Behavioral Factors in the Adoption and Diffusion of USDA Innovations

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U.S. Department of Agriculture
August 2021

Acknowledgements

Bryan Pratt and Sophia Tanner are economists at USDA, Economic Research Service. Suzanne Thornsbury is a senior advisor at USDA, Office of the Chief Scientist. We thank Kerry Smith of USDA, Agricultural Marketing Service; Heather Allen and Tracey Dutcher of USDA, Animal and Plant Health Inspection Service; Peter Vadas of USDA, Agricultural Research Service; Kelly Maguire of USDA, Economic Research Service; Pete Riley of USDA, Farm Production and Conservation – Business Center; Anne Marsh and Toral Patel-Weynand of USDA, Forest Service; Brad Rein of USDA, National Institute of Food and Agriculture; Greg Batson of USDA, Rural Development; and Duane Voy of USDA, Risk Management Agency for providing program experiences.

Introduction

This paper provides information on how behavioral factors can support adoption and diffusion of USDA innovations. Extending the reach of USDA innovations leverages public investment and has the potential to expand inclusion in Department programs. Driven by technology and research, there have been dramatic advances in production efficiency (i.e., productivity) from working lands and conservation performance over the past two decades.[1] Multiple USDA agencies invest in technology and research, but not all innovations move into widespread use. The process of individual adoption of new practices and diffusion across communities is complicated, requiring integration of assets from disparate sources in the successful delivery of solutions (USDA, 2020). Incorporating consideration of behavioral factors in program and project design increases the likelihood that USDA investments will actively contribute to future productivity and resource conservation.

We highlight information where assessment of behavioral factors positively influenced adoption of new technologies or practices and share knowledge in support of innovation dissemination and measurement. To draw on the widest available evidence, we examine the published literature and multiple USDA agency programs. Emerging themes from both sources lay the groundwork for increased Department efforts to enhance individual adoption and widespread diffusion of innovations. While we focus primarily on innovation in the agricultural, forestry, and resource management sectors for the literature review, we also incorporate agency lessons from rural development, in addition to agency lessons related to forestry, natural resource management, and agriculture and food systems. Many of the behavioral factors discussed in this paper are also applicable to consumers and others who may be driving innovation from a demand perspective.

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[1] Working lands include agriculture, forestry and grasslands. USDA ERS "Agricultural Productivity in the U.S." provides detailed discussion and data for the agriculture sector (https://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us/). The summary notes that "agricultural productivity is driven by innovations in on-farm tasks, changes in the organization and structure of the farm sector, and research aimed at improvements in farm production."

through these pathways. Consistent with a broad definition, we consider the interaction of demographics and behavioral factors.

Policy and consumer preferences, expressed through market forces, can also be significant drivers of innovation adoption. For example, shifting consumer preferences for organic products–-expressed through relative market prices–-encouraged adoption of alternative practices for some producers where organic production was technically and economically feasible. Behavioral factors-including information, attitudes, reputational effects, and networks, for example-–influence consumer preferences, and therefore demand for these agricultural innovations. Behavioral factors also impact operator willingness to make a change. However, for the adoption and diffusion of innovations, we generally consider behavioral factors influencing consumer demand to operate indirectly through economic factors, particularly market prices and the profitability of adoption.[4]

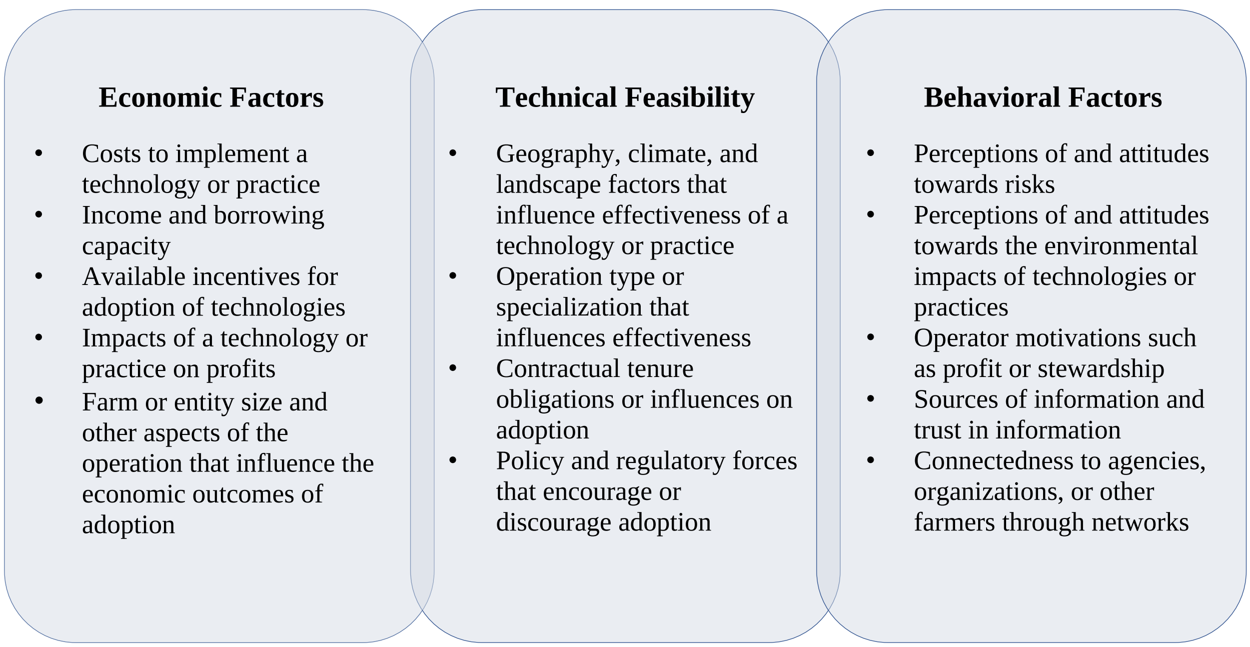

Figure 1. Three overlapping categories of factors that influence adoption of innovations

[4] The nature of some innovations (e.g., organic production practices, genetically modified organisms (GMO), soil nutrient testing, use of GPS (spell out) technologies) is such that consumers may not be able to form preferences about adoption because of lack of awareness or readily available information. In some cases, these credence goods are subject to voluntary or mandatory certification or labeling schemes which may be adopted by producers in order to signal buyers and target certain markets. The labeling itself can then have value as an innovation for consumers and producers.

Innovation

Likewise, we define "innovation" very broadly in this paper. There are more than 20 agencies and offices within USDA, all with unique missions that contribute to the overall USDA vision to provide economic opportunity through innovation, helping rural America to thrive; to promote agriculture production that better nourishes Americans while also helping feed others throughout the world; and to preserve our Nation's natural resources through conservation, restored forests, improved watersheds, and healthy private working lands (USDA, 2021). Innovations are defined to include:

- Technologies or new uses for existing technology, new or modified management practices, or other new processes or products;
- Research or technology transfer to increase agriculture, forestry, or rangeland/pastureland productivity, natural resource conservation, or reduced environmental impact resulting from food or fiber production;
- Efforts to increase agricultural productivity, resource conservation, or both; and
- New technologies, new practices, or other new processes or products.

Several USDA agencies generate science research that includes technology development applicable to working lands and environmental sectors.[5] While there are relatively few USDA agencies primarily engaged in direct research in the physical and life science areas, additional agencies contribute resources and services to enhance the success and global competitiveness of the businesses that adopt the research for use. There are some agencies whose mission explicitly includes incentivizing adoption of innovations and others that have an explicit regulatory role that can influence the adoption and diffusion of innovations. All USDA agencies and offices engage in innovation within their own processes and outputs to better serve internal and external customers. A recent report highlighted the connections between government workforce, innovation, technology, and security based on a survey and discussions with 300 Federal Government leaders. Implementing new approaches to tackle old problems was broadly viewed as the pathway to building a resilient government. Almost half (49 percent) of respondents believed that an immediate focus on encouraging continual innovation was critical to improving resilience (Partnership for Public Service, 2021).

Adoption and Diffusion

Innovation implies change and can be risky. It is something new and people can be inherently reluctant to change. Adoption means that a person or business does something differently than they had previously (i.e., purchase or use a new product, acquire and perform a new behavior, etc.). The stages by which a person adopts an innovation include <u>awareness</u> of the need for an innovation, <u>persuasion</u> through using information to reduce uncertainty, <u>decision to adopt</u> (or reject) the innovation, <u>initial use</u> of the innovation to test it, and <u>continued use</u> of the

[5] USDA (2012) identified Agricultural Research Service (ARS), Animal and Plant Health Inspection Service (APHIS), Forest Service (FS), and National Institute of Food and Agriculture (NIFA) as the agencies with significant intramural research or management of extramural research likely to produce direct technology transfer transactions, including licensable research outcomes.

innovation.[6] We focus largely on persuasion and the decision to adopt as the steps where behavioral factors can have the most impact.

Rogers (1962) articulates a framework that links individual characteristics to likelihood to adopt something new (figure 2). The framework can be modified to incorporate nuances associated with a particular innovation or population but remains a foundational approach to innovation diffusion. There are economic, technical feasibility, and behavioral factors that determine whether an individual is an innovator, a laggard, or at a stage in between. While individuals fall somewhere on the spectrum, the reach and speed of dispersion throughout a population depends on the overall shape of the curve. “Few social science theories have a history of conceptual and empirical study as long as does the diffusion of innovations” (Dearing, 2009, p1).

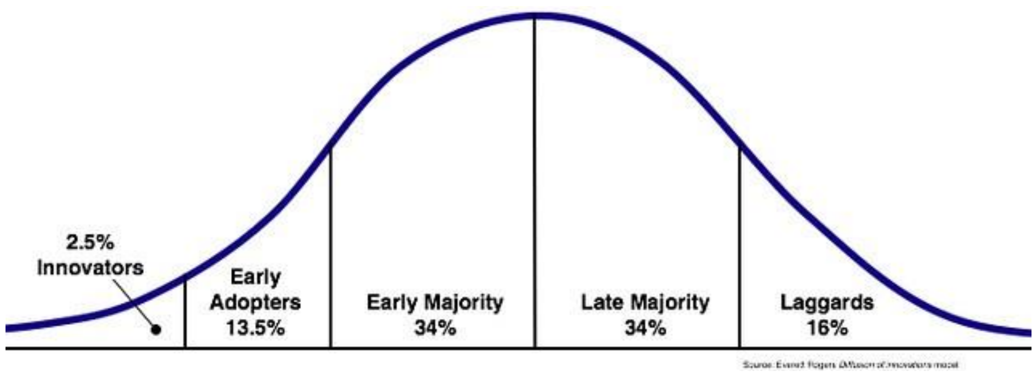

Figure 2. Adoption of innovations
Source: Rogers, 1962

The most successful and widespread diffusion of a product or program results from understanding factors influencing the rate of individual adoption and aggregate target population. One (but not the only) measure of innovation success is technology transfer, in which the private sector adapts research for use in the marketplace. Annual reports provide quantitative measures of invention disclosure and patents from USDA science agencies as one indicator of uptake of USDA technology and research (table 1). Technology transfer functions are critical to accelerating diffusion of public research and development (R&D) investments, creating economic activity, job creation, and sustainable economic development.

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[6] This depiction of adoption was first exposited by Rogers (1962). While all five stages will be impacted by behavioral factors, awareness is relatively more influenced by communication strategies and availability, while initial and continued use are relatively more influenced by characteristics of the innovation itself. Similar to the discussion of economic, technical feasibility, and behavioral factors, the five stages of adoption are not mutually exclusive.

