FROM FIBER TO FIELD: THE ROLE OF RURAL BROADBAND IN EMERGING AGRICULTURAL TECHNOLOGY

Joshua Seidemann
Vice President of Policy
NTCA–The Rural Broadband Association

4121 Wilson Blvd., Suite 1000
Arlington, VA 22203
703-351-2000
www.ntca.org

FROM FIBER TO FIELD:
THE ROLE OF RURAL BROADBAND IN EMERGING AGRICULTURAL TECHNOLOGY

Joshua Seidemann
Vice President of Policy
NTCA–The Rural Broadband Association

ACKNOWLEDGEMENTS

Smart Rural Community^{SM} acknowledges the support of its program sponsors

MAPCOM Systems

National Information Solutions Cooperative (NISC)

NRTC

CONTENTS

ABSTRACT

The use of broadband and other advanced technology in agriculture is increasing. These applications enable users to obtain greater input efficiencies and yields while mitigating potential climate impacts and carbon footprints. Agricultural technology, or ag tech, can be deployed for crops and animal farming. As technology advances and prices decrease, ag tech adoption is anticipated to increase. Cloud-based and other ag tech systems rely upon secure and robust fixed and mobile broadband connections. Broadband availability in rural agricultural regions will be necessary to maintain domestic and international competitiveness and production capabilities. This paper provides an overview of agricultural markets and technology in the United States and demonstrates the imperative to deploy, develop and maintain broadband connectivity in rural U.S. agricultural regions.

I. INTRODUCTION

Broadband-enabled technology is intertwined in agriculture.[1] Continued advancement and evolution of this trend is important from a national policy perspective because it affects both food productivity and economic activity. Agricultural technology, or ag tech,[2] refers to the incorporation of technology, generally electronic and computer controlled as opposed to mechanical, in agricultural endeavors. It can be invoked to support crop efficiencies and blockchain logistics.[3] Ag tech can play a decisive role in many farming sectors, including row crops, specialty crops, livestock, and dairy production.

The role of agriculture, food, and related industries in the U.S. economy supports measures to enhance productivity in those sectors. The collective industry represented approximately 5.2% of U.S. GDP in 2019. While U.S. farms alone contributed more than $136 billion, that amount represents merely the foundation of greater economic activity arising out of dependent sectors, including food and beverage manufacturers, retailers, and food services industries.[4] This paper will explore the increasing and evolving role of broadband in agriculture and present documented and anticipated positive impacts of ag tech. The analysis will address agricultural trends in the United States, ag tech development, and the role of rural broadband providers. The discussion will demonstrate the critical value of robust broadband deployments in rural agricultural regions.

II. OVERVIEW OF U.S. FARMING

The U.S. Department of Agriculture (USDA) estimates that there are about two million farms in the United States.[5] While the number of operating farms is decreasing, farms are getting bigger. The average farm in 1935 was 135 acres, whereas the average farm in 2017 was 444 acres. From

---

[1] The author thanks Roberto Gallardo, Ph.D, Director, Purdue Center for Regional Development and C&RE Specialist, Purdue Extension; Michael Gomes, Vice President, Business Development, Topcon Agriculture; and Robert Tse, Senior Policy Advisor, Telecommunications Program, Rural Utilities Service, USDA, for their gracious and expert review of this paper. The conclusions herein are the author's own and do not represent the respective opinions of the reviewers or their organizations.

[2] The terms "ag tech," "smart ag," and "precision agriculture" convey different nuances in their respective meanings. For purposes of this paper, "ag tech" will refer generally to technology that is applied to the full scope of agricultural endeavors, while "precision ag" will used mostly to define the subset of ag tech that pertains to row or specialty crops.

[3] From Agriculture to Agtech: An Industry Transformed Beyond Molecules and Chemicals, Deloitte, at 5 (Aug. 2016) (https://www2.deloitte.com/content/dam/Deloitte/de/Documents/consumer-industrial-products/Deloitte-Tranformation-from-Agriculture-to-AgTech-2016.pdf) (visited Mar. 11, 2021).

[4] Ag and Food Sectors and the Economy, Economic Research Service, USDA (Dec. 16, 2020) (https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/#:~:text=Agriculture%2C%20food%2C%20and%20related%20industries,about%200.6%20percent%20of%20GDP) (visited Mar. 11, 2021).

