives.

Current impediments to research and development using these approaches include short-term grant funding, which limits researchers' ability to maintain these toolboxes long-term. Compliance with intellectual property protection is another roadblock, and agreements for shared intellectual property will be essential for affordable technology adoption and realization of its benefits for increasing productivity while decreasing the environmental footprint. Lastly, even scientists using the advanced breeding tools currently available are hamstrung by the lack of long-term, supported data repositories, as mentioned above. A repository structured with FAIR principles for storing, accessing and utilizing sequence, trait and allele information would help major and minor agronomic crop breeders alike.

Cover crops, double cropping, and perennial crops

Increasing agricultural productivity while reducing agriculture's environmental footprint need not be competing priorities. Incorporating cover and double cropping into agricultural rotations could address both these goals and provide additional producer revenue. Additional benefits include reduced erosion, increased water infiltration, improved soil health, reduced nutrient loss to surface and groundwater, and a more resilient system. Major challenges, however, are that cover and double cropping systems are complex and that benefits can accrue slowly. Advantages have been shown for diverse cover crop mixtures and complex systems, but research is needed to determine the optimal mixtures and management for diverse soil and other environmental variables.

Similarly, many perennial grain crops and forages are currently under limited development (e.g. wheat, rice, sorghum, corn, etc. that live for more than one year); these would provide many of the benefits of cover crops while also sustainably increasing production. Similar to what occurred over the last 85 years for the annual versions of these major grain crops, the initial breeding and development must occur in the public sector. Only then will the private sector invest in the improvements needed to market them to farmers. Given the longer time requirement for development and the lack of an existing infrastructure, USDA should identify new, dedicated ways to support the development and genetic improvement of these game-changing crops for the future.

Autonomous/robotic systems

Machine systems are poised to solve many of agriculture's labor challenges, especially where repetitive or otherwise dangerous tasks predominate. Autonomous or robotic systems have the advantage of supporting sterile production for improved food safety and shelf-life, and such systems can provide advantages throughout the food supply chain, not just in field production. In fact, robotic solutions have been developed for many agricultural challenges, but their adoption has been limited due to cost concerns. Continued investment by USDA is needed to improve the functionality of these systems and to facilitate the human/machine interface to integrate the best abilities of each.

Specific opportunities that should be addressed in the next 10-30 years

Many facets of the vision of agriculture described above depend on policies that USDA can and should put in place right now, such as whole-farm crop insurance and dedicated funding for agriculture education and graduate students. But other advancements will only be realized with sustained and specific investments in research and deployment of findings through the Extension service and other

educational programs. Below is a selective collection of specific ideas that such investments may produce and the outcomes they would achieve.

1. True sustainability models
 - a. Details/outcomes: Decision support tools based on true sustainability models will enable growers to safely combine their own data with data mined from across the country or globally to make informed management decisions for responding to environmental and biotic shocks. Growers will be able to evaluate economic and environmental benefits and trade-offs of different practices at any scale.
 - b. USDA Goals/Benchmarks:
 - i. Agricultural productivity – Models can overlay many years of yield data to obtain yield stability zones.
 - ii. Carbon sequestration and greenhouse gas – Models can simulate long-term, continuous agronomic management impacts on soil health and greenhouse gas emissions to help identify the optimal sets of practices that will reduce a farm's carbon footprint.
 - iii. Water quality – Models that are able to simulate the impacts of management on nutrient loss and pesticide use can be tested to find the best agronomic management practices to reduce pesticide use and nutrient loss while maintaining productivity.
 - c. Benefiting stakeholders: All growers, researchers, breeders, policy-makers, conservation groups.
 - d. Innovation Area(s) needed:
 - i. Systems based farm management – Accurate models will require studying the interactions of many facets of production.
 - ii. Prescriptive intervention – Data analytics are necessary to integrate data from across production systems.
 - iii. Digital/Automation – Sensors of all kinds will be needed to accumulate the data necessary for accurate models.
 - e. Feasibility: 10-15 years.
2. Real-time, low-cost, biodegradable sensor systems
 - a. Details/outcomes: Precise, accurate, and field-based sensors that collect information in real-time will monitor the status of plants, soils, animals, and the environment on a temporally and spatially dense basis to enable management responses that can minimize the environmental impact of agriculture and enhance productivity.
 - b. USDA Goals/Benchmarks:
 - i. Agricultural productivity – Sensors will identify biotic and abiotic stressors and enable rapid mitigation strategies that ultimately increase yields.
 - ii. Food loss and waste – Sensors may be able to indicate when crops are ready for harvest.
 - iii. Carbon sequestration and greenhouse gas – By sensing biotic and abiotic stressors early, growers can respond with precision to reduce inputs, save money and reduce the ecological footprint of agriculture.
 - iv. Water quality – Sensors will inform where and when chemical pesticides and fertilizers are needed. This will ultimately reduce run-off and water pollution.
 - v. Renewable energy – Through increased efficiency, the costs associated with biofuel crops will be reduced, making renewable energy more cost-competitive.