Table 1: Number of USDA invention disclosures and patents from the Animal and Plant Health Inspection Service, Agricultural Research Service, and Forest Service

	FY15	FY16	FY17	FY18	FY19
Invention Disclosures					
New inventions disclosed	222	244	166	320	243
Patents					
Patent applications filed	125	109	111	120	97
Patents received	94	60	68	67	69

Source: "FY19 Report on Technology Transfer" USDA (2020), p. 8. FY = fiscal year

Why It Matters

Systematically incorporating consideration of behavioral factors into USDA innovation efforts could improve the probability of widespread adoption and support best use of Federal resources. Practices could be designed *a priori* to increase the likelihood of shifting the Rogers curve to the left (i.e., encouraging a greater number of early adopters relative to laggards).

Increasing productivity has significant social and economic benefits for society. A 2011 Presidential memo identified innovation as a core contributor to the U.S. economy with adoption and diffusion of new technologies and practices as drivers of "economic growth, the creation of new industries, companies, jobs, products and services, and the global competitiveness of U.S. industries" (U.S. Office of the Federal Register, 2011). In 2011, global research and development spending in food and agriculture was $75.9 billion, with $42.3 billion of that from public research, including approximately $4.8 billion from U.S. public research sources (Heisey and Fuglie, 2018).[7]

USDA makes significant investments in technology and research to better serve the public. Science-based innovations create new or improved technologies or products. Process or service-based innovations create new ways of gathering, disseminating, or communicating with customers. All benefit the Nation by increasing productivity, increasing efficiency (keeping costs low), and enhancing global competitiveness. Heisey and Fuglie (2018) found that the average intensity ratio for agricultural research between 2009 and 2013 was approximately three times greater than a similar intensity ratio for all public research and development.[8]

Even as productivity gains are achieved, environmental, safety, diversity and equity, animal welfare, and other social objectives are of growing importance in research policy. The agriculture and forest sectors focus on meeting basic needs of fiber, safe and abundant foods to promote lifelong good health, safe water for a growing population, and energy, all while protecting the health, vitality, and abundance of natural resources. Achieving this means careful

[7] Public research was defined to include government and university sources in contrast to private industry sources.
[8] Agriculture intensity ratio is defined as U.S. public agriculture research and development funding divided by U.S. agricultural GDP.

management of scarce and precious natural resources of forest and arable land, energy, and water.

Consistent with the approach in this paper, the USDA response to the 2011 memo notes the following:

> *The U.S. Department of Agriculture views the Presidential Memorandum with a broad interpretation, defining technology transfer as the adoption of research outcomes (i.e., solutions) for public benefit. Successful adoption of USDA knowledge and research outcomes typically requires complementary assets and services provided by multiple agencies in USDA, including agencies that are not primarily engaged in direct research in the physical and life science arenas. It is a call to support the agriculture and forest sectors in a manner that ensures sustainable agriculture and forests, creates and nurtures opportunities for farmers, ranchers, forest owners, and entrepreneurs to flourish in both urban and rural areas, protects the nation's food supply, and enhances global competitiveness of U.S. agriculture and forest industries. (USDA, 2012)*

Adoption of Innovations in Production and Conservation

Adaptation is necessary within a system in order to increase productivity to meet rising needs and future challenges. Yet even when new technologies and practices exist, individuals may be slow to change. Between the development of innovations and their widespread dissemination, individual operators of working lands can face economic, technical, or behavioral barriers. USDA agencies have multiple tools to reduce barriers to adoption that may be suited to different contexts. For example, cost-share and other financial assistance programs reduce the upfront costs of a new practice. Partnerships with networks that provide technical assistance or the opportunity to try new technologies before committing to them can encourage adoption by making the learning process easier and reducing uncertainty about outcomes. Understanding the factors that drive adoption of innovations and how to lower barriers that discourage adoption is key to effective dissemination.

The innovation literature is extensive as is the literature on adoption. Recent theories focus on complex drivers of adoption and their interactions with each other. Individual adoption and widespread diffusion are processes that develop over time, influenced by different factors for different technologies and stages of the diffusion process. For example, Greenhalgh et al. (2004) developed a framework that identifies multiple components that influence adoption of precision agriculture (PA) technologies. Components include characteristics of the innovation, information availability, the regulatory environment, economic context, and characteristics of the adopters, as well as other systems and processes that may influence adoption. The framework allows interaction between these components.

Another, more recent, framework for understanding the adoption and diffusion of innovations is the ADOPT model (Kuehne et al., 2017) which identifies four different components relating to an innovation. The first two components concern the innovation itself. First, relative advantage of the practice, encompassing both financial considerations, such as profit, investment cost, and time to returns, as well as environmental and other considerations can drive innovation. This component roughly corresponds to direct economic and technical feasibility factors and is most often included in project or program design. The second component of the ADOPT model is learnability of the practice, which involves the relative complexity of an innovation and how easy the innovation is for potential adopters to observe and conduct a trial. Learnability can be affected by agency programs, such as extension, where the focus is transmitting information through non-formal education and learning activities to people throughout the country.

The remaining two ADOPT model components focus on characteristics of the population of potential adopters. These components are behavioral in nature, emphasizing that operator attitudes, goals, and network connections are a key part of innovation adoption and diffusion. Certain operators may value aspects of an innovation while others do not value them. The relative advantage for the population relates to attitudes and management goals, including risk orientation and relative importance of profit and environmental impacts. Finally, population-specific influences on learning ability include experience, skills, support, and networks.

These overarching frameworks both suggest that individual adoption and widespread diffusion are context-dependent. Success involves a complex interaction of economics and policy; characteristics and attitudes of individuals, including their networks and information sources; operation and local/environmental factors, such as geography and climate; and characteristics of technologies or practices. Innovation and population characteristics interact with each other. A practice that increases profits but degrades the environment may be more likely to be adopted by those who have a strong profit orientation but less likely by those who strongly value environmental stewardship. Similarly, an innovation may be simple, but it will not be adopted if awareness or availability to the population is low.

To focus on concepts most directly applicable to USDA, we include the last 20 years of literature focused on the U.S. context and limit innovation adoption to technologies, practices, and procedures used on working lands. This is not an exhaustive search, but the goal is to understand general trends about motivations for, and barriers to, adoption. We discuss the literature in two groups: (1) adoption of technologies that improve efficiency or production capability (primarily precision agriculture); and (2) adoption of conservation practices that improve or preserve soil health, water quality, or other environmental services flowing from working lands.[9] Production innovations tend to have a more immediate observable impact with more directly quantifiable outcomes for profitability in the short-run. Innovations in conservation or environmental services tend to be realized over a longer period with less easily quantified direct impacts. Because innovation in these two spaces serves different purposes and is often perceived by operators differently, we summarize the main findings from both and compare the common and opposing themes.

Precision Agriculture Technologies

Precision agriculture (PA) technologies are those that facilitate site-specific management techniques through increased automation or gathering of information including aerial and satellite imagery, autosteer, GPS guidance, grid soil sampling, yield monitors, variable-rate technologies (VRT), remote sensing, and others. Pathak et al. (2019) divide PA technologies into

[9] Our literature search was conducted on Google Scholar searching for agricultural innovation, agricultural technology, agricultural conservation practices, and agricultural best management practices. We limited our search to peer-reviewed journal articles with data from the United States published 2000-2020, resulting in 12 publications on adoption of precision agriculture, and 23 publications on adoption of conservation practices.

two groups. Information technologies provide information about soil health, crops, or other things and include yield mapping, soil monitoring technologies, remote sensing technologies, and use of Geographic Information Systems (GIS). Management technologies are those that allow for precise control of inputs and include variable-rate technologies and automation technologies.

Table 2. Technologies included in precision agriculture citations

Citation	**Information Technologies**							**Management Technologies**						
	Precision Maps	Soil samples/testing	Precision Guidance/GPS	Yield Maps	Yield Monitors	Remote Sensing	Tissue Samples	Variable Rate	Lightbar	Autosteer	Section Control	Spot Spraying	Auto Section Control	Not Defined
Khanna (2001)		✓						✓						
Daberkow and McBride (2003)		✓		✓		✓		✓						
McBride and Daberkow (2003)		✓		✓		✓		✓						
Adrian et al. (2005)	✓	✓			✓	✓		✓	✓	✓				
Isgin et al. (2008)	✓		✓		✓	✓		✓				✓		
Larson et al. (2008)						✓		✓						
Watcharaanantapong et al. (2014)		✓			✓	✓								
Thompson et al. (2015)		✓			✓	✓		✓		✓				
Schimmelpfenig and Ebel (2016)				✓	✓			✓						
Miller et al. (2017)		✓			✓			✓						
Gardezi and Bronson (2019)														✓
Kolady et al. (2020a)	✓	✓		✓	✓	✓	✓	✓		✓	✓			

Information and management technologies are defined following Pathak et al. (2019). Precision maps include mapping software, prescription maps, and boundary maps. Soil samples/testing include site sampling, grid soil sampling, and soil testing. Remote sensing includes aerial, satellite, and infrared sensing.

Most of the PA studies cover multiple technologies, and three explicitly focus on bundling of technologies (Khanna, 2001; Schimmelpfenig and Ebel, 2016; Miller et al., 2017) (table 2). Many of the papers include quantitative models of adoption decisions based on factors of interest, with two publications using other methods (Thompson et al., 2015; Miller et al., 2017). Adoption is measured as either a binary choice (having adopted the use of one or more PA technologies) or a count (the number of new technologies adopted). Whereas the ADOPT model focuses primarily on attitudinal drivers of adoption, the majority of PA papers measure the influence of demographic characteristics such as age, education, and off-farm employment which are more easily observed. Though some papers include a proxy for borrowing capacity, it is not the norm. Only two PA studies include perception of environmental benefits or risks (Watcharaanantapong et al., 2014; Kolady et al, 2020a).

Economic Factors

As noted above, behavioral factors are not mutually exclusive from economic and technical feasibility of new innovations. The PA literature highlights some of this overlap. Economic feasibility of innovations involves aspects such as initial investment, profitability, ability to take on debt, and size of the farm enterprise.[10] Many PA technologies have economies of scale, i.e., are more profitable when used on a large scale but less appropriate for small operations. Farm acreage and the value of farm sales were both used as measurements of enterprise scale in the reviewed literature. In general, both are generally found to positively influence adoption (Khanna 2001; McBride and Daberkow 2003; Adrian et al., 2005; Isgin et al., 2008; Larson et al., 2008; Gardezi and Bronson 2019; Kolady et al., 2020a).

Interestingly, income and farm profits are not consistently found to be significant predictors of adoption (McBride and Daberkow, 2003; Larson et al., 2008; Walton et al., 2008). Watcharaanantapong et al. (2014) find that medium- and high-income farmers adopted yield monitors earlier than lower income farmers, however, income is not associated with the timing of adoption of either grid soil sampling or remote sensing. These mixed results suggest that the effect of income is varied, and likely interacts with other characteristics of the innovation and adopter. Rather than income, measures of increased borrowing capacity do significantly increase adoption (McBride and Daberkow, 2003; Isgin et al., 2008). Greater off-farm employment and off-farm income are found to decrease the likelihood of adoption of PA technologies (Daberkow and McBride, 2003; Kolady et al., 2020a). There is also mixed to positive evidence on the effect of perceived profitability of new technologies: Adrian et al. (2005) and Kolady et al. (2020a) both find that perceived benefits increase adoption, while Watcharaanantapong et al. (2014) indicates it matters for yield monitors but not for grid soil sampling or remote sensing.

Technical Feasibility

Technical feasibility of an innovation includes characteristics of the innovation itself—for example, suitability for certain geographic areas, soil types, and landscapes. USDA agencies generally focus on ensuring the technical feasibility of innovations such as the effectiveness of innovations for a particular use or type of working land. Accounting for regional heterogeneity in adoption is important in defining the population of potential adopters and impact of widespread diffusion. All studies reviewed that used data from a large geographic area included locational variables, and many included information on the crop specialty of the operation as measures of technical feasibility. Locational and crop specialty variables are frequently statistically significant, and indicators that local climatic, soil health, and other technical aspects impact adoption intensity. Other climate and landscape factors are not emphasized among the PA studies reviewed; however, one exception is the productivity potential of land. Several studies (Khanna, 2001; Isgin et al., 2008; Kolady et al., 2020a) find that higher soil quality predicted PA adoption, and this result is consistent across model specifications.