[5] "Farms and Land in Farms: 2019 Summary," National Agricultural Statistics Service, USDA, at 3 (Feb. 2020) (https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0220.pdf) (visited Mar. 22, 2021).

1935 until the 1970s, as the number of U.S. farms declined, total farm acreage also decreased. However, overall cropland acreage did not decrease at the same rate as the decline in total number of farms; many farm were consolidated beneath common ownership. The result is fewer, but on average larger, farms. Approximately 15% of U.S. farms control about 80% of total farm acres. These trends are expected to continue, with expectations that by 2040, 5% of farms will account for 75% of farm production.[6] Even as farmed acreage decreases, technological development, including advances in both plant and animal management, has enabled total farm output to nearly triple between 1948 and 2015.[7]

The USDA reports that agriculture and related industries support approximately 11% of total U.S. employment, while food represents nearly 13% of U.S. household expenditures.[8] In 2019, net farm income was projected to reach $69.4 billion, an increase of 10% from 2018.[9] In 2019, receipts for cash crops (crops grown for sale in the marketplace, as opposed to those intended to feed the farm's animals or for personal subsistence) totaled $193.3 billion; corn and soybean crops accounted for 43.2% of that total, or $76 billion.[10] Cash receipts for animals and animal products that year totaled $176 billion.[11]

At the same time, U.S. farmers continue to face pressure from global competitors, highlighting the need to increase operational and economical efficiencies.[12] While U.S. farm exports accounted for $139.6 billion in 2018, edging out imports by $10.9 billion (the nation imported $128.7 billion of food products), U.S. food imports have increased more rapidly and steadily since 2010.[13] However, export opportunities yet exist as it is anticipated that the world will need

---

[6] Wyant, Sara, "Six Trends Shaping the Future of Farming and Ranching," Agri-Pulse Communications (Feb 17, 2019) (www.agweek/com/opinion/columns/4571716-six-trends-shaping-future-farming-and-ranching) (visited Apr. 6, 2021) (Wyant).

[7] "Farming and Farm Income," Economic Research Service, USDA (www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income) (visited Apr. 6, 2021) (ERS Farming and Farm Income).

[8] "Ag and Food Statistics: Charting the Essentials, February 2020," Economic Research Service, USDA, at 4, 5 (Feb. 2020) (https://www.ers.usda.gov/webdocs/publications/96957/ap-083.pdf?v=3264.8) (visited Mar. 11, 2021) (ERS Ag and Food Statistics).

[9] "USDA's Early Look at 2019 Farm Income," American Farm Bureau Federation (Mar. 6, 2019) (www.fb.org/market-intel/usdas-early-look-at-2019-farm-income) (visited Apr. 6, 2021) (American Farm Bureau Federation).

[10] ERS Farming and Farm Income.

[11] ERS Farming and Farm Income.

[12] American Farm Bureau Federation.

[13] ERS Ag and Food Statistics at 17.

70% more food from 2009 to 2050.[14] These data suggest a fertile opportunity where ag tech enabled efficiencies can lower input costs and increase net revenues.

III. AG TECH FOR CROP AND ANIMAL FARMING

A. CROPS

Precision agriculture (PA) has been defined as

> using technology to improve input efficiency and collect output data to facilitate future production decisions. . . . It allows farmers to apply the optimal amount of nutrients, seed, and pesticides in the right location, at the right time, using the right product and right amount to maximize crop yield and save on labor and time.[15]

The value of precision ag is conveyed effectively when agriculture is viewed as a business of logistics. Row and specialty crops are particularly suited to tech-enabled efficiencies during planting and cultivation that enable farmers to harvest and deliver product to market at peak times.