- c. Benefiting stakeholders: Growers, agri-business consultants, processors, distributors, and consumers.
 - d. Innovation Area(s) needed:
 - i. Systems based farm management – Sensors will need to collect and integrate a broad range of information.
 - ii. Digital/Automation – In order to visualize changing conditions and to respond automatically with interventions, such systems will require new sensing techniques, a ubiquitous wireless communication system, computing and storage capacity, and the artificial intelligence to identify developing trends. The type of intelligence monitoring and surveillance techniques now used by security agencies can be applied to agriculture. This includes the ability to associate location and management metadata with specific products and to track those products from production to consumption.
 - iii. Prescriptive Intervention – The application and integration of data sciences, software tools, and systems models, especially artificial intelligence, will enable advanced analytics for managing the food and agricultural system.
 - iv. Food safety – Sensors will support traceability functions, enhancing food safety.
 - e. Feasibility: 10-30 years
3. Increased photosynthetic efficiency
- a. Details/outcomes: The photosynthetically active portion of the solar energy spectrum is only about 45% of total solar energy, resulting in a theoretical maximum efficiency of approximately 11%. However, for a variety of reasons, typical efficiencies are only 3-6%. The minimization of various biotic stressors coupled with genetic and phenotypic improvements will enhance a crop's ability to convert light energy into harvestable biomass
 - b. USDA Goals/Benchmarks:
 - i. Agricultural productivity – Increasing a crop's photosynthetic efficiency will directly increase production.
 - c. Benefiting stakeholders: Growers, agribusinesses, consumers.
 - d. Innovation Area(s) needed:
 - i. Genome design – Growers will need varieties that capture and use more available light energy; researchers will benefit from an enhanced understanding of the biochemical pathways and genetics of photosynthetic organisms living in light-starved ecological niches, and perennial crops should be investigated – they capture light much earlier and later in the season than annual crops, which must be planted each year.
 - e. Feasibility: Within 30 years.
4. Soil Testing 2.0
- a. Details/outcomes: Collecting and processing soil data, including quantifying soil organic matter, nutrient testing, and microbial activity across geographies and cropping systems, will reveal connections between soil measurements, crop productivity, and environmental outcomes.
 - b. USDA Goals/Benchmarks:
 - i. Agricultural productivity – Growers can use soil testing information to optimize land management for metrics like productivity.