[10] A separate aspect of economic feasibility which we do not examine here relates to the existence of markets for new products. When new products are introduced to consumers, adoption may be tied to general acceptance and the size of that new market. Likewise, if consumers demand a new product (e.g., organic), producers may adopt practices to meet that demand.

Although not a direct measure of economic or technical feasibility, land tenure agreements can serve as one indicator of legal barriers or capacity to undertake large investments as incentives to adoption. In the literature, land tenure is sometimes measured as a binary variable but more often indicated by the percentage of acres owned. Evidence of tenure on innovation adoption varies with insignificant results in several studies, while others show mixed results depending on context. Khanna (2001) in an early study of cash grain farmers in the Midwest finds that landowners are less likely to adopt soil testing or VRT than those who rent land. In a more recent study of corn and soybean growers, Gardezi and Bronson (2019) find the same in cases where the landowner operates both owned and rented land for corn and soybeans. Consistent with Khanna, operators who only rent land are even more likely to adopt VRT. McBride and Daberkow (2003) examine information technologies (grid soil sampling, remote sensing, and yield mapping) separately from VRT. In their information technologies model, a larger share of owned acreage actually increases the likelihood of adoption of information technologies, but tenure is not included in the separate VRT model.

Behavioral Factors

Behavioral factors, as we define them, include operator perceptions of and attitudes toward innovations and the environment, as well as the ways in which those perceptions and attitudes are influenced by information sources and social networks. Behavioral aspects of innovation adoption are highly related to risk and uncertainty, as perceived risk can vary across people, as well as individual preferences for risk-taking. Few of the PA studies we examined directly include operator perceptions of uncertainty toward technical feasibility or environmental benefits, but most did use measures of demographics and operation characteristics. These variables are frequently used as indicators because they are easily observable. Significance is interpreted as a relationship with attitudes, social connectedness, and learnability of new innovations. Potential adopters with more experience or with a higher dependence on income from the farm enterprise are generally hypothesized to be earlier adopters through greater confidence in their abilities and a greater willingness to invest in the operation. Khanna (2001) reports a positive influence from years of experience. Age and education positively influence adoption in many studies (Khanna, 2001; Daberkow and McBride, 2003; McBride and Daberkow, 2003; Isgin et al., 2008; Larson et al., 2008; Gardezi and Bronson, 2019). However, those who were retired are less likely to adopt, potentially because the time to returns is not appropriate for their planning horizon (Khanna, 2001).

Adrian et al. (2005) more directly includes the effect of attitudes towards current and planned PA using structural equation modeling. Adopters' confidence in their own ability to learn and use PA technologies increase adoption, while perceptions of the innovation's usefulness and perceived ease of use are not directly associated with either greater or lesser adoption. Kolady et al. (2020a) estimates adoption of management and information technologies separately. Perception of environmental benefits had a mixed impact on adoption of management technologies (GPS guidance and automatic section control), but increased adoption of information technologies (yield monitors, VRT, grid soil sampling, prescription field maps, aerial imagery, and crop tissue sampling).

Likewise, few of the reviewed studies include a direct measure of farmer risk attitudes (i.e., willingness to undertake uncertainty), relying again on indirect measures such as farm size and income as a proxy for risk. Daberkow and McBride (2003) and McBride and Daberkow

(2003) include a score developed from responses to various risk management questions; however, this score is not significant in either awareness or adoption of technologies in either study. Rather than an overall risk attitude variable, Gardezi and Bronson (2019) measure perceptions of climatic risk including measures of concern for drought, flood, erosion, and climate. Of those, they find that flood and erosion concern increase use of PA, but that concerns about climate and drought do not increase use of PA.

Many studies include prior use of complementary technologies as predictors of adoption. In particular, on-farm computer use for records is shown to increase adoption, as is smartphone use (Khanna, 2001; Daberkow and McBride, 2003; McBride and Daberkow, 2003; Adrian et al., 2005; Isgin et al., 2008; Larson et al., 2008; Walton et al., 2008; Watcharaanantapong et al., 2014). This may be because of complementarity between computers and PA technologies. Use of computers and smartphones in farm management makes incorporating many PA technologies easier to implement. Another possible explanation is that adopters of computers and smartphones are early adopters of innovations in general, and this behavior is applied to both technologies. A third explanation is that greater financial resources allow adoption of all these technologies. Alternatively, lack of access to foundational technologies such as broadband could limit adoption in some areas. More research is needed to determine the relative impacts of each of these effects.

Similarly, it is likely those more receptive to new innovations may simultaneously adopt bundles as complementary technologies. Several studies estimate the adoption of two or more practices at once (Khanna, 2001; Schimmelpfenig and Ebel, 2016). Miller et al. (2017) investigate adoption paths by estimating transition probabilities between various bundles of technology consisting of yield monitoring, precision soil sampling, and VRT. They find that those who adopt no technologies, or all three technologies, are more likely to persist at their current level of adoption. However, those adopting bundles of one or two technologies are more likely than others to transition between bundles or abandon technologies altogether. Finally, they find that non-adopters are more likely to adopt a single technology in the next year than they are to adopt a bundle.

The flow of information between individuals and through networks is an important subset of behavioral factors. Adoption of new technologies and practices is influenced by social networks, such as neighbors or membership in organizations. Interaction with extension, universities, or other programs provides information and can increase learning; however, more research is needed on the effectiveness of trial programs, demonstrations, and interactions with information sources. None of the PA studies reviewed focus specifically on social networks, but several papers investigate the role of information sources on adoption. McBride and Daberkow (2003) find that farmers receiving information from extension, crop consultants, input suppliers, demonstrations, or grower associations are all more likely to adopt diagnostic technologies (grid soil sampling, yield mapping, and remote sensing) than those receiving information from the media. Likewise, finding information from extension, crop consultants, and input suppliers increases adoption of VRT, but demonstrations and grower associations are not significant. Interactions with extension and crop consultants increase the likelihood of adopting remote sensing as well (Larson et al., 2008). Similarly, Watcharaanantapong et al. (2014) find that obtaining information from the internet and news media is generally associated with slower adoption of PA technologies.

Conservation Practices

In contrast to adoption of PA practices, which often directly benefit individual operators in terms of increased productivity, more information, and greater control over operations, the benefits of conservation practices can take several years to materialize and may accrue off-site (e.g., downstream water quality improvements). As a result, implementation of conservation practices is more likely to be incentivized through cost-share or other assistance programs. While the PA literature examines observed or planned adoption of specific technologies, much of the conservation literature focuses on participation in incentive programs as the indicator of adoption. We review 23 studies on agricultural conservation practices for managing soil health, water quality, management for carbon sequestration and other outcomes.

Economic Factors

As with PA technologies, larger farms tend to adopt conservation practices that have economies of scale. In general, larger farms are more likely to adopt cover crops (Kolady et al., 2020b) and plant more diverse species (Moore et al., 2016). Farms with more acreage are also more likely to adopt diverse crop rotations (Wang et al., 2019; Kolady et al., 2020b), no-till or conservation tillage (Soule et al., 2000; Zhong et al., 2016), and participate in forest carbon programs (Miller et al., 2012; Khanal et al., 2017). In a study of cattle producers' willingness to afforest for carbon sequestration, Claytor et al. (2018) find that larger producers are willing to enroll more acres in a hypothetical program. However, farm size has no effect or a negative effect on the adoption of other practices, such as buffer strips (Tosakana et al., 2010) or integrated crop and livestock systems (Wang et al., 2019).

Most conservation studies do not focus on income to the operation itself but examine the role of various sources of income on adoption decisions. In one study that does include income, Tosakana et al. (2010) find that it does not play a significant role in the adoption of gully plugs or buffer strips, but that concerns (i.e., perceptions) about maintenance costs are a barrier. The type of operation can play a significant role in adoption. For example, Canales et al. (2020) find that greater farm income from crops leads to faster adoption of practices that can improve production, such as VRA, but slows down adoption of cover crops. Several studies find that relative crop prices play a role in conservation program participation (Schaible et al., 2015) and that higher crop prices encourage adoption of cover crops and VRA but have no impact on no-till (Canales et al., 2020). Finally, a higher percentage of total income from farming increases the likelihood of adopting no-till practices (Zhong et al., 2016), strip cropping, waterways, and diversions (Lichtenberg, 2014).

The influence of a profit motivation is mixed for conservation practices. Profit motive increases the use of buffer strips but generally not gully plugs, in a study of water-related practices (Tosakana et al., 2010), and slows down the adoption of continuous no-till (Canales et al., 2020). Diverse crop rotation and integrated crop and livestock systems are more likely to be adopted by those for whom increases in profitability from a new practice were not as important as other factors (Wang et al., 2019).

Table 3. Technologies included in conservation practice citations

Citation	Soil Health Practices							Water Quality Practices					Other Practices							
	Conservation Tillage	Cover Crops	Crop Rotation	Contour Farming, Strip Cropping, Terraces	Critical Area Seeding	Nutrient Management	Soil Nutrient Testing	Lined Waterways	Buffer Strips / Riparian Buffers	Gully Plugs	Diversions	Runoff Control Practices	Carbon Sequestration	Pollinator Practices	Farm Management Plans	Pest Management Strategies	Conservation Program Participation	Wildlife Habitat Enhancement	Integrated Cropping & Livestock System	Livestock Management Practices
Soule et al. (2000)	✓			✓				✓												
Welch and Marc-Aurele, Jr. (2001)															✓					
Kara et al. (2007)	✓						✓	✓	✓						✓					
Parker et al. (2007)	✓							✓	✓											✓
Lubell and Fulton (2008)												✓				✓				
Tosakana et al. (2010)									✓	✓										
Miller et al. (2012)													✓							
Lichtenberg (2014)		✓		✓	✓			✓			✓									
O'Connell et al. (2015)		✓																		
Schaible et al. (2015)																	✓			
Moore et al. (2016)		✓																		
Ulrich-Schad et al. (2016)	✓	✓				✓		✓	✓									✓		
Varble et al. (2016)	✓	✓																		

Citation	Soil Health Practices							Water Quality Practices					Other Practices							
	Conservation Tillage	Cover Crops	Crop Rotation	Contour Farming, Strip Cropping, Terraces	Critical Area Seeding	Nutrient Management	Soil Nutrient Testing	Lined Waterways	Buffer Strips / Riparian Buffers	Gully Plugs	Diversions	Runoff Control Practices	Carbon Sequestration	Pollinator Practices	Farm Management Plans	Pest Management Strategies	Conservation Program Participation	Wildlife Habitat Enhancement	Integrated Cropping & Livestock System	Livestock Management Practices
Zhong et al. (2016)	✓					✓			✓											✓
Garbach and Morgan (2017)														✓						
Khanal et al. (2017)													✓							
Claytor et al. (2018)													✓							
Alhassan et al. (2019)													✓							
Ramsey et al. (2019)	✓	✓	✓																	
Wang et al. (2019)			✓																✓	
Canales et al. (2020)	✓	✓																		
Reddy et al. (2020)		✓																		
Kolady et al. (2020b)	✓		✓																	

Farm management plans include individual plans (e.g., erosion plans, manure management plans) as well as whole farm plans. Nutrient management also includes adaptive nutrient management. Livestock management practices include animal fences, waste storage facilities, and manure management. Kara et al. (2007) also examine the use of yield monitors, and Ramsey et al. 2019 and Canales et al. (2020) both examine the use of VRT.