The first major iteration of precision ag was the incorporation of global positioning systems (GPS) and guidance systems in the late 1990s.[16] These include guided steering systems on tractors as well as sprayers and other implements that adjust output based upon GPS coordinates. Even seemingly rudimentary efficiencies can yield substantial benefit. GPS-enabled autosteering enables tractors to travel in straight lines. This can enable efficiencies by ensuring uniform rows that maximize acreage and ensuring that rows do not encroach upon each other; one study predicts overall efficiency gains of 20% on small farms.[17] In this context, "efficiencies" refers to measures such as reducing gaps or overlaps among rows.[18] GPS systems can enable drivers to maintain a constant distance (typically approximately 18") between rows while manipulating a 100-foot boom while travelling 15-25 mph. Farmers can also rely on autosteer while monitoring other systems:

---

[14] Konstantinos, Demestichas; Peppes, Nikolaus; Alexakis, Theodoros, "Survey on Security Threats and Agricultural IoT and Smart Farming," Sensors, MDPI, at 1 (2020) (https://www.mdpi.com/1424-8220/20/22/6458/htm) (visited Mar. 19, 2021) (Konstantinos, et al.).

[15] "Threats to Precision Agriculture," 2018 Public-Private Analytic Exchange Program, U.S. Department of Homeland Security, at 8 (https://www.dhs.gov/sites/default/files/publications/2018%20AEP_Threats_to_Precision_Agriculture.pdf) (visited Apr. 6, 2021) (DHS).

[16] Konstantinos, et al. at 3.

[17] Kharil, Tulsi P,; Ashworth, Amanda J; Shew, Aaron; Popp, Michael P.; Owens, Phillip R., "Tractor Guidance Improves Production Efficiencies by Reducing Overlaps and Gaps," Agricultural & Environmental Letters, Vol. 5, Issue 1 (2020) (https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/ael2.20012) (visited Apr. 8, 2021).

[18] *See,* "Benefits and Evolution of Precision Agriculture," Agriculture Research Service, USDA (Aug. 12, 2020) (https://www.ars.usda.gov/oc/utm/benefits-and-evolution-of-precision-agriculture/) (visited Apr. 8, 2021).

> If I have to stare down the hood of a tractor to drive it, I pay less attention to sensors that are bringing information into the cab. I could miss a problem with ground (seed-to-soil) contact or a plugged row nozzle because I am steering instead of looking at cab monitors.[19]

Autosteer and GPS-guided travel also help maintain soil density by reducing soil compaction, while guidance systems can lay fertilizer within five inches of a targeted zone, avoiding drifting, wasted fertilizer and unnecessary fuel consumption. "See and treat" systems feature sensors at the front of a tractor that can determine the color of a plant (plants lacking nitrogen are pale green or yellow) and trigger an implement at the back of the tractor to dispense fertilizer.[20] It is estimated that fertilizer placement has improved 7% with PA and can improve an additional 14% with further ag tech adoption.[21] Irrigation, as well, is aided by PA, which can map fields and curve rows so that rainwater can be directed for natural irrigation. A study found current PA adoption has decreased water usage in agriculture by 4%, and that an additional 21% reduction could be realized at full PA adoption.[22]

These systems rely upon the analysis of data gathered in the field. In early years, farmers would download this data on thumb drives and process the data at their office using the "sneaker net" (literally, walking data back to the office). Newer technology, by contrast, including robust wireless broadband, cloud computing, and artificial intelligence (AI), enables "crop scouting," specifically, "continuous monitoring to acquire information about plant status, disease incidence, and infestations affecting crop growth."[23] Sensors can collect and transmit data rapidly; robots can execute on-the-go responses including pest control and weed removal.

PA also facilitates better future planning. Visual inspection of crop development (either by surface imaging or drones) combined with sensors that assess soil conditions can help farmers create a forward-looking plan of action.[24] Data gathered during harvest can contribute to strategic future planting. For example, sensors can measure the mass-flow in a combine's grain

---

[19] Gullickson, Gil, "How Automated Guidance Changed Farming," Successful Farming (Dec. 2, 2019) (https://www.agriculture.com/crops/how-automated-guidance-changed-farming) (visited Apr. 5, 2021).

[20] *See,* Lowenberg-DeBoer, Jess, "Yield of Dreams: How Precision Ag Will Help Feed the Planet," Trend Magazine, Pew, (Jun. 12, 2017) (https://www.pewtrusts.org/en/trend/archive/summer-2017/yield-of-dreams-how-precision-agriculture-will-help-feed-the-planet) (visited Apr. 2, 2021).

[21] "The Environmental Benefits of Precision Agriculture in the United States," AEM, ASA, CropLife America, National Corn Growers Association, at 15 (2021) (https://newsroom.aem.org/asset/977839/environmentalbenefitsofprecisionagriculture-2#.YBdQZR2Lc74.link) (visited Apr. 2, 2021) (AEM, et al.).