- ii. Carbon sequestration and greenhouse gas – Advanced soil testing will yield validated connections between land management decisions and carbon sequestration.
 - iii. Water quality – Advanced soil testing has the potential to promote soil health, increasing the retention and availability of nutrients and reducing the likelihood of runoff.
 - c. Benefiting stakeholders: All growers, conservation groups, ecosystem services markets.
 - d. Innovation Area(s) needed:
 - i. Systems based farm management – Soil tests will need to include and integrate across a broad range of data.
 - ii. Prescriptive Intervention – Application of artificial intelligence and to augment current soil testing protocols to reveal previously unknown relationships between soil attributes and crop productivity. Data repositories, data sciences, software, and systems models will be needed to translate the collected data into usable knowledge.
 - e. Feasibility: Within 30 years.
5. Breeding “Toolbox”
 - a. Details/outcomes: Advanced breeding could lead to products that expand existing markets or open up new ones for growers, including traditional crops and vegetables with enhanced nutrient or nutritional profiles, cover crops that sequester more carbon for ecosystem services markets, perennial crops that may replace or augment current crops, and crops capable of replacing fossil fuels.
 - b. USDA Goals/Benchmarks:
 - i. Agricultural productivity – Breeding tools will continue to improve crop productivity. These tools may also be applied to new or under-developed plant systems with the potential to enhance existing agricultural systems.
 - ii. Carbon sequestration and greenhouse gas – Energy crops stand to benefit from advanced breeding tools; crops requiring fewer pesticides will reduce fossil fuel use in the reduction of pesticide production and application.
 - iii. Water quality – Breeding will continue to create crops that utilize water and fertilizers more efficiently.
 - c. Benefiting stakeholders: All sectors of agriculture will benefit, including growers, consumers, distributors, and manufacturers.
 - d. Innovation Area(s) needed:
 - i. Systems based farm management – Breeders need a whole-system understanding of crop traits as they relate to genotype, environment, and management.
 - ii. Genome design – Advanced breeding tools depend on molecular knowledge and advancements.
 - iii. Prescriptive intervention – Synchronizing vast quantities of genetic and environmental information to achieve optimized varieties will require advanced data analytics and machine learning.
 - e. Feasibility: Immediately deployable for some crops; investments needed for others.
6. Versatile cover crop mixtures and perennial cropping systems

- a. Details/outcomes: Cover, double cropping, and perennial crops are innovations that will increase production, reduce agriculture’s environmental footprint, and provide producers with additional economic and climate resilience.
 - b. USDA Goals/Benchmarks:
 - i. Agricultural productivity – Incorporating cover and double cropping into agricultural rotations will increase food production, soil health, and bioenergy feedstocks while providing additional producer revenue. Highly productive perennial grain and bioenergy crops should be developed that would augment existing agriculture systems while decreasing tillage.
 - ii. Water quality – Limited studies suggest systems with two or more crops in a year will reduce erosion, enhance ecosystem services, improve microbial diversity and soil health, and keep nitrogen from leaching out of the soil while supplying more to subsequent crops. Similarly, productive perennial crops would be an ecologically sensitive alternative to traditional cropping systems.
 - c. Benefiting stakeholders: Producers, seed companies, conservation groups, those living near or earning their living from natural bodies of water.
 - d. Innovation Area(s) needed:
 - i. Systems based farm management – Much research is needed to assess optimal planting and management practices (e.g. planting density, planting and harvesting timing, locations and soils, fertilizer and pesticide application and timing, optimal cover and double crop mixtures), and the various effects of different practices on soil health and water quality, soil microbes, and potential impacts to main crop resiliency and production.
 - ii. Genome design – New crops are needed that are specifically bred for cover, double cropping, or perennial systems, for example crops that can be planted after a freeze and that do not negatively affect the main crop.
 - e. Feasibility: Less than 30 years.
7. Crops for cost-effective, biodegradable packaging materials
- a. Details/outcomes: Consumers are demanding cost-effective, biodegradable packaging materials, and agriculture is the logical sector to provide them. Much research is needed to develop and bring these materials to market, but the impact on reducing agriculture’s environmental footprint through huge reductions in plastic production and fossil fuel use could be formidable, and biodegradable packaging is a new, untapped market for growers.
 - b. USDA Goals/Benchmarks
 - i. Carbon sequestration and greenhouse gas – There is great potential in utilizing crop-based materials for packaging, which would reduce fossil fuel use.
 - c. Benefiting stakeholders: Growers, consumers, environmental groups.
 - d. Innovation Area(s) needed:
 - i. Genome design – New varieties and, potentially, new crops will be needed to supplant fossil fuel-based plastic packaging.
 - e. Feasibility: Unknown.

Sincerely,

American Society of Agricultural and Biological Engineers
 American Society of Agronomy

American Society of Plant Biologists
Crop Science Society of America
Entomological Society of America
National Association of Plant Breeders
International Certified Crop Adviser
Soil Science Society of America