Technical Feasibility

In general, some conservation practices are more suited to farms with certain types of land or operations than others (e.g., adoption of manure management is only relevant for operations with a significant livestock component). Similar to the PA literature, impacts of land tenure are a matter of great interest in the conservation literature, as owners and renters may have different incentives regarding the long-term environmental impacts of practices. A higher ownership percentage is associated with a greater likelihood of erosion control practices (Kara et al., 2007; Lichtenberg, 2014). Other studies find a negative relationship between leased land and adoption of best management practices (BMPs) more generally (Parker et al., 2007).

Recognizing that not all tenure agreements are the same, Soule et al. (2000) differentiates between owner-operators, cash-renters, and share-renters. They find that cash renters are less likely to use conservation tillage, but there is no difference between owner-operators and share-renters for that practice. For more medium-term conservation practices (contour farming, strip cropping, and grassed waterways), both renter types are less likely to adopt than owner-operators. However, evidence on conservation tillage is mixed in the literature. In a later study, Zhong et al. (2016) find that conservation tillage seems more suited to renters, with a greater percentage of acreage rented being positively associated with adoption. Varble et al. (2016) also find that those who rent some or all their operated land are less likely to practice conventional tillage than those who own all the land they farm.

The influence of landowners through the encouragement of conservation practices is also examined. Tosakana et al. (2010) find that lessee decisions are significantly impacted by landowner willingness to invest in conservation practices, as well as the risk of losing their lease. An increased percentage of leased acreage decreases the use of gully plugs and buffer strips on sloped land (Tosakana et al., 2010). Ulrich-Schad et al. (2016) study non-operator landowners' willingness to encourage or require conservation practices on their leased land.[11] More engaged landowners (closer, more frequent visits) increase willingness to encourage conservation practices. Of the practices studied, landowners are more likely to encourage or require no-till, grassed waterways, and soil erosion practices, while less likely to encourage filter strips.

The conservation studies reviewed put more emphasis on interactions with broader market forces than the PA literature. Kolady et al. (2020b) find that locations at a greater distance from ethanol plants increase the likelihood of adopting a diverse crop rotation. This is likely because farms located closer to plants find it far more profitable to specialize in corn or soy for ethanol production. Other input costs such as agricultural wages and the cost of diesel fuel explain the adoption of conservation practices for wheat producers (Schaible et al., 2015).

Individual decisions take place in a broad policy environment that includes aspects of economic, technical feasibility, and behavioral factors.[12] The reviewed literature focused on perceptions of regulatory burden and impacts on innovation adoption. Farmers are more likely to adopt practices when they feel they will be treated fairly by regulators and that regulation is not

[11] As indicated by agreement with the statement that they are "somewhat and very comfortable with [encouraging the] practice".

[12] Policies may impact innovation adoption directly through mandating (or prohibiting) particular practices or actions, or they may impact innovation indirectly through shifting relative prices (e.g., taxes or subsidies) or through altering operator or user perceptions or incentives.

too stringent (Welch and Marc-Aurele Jr., 2001; Kara et al., 2007; Tosakana, 2010). Kara et al., (2007) examine how State-level environmental stringency, as measured by regulations, specifically aimed at livestock operations influence variability in conservation practice adoption among States. The regulations used to create the index include limitations on corporate-owned livestock operations; limitations on animal production; local enforcement of regulations; restrictions on manure application; and others. Results show adoption of grassed waterways and erosion plans is more likely in States with a higher environmental stringency index.

However, adoption of several other practices and technologies studied (conservation tillage, yield monitors, commercial fertilizer plans, manure management plans, soil nutrient testing, and filter strips) are not impacted by environmental regulatory stringency. By contrast, Welch and Marc-Aurele, Jr. (2001) and Tosakana et al. (2010) both use self-reported measures of regulatory pressure or stringency. Welch and Marc-Aurele, Jr. find that stronger beliefs in future regulatory pressure is associated with early adoption of whole-farm plans, as is greater agreement about the equitable treatment of farmers as measured by Likert-scale questions regarding the specific targeting of farmers for water quality concerns. Tosakana et al. (2010) find the probability of using gully plugs on sloped land decreases for those who felt regulatory burdens are not worth the effort, and the effect is higher on moderately sloped land than highly sloped land. Use of buffer strips also decreases by perceived regulatory burden on slightly, moderately, and highly sloped land.

Behavioral Factors

Because conservation behaviors are often voluntary, incentivized, and have less direct impacts on profitability, behavioral factors may play a large role in driving adoption patterns. Attitudes, beliefs, and trust in information interact to encourage or discourage adoption of conservation practices. Adoption of conservation practices is generally positively associated with perceived environmental benefits and greater environmental concerns (Welch and Marc-Aurele, Jr., 2001; Tosakana et al., 2010; Claytor et al. 2018; Ramsey et al., 2019; Kolady et al., 2020b). Among the forest carbon literature, greater concerns about climate change increase likelihood of participation (Miller et al., 2012). In a study focusing on farmer perceptions of the risks and benefits of conservation practices, the authors find an increase in the probability of adoption with the belief that no-till, crop rotation, and cover crops reduce yield risk, with the increase in adoption larger for cover crops than the other two practices (Ramsey et al., 2019). Similarly, perceived soil quality improvements from practices also increase adoption.

Other evidence indicates that just providing more information about environmental benefits does not necessarily motivate early adoption of certain BMPs (Zhong et al., 2016; Reddy et al., 2020), suggesting a potential gap between environmental information and environmental perceptions. In particular, Alhassan, et al., (2019) find that forestland owners with greater trust in information about climate change are more likely to participate in a hypothetical carbon program. Similarly, environmentalist attitudes are not always predictive of early adopters if they are also associated with factors that act in the other direction. A 2001 study finds that operators with more environmentalist attitudes were among the second wave of adopters of whole farm plans, rather than the first; the authors suggest that the second wave of adopters are less reliant on farm income and have less belief in equitable treatment by regulators than the first adopters (Welch and Marc-Aurele, Jr., 2001). Altogether these results suggest that trusted information regarding yield and environmental impacts of practices may increase adoption of selected conservation practices and is more likely to increase adoption when combined with positive environmental attitudes or greater environmental concerns.

Characteristics of the farm and farmer are widely used variables in conservation practice adoption studies. In a study of cover crops, O'Connell et al. (2015) find that less experienced farmers are more likely to have positive views of cover cropping, but lower levels of actual implementation. More experienced farmers are more likely to adopt no-till, but less likely to adopt riparian buffers (Zhong et al., 2016). Although some papers posit that older farmers have shorter time horizons and find that they are less likely to adopt conservation practices (Soule et al., 2000; Lichtenberg, 2014; Zhong et al., 2016; Wang et al., 2019), others find mixed evidence with older farmers more likely to adopt conservation tillage and less likely to adopt cover crops (Kolady et al., 2020b). Canales et al. (2020) examine the time to adopt conservation practices and find older farmers tend to be later adopters. Farmers with more education or a college degree are more likely to use some practices, and less likely to use others. Kara et al. (2007) find that college graduates are more likely to use yield monitors. More education is also associated with adoption of conservation tillage (Soule et al., 2000) and water related BMPs (Zhong et al., 2016) but not integrated crop and livestock systems (Wang et al., 2019).

Similar to the literature on PA adoption, experience with other conservation practices and complementarity among practices influence adoption (O'Connell et al., 2015; Canales et al., 2020). When practices are complementary, incentives needed for adoption of the bundle are lower than if practices are adopted separately (Cooper, 2003). Lichtenberg (2014) finds evidence of complementarity between critical area seeding, cover crops, and waterways, suggesting that combined cost-share programs would be less costly than for each technology alone. Similarly, Zhong et al. (2016) find that no-till, storage facilities, and nutrient practices are likely to be practiced together.

Compared to the PA literature, literature on adoption of conservation practices has more emphasis on the diffusion of practices through information networks, such as neighbors, organizations, and online resources. A major theme of the conservation literature is the impact of social networks and sources of information. Garbach and Morgan (2017) use network analysis to examine adoption of pollination practices at different levels of adoption in the community, including such practices as flowering cover crops, permanent pollinator habitat, and combinations of native and non-native pollinators. They find that networks do not consistently influence adoption of the three practices studied. Adopters of multiple pollinator species have more connections with both extension and USDA's Natural Resources Conservation Service (NRCS), while adopters of flowering cover crops have more connections with NRCS only. Connection to neighbors positively influences adoption of combinations of pollinators, with little effect on the other two practices. Flowering cover crops, which are more widely adopted than the other two practices, are not influenced by social factors but are supported by connections with government agencies. Finally, permanent habitat adoption does not appear to be influenced by either social or government connections.

Other studies examine spatial effects of adoption: Kolady et al. (2020b) find that adoption of conservation tillage increases with more nearby adopters, while peer effects are not significant for cover crops. Ramsey et al. (2019) find no impact of neighboring peers on adoption of no-till, cover crops, crop rotations, or variable-rate application; however, they noted that physical connections are not necessarily equivalent to social connections. They also find that cover crops are positively impacted by experience with government program participation. In a study of local watershed management, Lubell and Fulton (2008) find that policy networks increase awareness and adoption of BMPs, with the greatest effect on conventional pest management practices, a smaller effect on runoff control, and a negligible effect on the newest innovation, alternative pest management.

Agency Experience With Adoption of USDA Innovations[13]

To better understand how USDA agencies are already incorporating behavioral factors to encourage the adoption and diffusion of innovation, we engaged with nine agencies and one interagency collaboration about projects and areas where these factors are and are not being considered. It is important to note that innovation is broadly defined, and consequently, the agency perspectives include innovations not only in production technology and practices for working lands, but also processes and services, risk management products, safety, and resource management. This diversity of innovation reflects the diversity of areas within the purview of the USDA. Each agency identified activities that were viewed as successful and highlighted specific actions taken to support that success. The compilation allows for examining how behavioral factors influencing adoption are both common and unique across programs.

This effort uncovered areas where USDA agencies are incorporating behavioral factors when thinking about adoption, as well as a stated desire to increase the consideration of such factors in the future. Some of the behavioral factors that agencies consider include using trusted sources to introduce innovations, adapting programs to support operators with practical or cultural obstacles to traditional program engagement, and direct efforts to identify which behavioral factors influence adoption outcomes. Other relevant aspects fall broadly under information and network aspects, including reducing uncertainty about the true impacts of an innovation. All this is in addition to traditional components which most agencies highlight, such as technical feasibility, suitability, and costs and benefits.

Agencies emphasized removing bureaucratic barriers as an important component of encouraging adoption and diffusion. Some agencies highlighted the need to assess unintended consequences of policy for adoption of related innovations, for example, ensuring that program qualifications do not needlessly preclude operators from adopting novel production technologies or practices. FSA and RMA both emphasized areas where they have changed rules around cover cropping, crop insurance, and other programs to reduce the potential for bureaucratic requirements limiting adoption of innovations in cover cropping, novel production techniques, risk management products, and related programs. For example, RMA includes details on the use of the Whole-Farm Revenue program to ensure access to risk management programs for farmers with portfolios beyond row cropping. In the same vein, APHIS highlights consideration of

[13] In this section we highlight a small sample of the perspectives and concrete examples shared by USDA agencies with each agency providing valuable information from multiple programs. More detail can be found in the Appendix to this report. Agencies include the Agricultural Marketing Service (AMS), the Animal and Plant Health Inspection Service (APHIS), the Agricultural Research Service (ARS), the Economic Research Service (ERS), the Forest Service (FS), the Farm Service Agency (FSA), the National Institute of Food and Agriculture (NIFA), Rural Development (RD), and the Risk Management Agency (RMA). In addition, we present a response from the Climate Hubs, an interagency collaboration led and hosted by ARS and FS, with contributions from APHIS, FSA, NRCS, and RMA.

regulatory burden in their policy decision-making framework, and FS details promotion of mass timber construction through lowering barriers in building codes.

Several common themes emerge, including prioritization of stakeholder engagement and involvement early and throughout successful projects. While the term stakeholder can refer to a variety of actors, one of the fundamental aspects of stakeholder engagement is developing a more precise understanding of the population of potential adopters for a given innovation. For working lands production technology, the primary stakeholders are typically operators, but for many innovations, stakeholders can include agency staff, other agencies at the State and Federal level, conservation and industry groups, banks and other businesses involved with the innovation, and community members who may be affected. RD highlights how consolidation of its Guaranteed Loan Program into the OneRD framework responded to stakeholder needs for centralized access to the program.

Identification of stakeholders is the central question of who may — or may not — ultimately adopt the innovation in question. Most of the agencies referenced in this report provide examples of identifying who might adopt and then incorporating their perspectives. In many cases, understanding which potential adopters are currently not adopting a service, practice, or production technology can provide critical information. Understanding the barriers to adoption for these individuals — typically through stakeholder engagement — is a key step that might encourage innovation adoption or an understanding of why the current programs are insufficient to meet stakeholder needs. AMS highlights the ways in which their testing services respond to industry demand and consumer preferences, listening to the needs of their stakeholders.

In practice, engagement includes many pathways.[14] One successful approach that agencies highlight is working through field office staff and private sector program partners to hear about how potential adopters are interacting with agency programs and services. Local, trusted individuals can translate the reality of how potential adopters interact with programs and services, including any bureaucratic, social, cultural, or informational barriers that might exist. APHIS notes that its National Wildlife Research Center (NWRC) works with collaborators, from universities to NGOs and private companies, to identify such barriers and potential pathways forward. FS emphasizes this approach in its Shared Stewardship Framework, where FS works with State, local, Tribal, and non-governmental stakeholders to conduct broad-scale planning. Likewise, RD emphasizes stakeholder engagement with city halls, chambers of commerce, councils of governments, regional planning organizations, agencies on aging, religious institutions, civic organizations, public housing authorities, educational institutions, Tribal councils, charitable organizations, and community foundations. Furthermore, using local partners, which may include county or State extension agents, provides a trusted human to connect the agency with local producers and other stakeholders for two-way communication. One key component of stakeholder engagement for APHIS is a focus on what drives public acceptance and trust in pest management innovations. APHIS emphasizes the use of direct engagement with stakeholders, including commercial and residential communities that may be

[14] There is a large literature on evolving approaches to stakeholder engagement in scientific research and policy applications (e.g., Batie, 2008; Hunt and Thornsbury, 2014). Meadow et al. (2015) provide a discussion of modes of stakeholder engagement, including contractual, consultative, collaborative, and collegial.

affected by pests and by pest management practices. The Climate Hubs represents an approach to engage stakeholders in interagency collaboration broadly across specific projects.

Some of the agency highlights include overcoming social and behavioral factors that specifically pertain to historically underserved farmers and their ability to access USDA programs and innovations. For example, RMA implemented alternative documentation to enroll members of communities where standard documentation is not available. This provided novel products for farmers who do not engage in monoculture commodity crop production for which many crop insurance products are designed. In a similar vein, FS highlights the Shared Stewardship program which incorporates the membership, perspectives, and priorities of underserved or underrepresented communities, including Native American communities.

In addition to receiving information from stakeholders, engagement includes providing information on the innovations that are available to stakeholders. As noted above, partnering with local extension agents or field office staff can not only bring an understanding of stakeholders to the agency but also provide potential adopters with information about innovations. One key step in the process of adoption is ensuring that potential adopters both know about the existence of relevant innovations and understand the benefits and costs of such innovations. Not all innovations are beneficial for all stakeholders, and this information flow reduces uncertainty and helps potential adopters make informed decisions. ARS, NIFA, and ERS are all committed to creating objective research to support decision-making, as well as communicating data and research to relevant stakeholders within USDA and throughout the relevant communities. For FS, one innovation is the ability to model and deliver critical information about wildfires and wildfire risk to stakeholders, including firefighters and the affected public. The Climate Hubs response highlights the importance of providing information in useful and usable formats. AgRisk Viewer synthesizes existing data from a variety of sources to deliver actionable insights for stakeholders internal and external to USDA.

The extent to which adoption is tracked varies widely across agencies and across the type of innovation. Agencies generally track most closely those innovations which they are specifically encouraging or inventing, using metrics like enrollment in programs or use of patents. Certain innovations, such as patents for new technologies, are tracked with relative ease. The USDA Annual Technology Transfer Report includes quantified metrics and descriptive information on technology transfer for Department research agencies (USDA, 2020). The Forest Service tracks use of innovation or novel approaches incorporated in Shared Stewardship projects as part of the annual Performance Indicators. The FY21 Performance Indicators include outcome-based measures of resource management, as well social measures and metrics regarding collaboration and uptake of innovative stewardship. In a similar vein, many agencies track enrollment or use of innovative programs or services. However, it is intrinsically difficult to track application of many innovations, especially practices which are intended to be adapted to individual operation contexts and dispersed across the country. In agencies with limited resources to track the adoption of relevant innovations, tracking is not prioritized.

Multiple agencies indicated that consideration of most behavioral factors is outside their core expertise and highlighted a desire to expand work across disciplines to incorporate these factors; however, there can be constraints in actual development of partnerships. The capacity and time necessary to develop partnerships may prevent meeting targets or efficiency in the short term but can provide greater long-term benefits. AMS notes that one barrier to innovation in response to stakeholder demand is staffing and internal capacity. Likewise, ARS notes that there is limited capacity to engage in research regarding behavioral factors, as the agency employs few social scientists and seeks support from other agencies in these areas. ARS emphasizes partnering physical scientists with social scientists to examine the behavioral factors relevant to ARS projects and related innovations.

Collaboration across agencies can be, in part, a response. ERS produces reports tracking adoption and diffusion for some innovations, such as cover crops and no-till adoption, use of irrigation innovations, and implementation of technology to increase productivity. The ERS response also highlights the intrinsic challenge of producing high-quality research on these topics when data on new innovations is sparse, as such research requires time to develop and refine. Collaborations with non-government partners are also important. Several agencies, including ARS, ERS, FS, NIFA, RD, and RMA, have programs in place to work with academic institutions to study factors influencing adoption from a variety of perspectives.

Lessons Learned

Including explicit consideration of behavioral factors along with economic and technical feasibility considerations may accelerate innovation diffusion as a driver of the U.S. economy. Behavioral factors, such as risk attitudes, environmental attitudes, and social networks interact with economic and technical feasibility factors in the adoption of any innovation. Individual adoption and widespread diffusion of an innovation are context-dependent. The relationship between different influences depends on the innovation in question, broader social, policy, regulatory, and market conditions, and the adopter him or herself. This can be seen by comparing PA technologies with conservation practices. PA technologies directly influence the effectiveness and profitability of the operation whereas conservation practices either trade off some efficiency in favor of environmental benefits, or benefits are realized over longer periods of time (e.g., soil health). We find that adoption of these two innovation types is influenced by different factors regarding operator attitudes and motivations; use of other technologies, profitability, and a belief in his or her ability to use technologies plays a greater role in adoption of PA technologies. Environmental attitudes, attitudes towards government programs, and perceptions of environmental risk play a greater role in adoption of conservation technologies.

Adoption and diffusion of innovations requires planning and deliberate consideration of behavioral factors throughout the innovation life cycle. A recurring theme among agency responses is the need to consider a variety of factors that may influence adoption throughout the innovation process, from the basic research stages to incorporation into programs and outreach efforts. Many research and program implementation agencies are highly familiar with planning for investment costs, profitability, and technical suitability for climates and land types. However, stakeholder perceptions, information sources, and management goals, which influence adoption rates as well as diffusion among different communities should also be considered early, as they may inform the prioritization of research programs or practices, and the identification of potential adopters. One strategy for wider consideration of behavioral factors is fostering connections between different agencies and between agencies and outside stakeholders such as academia, NGOs, farmer groups, and other organizations. In interviews, agencies highlighted this need for collaboration which could bring in behavioral expertise to agencies that have traditionally focused on other factors.

Three practices relevant for all agencies working in the innovation space that would encourage consideration of behavioral factors throughout the process are (1) identification of stakeholders prior to the beginning of a project or program with as much specificity as possible, (2) detection and reduction of process-related barriers, and (3) post-project assessment. It is essential to define the relevant stakeholders for a given project at the beginning, as a clear definition paves the way for continual communication and trust between the agency and potential adopters. Stakeholder identification and engagement can then highlight the differing needs of heterogeneous communities. The willingness and ability to adopt innovations varies depending on individual geographies, backgrounds, and experiences, and there is value in identifying and addressing these needs up front. During the implementation of a program, internal agency processes and actions can make adoption of innovations either more or less difficult. Possible barriers that the agencies identified in interviews include the time and effort associated with both applying and fulfilling program requirements. Where possible, identifying and removing internal, process-related barriers through streamlining applications and providing assistance can improve uptake of USDA innovations.

Communication and managing the flow of information, both within and between agencies regarding the innovation process, between agencies and stakeholders, and between stakeholders within their networks, is an essential component to innovation adoption. Between agencies, shared expertise across physical science and social science researchers and program managers can serve to better plan for encouraging adoption. In the literature, we see that connections with USDA agencies significantly influence adoption and timing of adoption in some cases. Hence, upfront, two-way communication with stakeholders is an important tool that agencies can use to encourage the adoption of innovations. Having a trusted source of information is of great importance. Programs may focus on disseminating information through trusted networks and use early adopters as seeds for broader implementation.

Finally, networks — stakeholder groups, neighbors, and social networks — serve an important purpose in adoption diffusion. The learnability of innovations and farmers' level of confidence in their ability to implement them, and their impacts on their operation, depend in part on observing and learning from others. University extension, regional climate hubs, and other stakeholder outreach programs connect basic research and new technologies with the community of stakeholders who put new knowledge into practice. Additional research is needed on the role of USDA programs and agency activities on the diffusion of innovations. The information landscape has changed significantly in the last 20 years, with more information being shared through online platforms than through traditional neighbor networks. A better understanding of the information sources used by stakeholders most frequently and their trust in various sources can inform future outreach efforts.

Maintaining trust in USDA data and science is critical to increase adoption and diffusion of innovations. Stakeholders (external and internal) are more likely to act on information and adopt innovations from trusted sources. USDA is typically viewed as a trusted source, and maintaining the integrity, credibility, and transparency of Department science is critical. Likewise, ensuring that innovations are recognized by external stakeholders as having a basis in USDA science could increase their willingness to adopt. Incorporating strategic Department communication and dissemination (e.g., extension, newsletters, blogs, etc.) into projects could support adoption.

Clear guidelines for post-project assessment are necessary for a better understanding of what practices and processes are successful in encouraging adoption. Diffusion of new technologies and practices through communities happens over time; thus, *ex-post* tracking and assessment is an ongoing process. Two examples of ways that USDA agencies currently assess adoption are tracking patents and eliciting the use of a technology or practices through regular surveys such as the Agricultural Resource Management Survey (ARMS). Continued and related efforts to assess projects on a smaller scale will provide critical information on how innovations move through communities that can then inform research, processes, and programs going forward.

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Appendix: Summary of Individual Responses to the Data Call

Agencies were initially asked broad questions with follow-up discussion as needed. The focus was successful projects or activities that highlight efforts to incorporate behavioral factors to encourage adoption of the innovation. Responses are summarized below. The questions posed to each agency are below these individual summaries.

Agricultural Marketing Service

The Agricultural Marketing Service (AMS) responded with practices from both the Livestock and Poultry Program (L&P) and the Science and Technology Program (S&T). Primarily due to the ways in which AMS serves U.S. agriculture, the AMS response focuses primarily on agency innovations that have been a response to industry demand. Within L&P, AMS presented information on innovation in the verification of various sustainable practices, such as cage-free claims for poultry and egg products, through the USDA Process Verified Program (PVP) as a fee-based service. Within S&T, AMS presented information on innovation in testing for economically motivated adulteration (EMA) of honey and juice, which is conducted through the AMS National Science Laboratories (NSL) as a fee-based service.

Because of the nature of these innovations as emanating from the agency itself, AMS is focused on internal barriers to adoption by agency labs and producers, such as agency capacity, staff training, funding sources, operational costs, and technical capabilities. In terms of EMA testing, AMS has extensively funded the development of testing capacity and techniques to ensure NSL is capable of providing this innovative service. EMA testing is continuously changing and adapting as those seeking to sell fraudulent products respond to testing capabilities, and this requires institutional planning, resources, and commitment to ensure transparent dialogue with the industries.

However, there are also key factors driving demand and acceptance of these innovations from industry, including costs and technical requirements, as well as consumer preferences. Since AMS implementation of these innovations generally flow from increasing demand from industry, AMS is more focused on responding to novel needs rather than innovations which might require AMS to navigate the stigma or other behavioral obstacles to acceptance of an innovation that might be pushed from USDA towards industry.

Both in anticipating needs for innovation and in measuring the success of innovative programs, such as those referenced in the response, AMS engages in continual monitoring of program adoption and production practices. AMS tracks market data on production practices in the industry and internally records uptake of program services. The NSL tracks adoption by expenditures and revenue, by workload volume, by time, and by customer satisfaction or appreciation.

Animal and Plant Health Inspection Service

The Animal and Plant Health Inspection Service (APHIS) responded with information on three programs: APHIS Biotechnology Regulatory Services (BRS), which focuses on organisms developed using genetic engineering that are plants or plant pests; APHIS Plant Protection and Quarantine (PPQ), which focuses on preventing the entry, establishment, and spread of significant plant pests; and APHIS Wildlife Services' (WS) National Wildlife Research Center (NWRC), which focuses on solutions to challenging wildlife damage management problems.

In the APHIS response, the focus from BRS is on the facilitation of innovation through the Sustainable, Ecological, Consistent, Uniform, Responsible, Efficient (SECURE) rule, which pertains to APHIS biotechnology regulations. APHIS completed a regulatory impact analysis (RIA) that considers social and economic impacts on both adopters and non-adopters, as well as to consumers and other parties involved the in the supply chain. In addition, BRS completed an Environmental Impact Statement (EIS) that considers environmental impacts on the physical and biological environment, and to endangered and threatened species. These analyses informed the final SECURE rule.

Under the previous regulations, developers could seek deregulation of a product by providing BRS with field data about the product., and BRS would combine this data with publicly available data to assess the pest risk and environmental impacts of the product before rendering a decision. BRS also introduced a voluntary process known as “Am I Regulated” (AIR) to determine whether an organism is subject to the regulations. The AIR process does not require developers to submit field data, or the completion of an environmental review, and thereby enables qualifying innovations to be introduced with lower burden to developers and APHIS. The SECURE rule replaces this twofold system with exemptions for plants containing genetic modifications that could also be achieved through conventional breeding and a process known as regulatory status review (RSR). Under the RSR process, developers have the option to request a review at the outset of the regulatory pathway prior to commencing with field testing. If after initial review, APHIS finds there is no plausible plant pest risk, the plant is not regulated. The exemptions and RSR process reduce regulatory burden to developers and BRS identifies four barriers to adoption of innovative technologies. The first is public acceptance, with BRS noting that some crop innovations, such as herbicide-resistant wheat and rice, have yet to be commercialized due to developer concerns about market acceptance. A second barrier is the economic repercussions from commingling, including trade disruptions and costly litigation, as well as delayed product approvals. The third barrier is regulatory burden, including developers’ perceptions of uncertainty in domestic and international regulatory processes. The fourth barrier BRS identifies is messaging that decreases public acceptance, specifically from organizations opposed to biotechnology.

PPQ supports productivity and natural resources by mitigating the impacts or losses caused by invasive plant pests. PPQ supports innovation in methods development and technology to prevent the introduction of plant pests to the United States, for pest detection, pest management, pest mitigation and emergency response. In the PPQ response four factors may affect adoption of innovations in pest management and control. PPQ considers economic factors, environmental factors, industry impacts, and public acceptance. Economic factors include the costs of developing and implementing an innovation, as well as impacts on affected industries. These are weighed against the damage caused by a pest through cost-benefit analysis, and innovations that are costly to develop and implement are typically done in partnership with other agencies or industry.

Environmental factors include environmental impacts of an innovation and those of the pest, and these factors are considered prior to implementation through environmental assessments. Industry impacts include not only cost factors, but also industry participation and acceptance. These more behavioral factors are considered through stakeholder outreach to understand and consider potential impacts that may arise from PPQ program decisions. The final factor is public acceptance, which also involves issues that may be more behavioral in nature, as well as financial impacts to homeowners or other public resources. APHIS also conducts outreach with public stakeholders with respect to these factors, such as informing potentially impacted homeowners about pests and management actions that may affect the public.

PPQ identifies potential for adoption through extensive consultation and communication with State and industry stakeholders around development and implementation of innovations. Stakeholders often request PPQ assistance in developing new techniques for addressing invasive plant pest issues and have an interest in their implementation.

PPQ identifies barriers to adoption which mostly align with the four factors listed above. In terms of economic costs, PPQ points to balancing the initial and long-term costs of innovation implementation against the impact of the pest and of the innovation. A second factor is regulatory requirements, which may delay or limit certain innovations. A third factor is environmental impacts of a new process, which must be assessed and may delay implementation. The fourth factor is public acceptance, with methods that have high impacts on homeowners or public resources being precluded from implementation.

WS actively promotes exploratory research, product development, product registration, and technology transfer services. Maintaining these four functions at the National Wildlife Research Center (NWRC) facilitates economic and product development evaluations, including the likelihood of securing a private industry partner or downstream market adoption. To determine broad research and product development programs, NWRC conducts a Research Needs Assessment every 5 years. This process involves soliciting input from a diverse range of stakeholder ranging from impacted agricultural, environmental, and public safety communities, universities, and other government and public entities. Input from these stakeholders inform and often drive product development projects for the next 5-year research cycle; however, enough flexibility is built into the process to address new needs as they arise.

WS uses a variety of techniques to determine industry adoption of potential products. WS maintains a database that tracks daily work activities which can be queried to determine how often similar management issues have been addressed and techniques employed to resolve the issues. WS reaches out to internal and external stakeholders to determine the utility of potential products. Product adoption is also determined through the process of locating a development partner. Potential partners conduct market analyses and judge the interest of the Federal Government to invest in Cooperative Research and Development Agreements (CRADA) when choosing to enter into formal agreements. WS has a dedicated staff member serving as a Technology Transfer Manager to assist with these efforts. Patenting and particularly licensing successes are ways WS track product success. Judging the business health of a licensing partner can be quantitively assessed through royalties paid back to the Government. Publication citation rate is another quantitative measure of success. Success of new tools and techniques are also qualitatively assessed through the way they change wildlife management practices, such as changes observed in the way conflict situations are managed by professional wildlife managers and private industry.

WS has found that collaborative efforts between other entities, whether private sector, universities, industry groups, non-profits, other Federal and State agencies, or a combination thereof tend to be more successful. The benefits to partners under a CRADA, such as exclusive licensing rights and access to WS facilities and staff expertise, are highly attractive to these potential partners.

Across all three areas, APHIS points to the importance of building trust, working in collaboration with other entities, and obtaining "buy-in" from stakeholders and potential adopters. Early and appropriate engagement creates a pathway to successful implementation.

Agricultural Research Service

The response from the Agricultural Research Service (ARS) highlights examples across the agency, with the agency contact providing particular insight into the natural resources program by virtue of their position.

In choosing where to conduct research, ARS focuses on biophysical and other technical feasibility factors. However, certain projects, such as the Collaborative Adaptive Rangeland (CARM) research project in Colorado, the Climate Hubs, and the RUFAS (spell out) whole-farm dairy model development, more comprehensively integrate biophysical, social, and economic factors into research project design and implementation. ARS finds it most useful to integrate trained economists and social scientists from other agencies when conducting this work, rather than attempting to do this work within ARS, because ARS does not have many economists or social scientists on staff.

ARS research programs are structured around 5-year cycles, incorporating information from stakeholder listening sessions. However, biophysical feasibility is the primary concern when assessing the potential for adoption. ARS notes that the agency does not routinely estimate the extent of potential adoption before embarking on research projects, which is primarily due to agency capacity. As these innovations move into implementation, the agency provides an emphasis on tracking adoption. Adoption metrics vary by the form of innovation. Some innovations include a formal tech transfer agreement and can be tracked through patent metrics. Other innovations are more difficult to track, and ARS relies on implementing agencies, such as NRCS, to track adoption of innovations implemented by USDA.

Notably, ARS generally does not see the adoption piece of the innovation lifecycle. As a consequence, the agency is only able to focus on biophysical or technical barriers to adoption. The agency recognizes the importance of barriers to adoption but does not have the capacity to research economic and social barriers.

Climate Hubs

USDA Climate Hubs are an interagency collaboration led and hosted by the Agricultural Research Service (ARS) and Forest Service (FS), with contributions from the Animal and Plant Health Inspection Service (APHIS), Farm Service Agency (FSA), Natural Resources Conservation Service (NRCS), and Risk Management Agency (RMA). The central theme of Climate Hubs is working across agencies and developing tools for stakeholders across all sectors relevant to the USDA. The Climate Hubs aim to provide value added not only to farmers, ranchers, and forest landowners, but also to USDA agencies as well as partners in extension and land-grant universities.

The response from the Climate Hubs highlights the AgRisk Viewer, a web-based tool that provides accessible and discoverable crop insurance loss data at multiple spatial (county, State, Nation) and time scales (month and year) to support agricultural risk management and build climate resilience. Climate Hubs targets a variety of potential users for the AgRisk Viewer and brings data together that is separately held across multiple USDA agencies. The AgRisk Viewer project reflects the three workstreams of the Climate Hubs: research and data synthesis, tool and technology development, and stakeholder engagement and outreach. Building partnerships with ARS and RMA, the Climate Hubs synthesized crop insurance loss data and produced an innovative research product through a novel perspective to serve USDA customers, the general public, and decision-makers. Both AgRisk Viewer and other products have served to further strengthen partnerships with USDA customers, agencies, and the general public.

The Climate Hubs response notes that there are limited data available to assess the use and impact of the AgRisk Viewer. In addition to website metrics, Climate Hubs has received anecdotal feedback from partners and stakeholders about using the tool. One example is from Washington State, where AgRisk Viewer was used to help determine whether to issue a formal drought declaration, based on historic claims in the areas with the largest precipitation anomalies. The Climate Hubs response notes that a key lesson from the AgRisk Viewer is the extent to which it synthesizes the available data and presents this information in a way that is useful and usable.

Economic Research Service

The Economic Research Service (ERS) response highlights the ways in which the agency conducts demand-driven research, including and in addition to research projects specifically examining the factors driving adoption of innovations relevant to the USDA. Some of the programmatic examples include the National Household Food Acquisition and Purchase Survey (FoodAPS), the Agricultural Outlook program, and the recently conducted Survey of Irrigation Organizations. These examples show the range of data and analysis that can inform different aspects of the agriculture sector, including information that can aid a wide variety of stakeholders' decision-making around innovation. Across thematic categories, the ERS response notes the common driver is engaging stakeholders to understand the gaps in available data, analysis, and information, and what additional information and expertise are needed. ERS identifies these gaps through talking to farmers and ranchers, other agencies, congressional stakeholders, and other stakeholders who engage with the agricultural sector. In many cases, these engagements lead to research on understanding why people are or are not adopting or demanding certain innovations or USDA programs.

In order to meet both existing and anticipated research needs, ERS considers a wide variety of behavioral, social, physical, and financial factors driving the economic decisions across the agricultural sector. The range of factors that determines which research projects to undertake is defined primarily by the needs of stakeholders, and the ERS response highlights that research sometimes shows that an innovation is not adopted because it is not economically viable or otherwise sufficiently beneficial. Moreover, ERS research may identify innovations which are adopted for a number of reasons but ultimately do not yield corresponding benefits.

ERS tracks the use of agency research in decision-making, specifically tracking the citation of ERS research in Congressional documents, Federal Register notices, and Congressional testimony. While not a direct measure of the adoption of innovation, these indicators provide a broad measure of the impact of ERS research on outcomes in the agricultural sector.

One of the barriers identified in the ERS response is the challenge of producing timely and relevant research on these issues while maintaining the quality of the research and the review process. One of the key factors in adoption is the timeliness of information, such as the impact of report timeliness on the incorporation of relevant information into stakeholder decisions. ERS produces a variety of products, including online topic pages that convey information that is readily available, analyses that are quickly generated in response to stakeholder needs, and peer-reviewed publications, the latter of which may develop over the course of years. The ERS response highlights the balance between meeting the demand for legislative cycles or pressing current events and performing long-term work that enables ERS to produce high-quality outputs.

The ERS response highlights constant, ongoing communication with a variety of stakeholders as a key lesson learned. This communication helps ERS identify gaps in understanding, which topics are of importance and relevance, and where there might be interest in incorporating ERS findings or adopting relevant innovations.

Farm Service Agency

The Farm Service Agency (FSA) response is from the perspective of the Economic and Policy Analysis Division (EPAD). The FSA response covers a variety of programs, as well as discussion of overarching considerations at FSA regarding agricultural innovation and FSA's role.

At a broad scale, the FSA response highlights two mechanisms for FSA to promote innovation in agricultural production and conservation. The first is through FSA's administration of price and income support programs, disaster assistance, and several loan programs that help facilitate adoption of beneficial programs, practices, and technologies, at least indirectly. The FSA support provides the "safety net" for many producers to deal with weak markets and natural disasters. Loan programs are largely geared to support disadvantaged producers who are not able to secure commercial loans. The second is a focus on reducing roadblocks at FSA to farmer innovation. This includes providing an array of channels through which farmers can access FSA programs, including electronic and in-person options. It also includes FSA program changes to facilitate innovative and beneficial practices by reducing program restrictions. For example, the FSA response cites a 2019 example where the agency expanded the definition of a cover crop to corn and soybeans to ensure that some cover would be planted during prevented plant seasons with exceedingly wet conditions. FSA routinely requires conservation compliance for farmers with highly erodible land. The FSA response emphasizes the intention of FSA to ensure FSA regulations do not hinder the deployment of beneficial innovations.

One of the areas of emphasis is the Conservation Reserve Program (CRP), which is a national program that pays farmers to take land out of production and plant a conservation cover for the length of the contract, which is typically 10-15 years. FSA provides a number of incentives for participants to plant resource-conserving covers as well as annual rental payments and cost share assistance through General and Continuous Signups. FSA considers both cost and non-cost factors driving adoption and regularly examines trends in participation, as well as occasionally experimenting with the program format. The factors considered here can include a wide variety of areas, including costs and information.

Another area of emphasis in the FSA response has been the promotion of biofuels under several programs. The most notable of these, the Bioenergy Program, started about 20 years ago when biodiesel production and use was tiny. It encouraged increased purchases of eligible commodities to expand production of both ethanol and biodiesel by paying commercial bioenergy producers up to $150 million each FY on a quarterly basis, with a cap of 5 percent of the available funding from Commodity Credit Corporation (CCC) funds. The Bioenergy Program ended around 2006 but played a critical role in the expansion of biofuel capacity prior to the Renewable Fuel Standard (RFS).

FSA has had two other notable biofuel programs. The Biomass Crop Assistance Program (BCAP) started around 2008 and provided funds to assist farmers and forester landowners with growing, maintaining, and harvesting biomass that can be used for energy or biobased products, mainly for electricity generation. However, BCAP was not funded in the 2018 Farm Bill as it did not have great success.

The Biofuel Infrastructure Partnership was the other biofuel program that provided up to $100 million in 2015 in grants to pay a portion of the costs related to the installation of fuel pumps and related infrastructure dedicated to the distribution of higher ethanol blends. This was a success but was limited in funding.

Forest Service

The response from the Forest Service (FS) provides examples in four key areas: fire risk tools, mass timber, forest bioenergy, and Shared Stewardship.

The FS response highlights agency innovations in fire risk tools. The first is Blue Sky, a modeling framework that links a variety of information related to existing fires, their growth potential and activity, and their impacts through smoke and air quality. In addition, Wildfire SAFE and Wildfire Risk to Communities are programs designed to provide information on wildfire risk and activity. Wildfire SAFE includes a mobile application and a website, while Wildfire Risk to Communities is a web-only tool, but both tools are publicized through social media campaigns. FS has recently increased both search capabilities and the ease of use of Wildfire Risk to Communities.

The key focus from FS on adoption in the area of fire risk tools is the usage of these FS tools. The Blue Sky modeling platform primarily incorporates biophysical factors to provide smoke risk exposure information to both firefighters and the public, but the platform undergoes continuous innovation. In 2020, FS integrated information on COVID exposure with smoke exposure. With this tool in hand, FS prepares for heavy usage and scales cloud computing capacity to meet demand. Adoption, in terms of tool usage, is tracked through stakeholder sensing, National Wildland Fire Coordinating Group smoke/emissions and Risk committees, and EPA tracking systems.

FS identifies several key challenges, including the extent of fire season, budgetary limitations and technical capacity, and marketing and user engagement. The magnitude of fire activity contributes to the need for these services but also adds pressure on the system, while budgetary limitations and technical capacity constraints leave FS without a sustainable method of supporting the continued use and development of these innovations. For the web- and mobile-applications, marketing is a key constraint, as the tools are only useful for users who access them. FS has extensively promoted their applications and regularly improves them with user feedback. A beta test of Wildfire SAFE with fire professionals before it was widely released helped with these challenges.

The FS response also highlights innovations in the use of mass timber – the construction of tall, large commercial, institutional, and multifamily buildings with timber. The Forest Service Wood

Innovations program uses a variety of tools to support the implementation of mass timber innovation, including competitive and discretionary grant programs like the Wood Innovations grant program and the Mass Timber University Grant Program. During review of grant applications and active management of funded efforts, Mass Timber considers a variety of social, economic, and environmental factors. To encourage and activate these market opportunities, FS executes annual agreements with WoodWorks to track the number of mass timber buildings constructed and under design in the United States, and FS actively monitors this information to understand both the opportunities and the challenges identified with mass timber innovation. In addition, program staff regularly engage in connections with partners to track the number of manufacturing plants for mass timber, companies that have achieved or are pursuing certification, and new companies that are entering other parts of the supply chain.

While FS notes that construction costs, building codes, and insurance policies are adoption issues, the agency has seen extensive reduction in these barriers over time. FS indicates that the adoption of national building codes for mass timber materials has significantly increased adoption. Another key lesson for adoption is the importance of educating architects and engineers by having project design and engineering assistance available through WoodWorks. WoodWorks is a non-governmental organization that provides extensive education and project assistance services for developers, architects, and engineers performing mass timber construction, partially funded by FS and by industry sources.

The third innovation area in the FS response is forest bioenergy. The focus here is on bioenergy contributions from forest products, with a focus on forest-based cellulosic biofuels facilities. FS considers primarily economic factors and policy incentives, such as changes and perceptions about the Renewable Fuel Standard. For this innovation, FS measures adoption by the number of new forest-based cellulosic biofuels facilities being constructed in the United States. To identify potential adopters, program managers and field staff at FS work with biofuel companies interested in siting facilities in the United States, and FS is implementing a new cooperative agreement to monitor wood utilization market movements and track biofuels market progress.

While technologies are market ready, FS is focused on alignment with the Renewable Fuels Standard to address potential regulatory impediments. One of the keys here is communication between FS and the Environmental Protection Agency (EPA) around the implementation of the Renewable Fuels Standard, which includes requirements that apply to new facilities in this space. High upfront capital investments are also a barrier that interacts with regulatory uncertainty and requirements.

The final innovation area in the FS response pertains to an agency innovation in how it operates, the Shared Stewardship Strategy. Shared Stewardship involves joint planning and decision-making around resource management with States, Tribes, and other partners. The focus of Shared Stewardship is to incorporate a variety of factors into decision-making based on collaborations with partners, such as other Federal agencies, State and local governments, Tribal authorities, and non-governmental organizations.

Adoption of Shared Stewardship agreements depend on interest from various stakeholders, with a wide variety of agreements currently in place spanning much of the country.[15] FS measures

[15] As of 5/24/2021, there are 27 agreements with individual States, 3 with organizations (WGA, NMSFA, Chesapeake Bay) and 2 with Tribes. These cover a total of 47 States and 3 territories.

implementation with an initial Shared Stewardship Performance Framework, including both quantitative and qualitative indicators. Information for annual reporting derives from four efforts: (1) minor modifications of two existing databases to track accomplishments, grants, and agreements tied to Shared Stewardship, (2) narrative responses from each FS Region to 15 questions, (3) narratives on projects from each FS Region discussing innovation implementation, and (4) four case studies in four distinct geographic areas. Outputs include the number of acres treated, the number of grants or agreements, and the amount invested and leveraged by FS and others. Annual performance indicators for FY21 and subsequent years will include modifications that reflect internal and external input and refine the suite of outcome indicators. FY21 Performance Indicators emphasize the further integration of State, Tribal, and private lands data, as well as an emphasis on measures of the integration of State, Tribal, and local partners into collaborative resource management.

Current takeaways suggest that the effort has had several benefits: partnering in cross-boundary analysis to identify the "right work in the right pace," leveraging new cross-boundary capacity, selecting priority projects and aligning programs of work, jointly defining success, and innovating with partners.

The lessons learned for FS within the Shared Stewardship area include communication, building support, engaging stakeholders, and acknowledging the social environment, as well as economic, ecological, and political environments. FS notes the importance of consistency, frequency, and clarity of messaging. In addition, FS notes the importance of engaging others in the development and implementation of Shared Stewardship frameworks.

National Institute of Food and Agriculture

The National Institute of Food and Agriculture (NIFA) response highlights the Agriculture and Food Research Initiative's (AFRI) Sustainable Agricultural Systems (SAS) program. SAS provides grant funding and integrates research, education, and extension activities. Through the process of reviewing and funding proposals, the program works to incorporate the consideration of a variety of factors.

NIFA reviews SAS applicants for innovations that demonstrate changes crucial to safeguarding agricultural supply while ensuring the viability of the entire value chain. In addition to profitability, considerations include natural resources, food safety and quality, and the health and well-being of people and communities. Innovations in this area must also help develop and execute approaches to reducing the ecological footprint of food systems, including water and nutrient use, greenhouse gases, and energy use.

Applications are reviewed through a peer review process, in which NIFA staff assemble a diverse panel active in research, education, extension, or a combination of the foregoing related to the subject matter. SAS panels, in particular, are large and comprised of broad expertise, with biological and physical scientists, as well as social scientists and economists, engaged in research, education, and extension. Panels are intended to be balanced in expertise, while maintaining diversity in geographic location, institution size and type, professional rank, gender, and ethnicity. For temporal continuity, NIFA invites at least 30 percent of panelists to return for a subsequent year. These panels are the primary means of ensuring that funded proposals consider a broad spectrum of factors when developing and implementing innovations.

Funded projects must employ meaningful performance metrics during the grant period. NIFA notes that these metrics, for SAS, may include how the proposed system and its components contribute to productivity and profitability, reduced environmental footprint, enhanced natural resources, food safety and quality, nutritional security, human health and well-being, a skilled workforce, and more sustainable jobs in the agricultural sector. Because SAS was first implemented in fiscal year 2018, no projects have been completed. Annual progress reports are required, however, and the integration of research and extension enables informal education to encourage adoption and assess barriers to adoption. NIFA does not have a formal mechanism to track adoption of technologies after a funded project is completed.

While there are many factors influencing adoption, NIFA currently funds research to identify the social and economic implications of agricultural technologies, which can help identify barriers to adoption. In addition, NIFA science staff engage industry, academia, and other government agencies through a variety of channels, including workshops, conferences, multistate committees, and interagency working groups to identify barriers to adoption and future research and education needs. Common barriers currently identified include funding and return on investment, as well as knowledge gaps in how to apply technologies and what the benefits are for an adopter's production system and environmental goals.

NIFA highlights key lessons learned regarding adoption and factors driving adoption of innovations. The first is that there are some agents – early adopters – that are open to change and willing to share both their successes and their failures through extension and informal education channels. These early adopters are more influential in broad adoption than researchers, scientists, or government experts. The NIFA response notes that there is a higher level of credibility for peers, such as other farmers for a farmer considering adopting an innovation, than for outside actors. NIFA has programs, such as Sustainable Agriculture Research and Education (SARE), that include farmer-conducted research and demonstrations, and these efforts have resulted in widespread adoption of farm production practices, such as cover crops and no-till farming. The NIFA response also explains that the ability for potential adopters to trial technologies is critical to facilitating the adoption of agricultural innovations.

Risk Management Agency

The Risk Management Agency (RMA) response highlights three programmatic areas within the agency: pilot programs providing cover crop incentives through crop insurance; supporting local agriculture through Whole Farm Revenue Protection (WFRP); automated loss adjustment using satellite imagery and market indices. The cover crop pilots in Illinois, Indiana, and Iowa provide direct financial incentives for insured operations to engage in cover cropping, through a premium credit. WFRP provides an operation with multiple commodities a single insurance policy, which is available nationwide and includes specialty and organic operations with tailored marketing, such as those preserving farm identity. Automated loss adjustment provides for insurance products with payouts tied directly to either commodity indices, such as Chicago Mercantile Exchange (CME) and Chicago Board of Trade (CBOT) indices or observed climatological factors from NOAA's Climate Prediction Center (CPC).

Each of these programs highlights a different set of considerations around factors impacting innovation adoption. For the cover crop incentives, these factors are primarily economic incentives and the bureaucratic concerns for adopting cover crops and the impact on crop insurance coverage for the grain crop harvest. The cost of planting and terminating cover crops may be a barrier to their adoption. Historically, crop insurance guidelines have generated some concern from farmers around spring planting timelines, which RMA has addressed with NRCS to ensure crop insurance can attach at planting. WFRP addresses ways in which traditional crop insurance programs do not work well for smaller farms with diversified operations and local farmers' market and sales and you-pick operations. Conventional single-crop insurance products may be less suited to these operations, as it requires multiple policies (one for each crop) for a diversified farm and are oriented to conventional sales operations. WFRP, by contrast, offers a premium subsidy for farm diversification in accordance with lowered risk from diversification and allows all commodities on the farm to be covered by a single policy. Using satellite imagery and market indices for automated loss adjustment allows producers with measurement challenges to insure against negative shocks. Payouts are tied to known indices, such as the amount of precipitation a grazing area received or the CME index for milk prices, which reduces challenges that would be required for conventional crop insurance products, such as maintaining records of an operation's historical yield.

RMA tracks adoption of each of these programs and related practices both internally and through external partnerships. The RMA response notes how crop insurance incentives are one of a constellation of efforts on cover crops, including by the Natural Resources Conservation Service (NRCS), State government, and non-governmental organizations, such as Practical Farmers of Iowa (PFI) and the Environmental Initiative (EI) of Minnesota, which also include NRCS and other government agencies as members. Crop insurance is widely used across the country, with participation rates as high as 95 percent for corn producers in Iowa, which creates a large group of potential adopters. In practice, approximately 1,700 Iowa farmers have received a crop insurance discount for cover crops on approximately 500,000 acres during the first 3 years of the program, which is in cooperation with the Iowa Department of Agriculture and Land Stewardship (IDALS). It is worth noting, however, that total cover crop adoption was below 5 percent of harvested cropland nationally as of the 2017 Census of Agriculture. Adoption for WFRP and automated loss adjustment policies are tracked in standard RMA reporting, in addition to an external review for automated loss adjustment.

The precise impacts of cover crops on yields and other on-farm outcomes are still being assessed. RMA highlights work on understanding the actuarial consequences of cover crops as key to this area, as well as the decision-making process around cover crops. This work is done in partnership with a variety of stakeholders, with both USDA and local partners amplifying knowledge of the subsidy program and of cover crops more broadly. RMA has addressed crop insurance concerns with NRCS to ensure crop insurance can attach at planting time. A recent peer-reviewed study found that crop insurance is no longer a barrier to cover crop usage.

For WFRP, there are small producers and certain communities who may be unable or unwilling to provide the tax records necessary to apply WFRP, for which coverage is based on 5 years of revenue documentation from tax forms. To address some of these challenges, RMA highlights its work in including banks in the outreach to small farming operations, in addition to crop insurance agents. Not only are rural banks an important point of contact for small farming operations, but also banks can also work with crop insurance agents to rely on the WFRP policy as collateral to enable small operators to secure financing. The RMA response emphasizes feedback from delivery partners, producers, grower groups, and other users, such as banks, to make informed decisions about future modifications.

One of the challenges with automated loss adjustment is a lack of understanding of futures markets or Climate Prediction Center data among producers. These products rely on some complex indices, and the RMA response notes that futures markets may seem like speculation to some farmers. In addition, the Climate Prediction Center provides a uniform indicator across a large grid cell that contains a given operation. As a consequence, the individual farmer may experience a loss while the grid cell does not, or the grid cell may indicate a loss while the individual farmer does not experience one. RMA highlights education and outreach in addressing these challenges. Automated loss adjustment through climate data may be a good tool for some operations but a poor tool for other operations. RMA has also changed the pasture, rangeland, and forage (PRF) product, including changing the index from vegetative to rainfall in several States. Furthermore, RMA notes that grower group meetings and education from university extension or RMA are often better received because products are not sold by these trainers. RMA also focuses on educating agents, farmers, educators, bankers, and brokers, including providing publicly available fact sheets.

Rural Development

The Rural Development (RD) response highlights six programs and agency work areas. These include:

- The Innovation Center (IC), which works to identify and apply innovations in the delivery of RD programs and services;
- The OneRD Guaranteed Loan Program, which provides a single regulatory process to govern submission to RD commercial guaranteed loan programs;
- Dashboards as management decision-making tools;
- The Rural Innovation Stronger Economy (RISE) grant program, which provides grants designed to fund job accelerators in rural areas;
- The Rural Placemaking Innovation Challenge (RPIC), which funds eligible organization to help rural community leaders create greater social and cultural vitality in their neighborhoods; and
- Partner engagement and technical assistance.

Across all of these programs and work areas, RD highlights the consideration of cultural, community, economic, physical environmental, and social factors. Specifically, RPIC encourages planning processes to highlight and incorporate local cultural and social practices and values in developing community facilities. RISE recognizes the importance of unique community, economic and physical environmental barriers to accessing jobs. The RD response highlights multiple methods of incorporating these factors, including pilot programs to examine these impacts and local engagement. For example, the OneRD Guaranteed Loan Program centralization was piloted and assessed in terms of these factors and their impact on customer access to RD staff and programs under the centralized OneRD interface. More broadly, the RD response emphasizes the input of local staff and stakeholders both in general and in response to pilot programs. The pilot programs allow for local staff to interact with program beneficiaries and learn about the effectiveness and efficiency of programs and projects, and to understand the factors impacting adoption or uptake. Similarly, RD explores the potential for adoption through consultation with state staff and stakeholder engagement, both in formal and informal settings. These can range from Federal Register announcements and comments to meetings, technical assistance, and daily program delivery activities.

Programs are evaluated using Key Performance Indicators (KPIs) and dashboards that track outputs and program details. The KPIs include key statistics of community access to health facilities, borrowers' provision of new or improved telecommunication services, the percent of RD commercial and infrastructure investments with non-Federal funding, and the percent of RD assistance going to distressed communities. Dashboards track these outputs, as well as general information on investments, portfolios, and delinquencies, which include North American Industry Classification System (NAICS) codes. Spatially, the information can be tracked at the county or congressional district, or the zip code level for information on distressed communities. Some programs track job creation and retention and energy savings. The Data Analytics Team is working on the ability to track outcomes through such mechanisms as socioeconomic community indicators, to move beyond dollars and projects to community impact.

The RD response highlights the OneRD interface and regulation as a response to observed barriers to adoption in the fragmentation of RD service provision. OneRD supplants a process whereby lenders worked with four different application review and reporting processes from four separate administrative branches of RD. In a broader focus on barriers to adoption, the RD response highlights dashboards as the primary mechanism by which RD analyzes which innovations are not being adopted. Identifying areas with low adoption is a key pathway to understanding why adoption is limited. The RD response highlights, in particular, the ongoing development of a Tribal Nations Dashboard to identify gaps in program outreach and servicing in Tribal Nations. Some of the additional barriers include funding, staffing, and program awareness, which impact both internal use and external adoption.

The RD response highlights challenges specific to serving rural areas, including a lack of awareness among target populations and technological limitations. The RD response notes that the agency advertises agency programs in areas where potentially eligible applicants may see the program fact sheets, such as social service agencies, and staff contact migrant and immigrant assistance agencies. Outreach includes city halls, chambers of commerce, councils of governments, regional planning organizations, agencies on aging, religious institutions, civic organizations, public housing authorities, educational institutions, tribal councils, charitable organizations, and community foundations as conduits for reach unserved and underserved populations. This non-technological innovation in outreach is complemented by technological innovation, such as webinars for external customers, partners, and stakeholders. RD provides Stakeholder Announcements to follow the publication of Notices of Solicitations of Applications and Notices of Funding Available, and these announcements are disseminated through partner agencies at all levels and local staff outreach networks.

The RD response highlights the Innovation Center as an internal process designed to identify barriers and best practices. Through the examples noted here and beyond, the Center focuses on generating, developing, promoting, and implementing innovations, and as this has been successful, the innovations become more widespread and their benefits become more well known. This is virtuous cycle that depends on connection to internal and external customer needs, as well as the sharing of information and lessons learned.

Questions to the Agencies

The agency responses in this Appendix were based on the following six questions and their subcomponents. For each agency, the name of the agency would replace [your agency], as appropriate.

1. Which agency program or programs focused on innovation in research, technologies, practices, or processes to improve agriculture, forestry, or rangeland/pastureland productivity, natural resource conservation, or reduced environmental impact resulting from food or fiber production would you like to highlight?

2. Before undertaking a project in this program, does [your agency] consider factors that may affect adoption of innovations that the program is funding or otherwise supporting or promoting?

    a. If yes, what biophysical, economic, social, or other factors impacting innovation adoption does [your agency] consider?

    b. If yes, how does [your agency] incorporate these factors into program decision-making?

3. How does [your agency] estimate the extent to which potential users might adopt innovations that the program is funding or otherwise supporting or promoting?

4. After a project in this program is complete or has been operating, is [your agency] tracking adoption of innovations that the program is funding or otherwise supporting or promoting?

    a. If yes, what outputs and outcomes is the agency measuring to assess adoption, and how are they being measured?

    b. If yes, how long after the initial implementation or completion of a program is adoption measured, and on what scale?

5. What, if any, barriers has [your agency] observed that are preventing adoption or acceptance of new technologies, practices, or processes?

6. What has your agency learned about successfully encouraging the adoption of innovations?

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