[22] AEM, et. al, at 18.

[23] Saiz-Rubio, Veronica, and Rovira-Mas, Francisco, "From Smart Farming Towards Agriculture 5.0: A Review on Crop Data Management," Agricultural Robotics Laboratory, Universitat Politecnica de Valencia, Camino de Vera, at 7 (2020) (Saiz-Rubio, Rovira-Mas).

[24] *See,* Saiz-Rubio, Rovira-Mas, at 4.

elevator and mark that data with GPS coordinates. This enables farmers to compare yield to sensor-informed soil maps that disclose soil types, nitrate levels, and pH levels. Geolocated data from these maps can direct variable rate technology (VRT) in subsequent seasons to tailor seeding, fertilizer, and pesticides; VRT systems use data from sensors or GPS coordinates to vary the application rates. This enables users to plant "different types of hybrid corn seeds . . . at different locations in a farmer's field with a single pass of the tractor."[25]

The replacement of the "sneaker net" with PA relies on advanced fiber and mobile wireless networks – fiber to support office and backhaul needs and wireless deployments to support mobile systems. For example, drones can rely on cloud computing rather than drone-mounted processing equipment that would add weight and increase power demands.[26] These capabilities, however, and especially those that may rely on 5G, would require fiber deep into the local broadband network, with precise distances to be determined based on actual data needs.[27] But once a robust network of complementary platforms is achieved (the Federal Communications Commission (FCC) notes that users subscribe to mobile and fixed services concurrently and "treat them as complements,")[28] a combination of fiber and wireless networks can support cloud-based deep learning analytics. Enabled by machine learning, sensors can assess field conditions and implements can respond immediately with "on-the-go" decisions. Imaging and sensors can discern plant status, soil texture and water holding capabilities, and can inform AI systems to control pesticide and fertilizer application as weeds are identified within or beside crops. Drone-mounted sensors can "us[e] reflectance information from the visible and near infrared bands from either bare soil (to discern patterns of soil moisture, organic matter, etc.) and from crop canopies (to estimate crop health/biomass, nutrient deficiencies, crop damage, etc.)."[29] GPS-guided auto-steering can leverage digital records of planting, irrigation and feeding, in turn enabling automatic control of implements (namely, any instrument that is attached to and follows a tractor) and improved crop yields.[30]

---

[25] Schimmelpfennig, David, "Farm Profits and Adoption of Precision Agriculture," Economic Research Service, USDA, at 4 Oct. 2016) (https://www.ers.usda.gov/webdocs/publications/80326/err-217.pdf?v=0) (visited Apr. 7, 2021) (Schimmelpfennig).

[26] Estes, Vonnie, "5G Made Waves at CES But has Long Road to Relevance on-Farm," AgFunder Network (Jan 27, 2020) (https://agfundernews.com/) (visited Apr. 7, 2021) (Estes).

[27] Thompson, Larry D., and Vande Stadt, Warren H., "Evaluating 5G Wireless Technology as a Complement or Substitute for Wireline Broadband," Vantage Point Solutions (Mitchell, SD) (2017) (https://www.vantagepnt.com/2017/07/10/white-paper-evaluating-5g-technology/) (visited Apr. 7, 2021).

[28] *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion: 2020 Broadband Deployment Report,* Docket No. 19-285, Federal Communications Commission, at para. 12 (Apr. 24, 2020) ("The record also provides substantial evidence, however, that fixed and mobile services often continue to be used in distinct ways, and that users tend to subscribe to both services concurrently and treat them as complements.")

[29] DHS, at 12.

[30] *See, i.e.,* Tyler, Mark B., and Griffin, Terry, "Defining the Barriers to Telematics for Precision Agriculture," Kansas State University at 1, 2 (Southern Economic Association 2016 Annual Meeting, 2016) .

Post-harvest, ag tech can support traceability and security. "Data from the farm play a vital role in the post-farm-gate-supply chain, including identifying and dealing with food safety issues, mitigating spoilage and food waste, and cold chain monitoring."[31] For example, without traceability, an outbreak of food poisoning linked to a particular type of produce (for example, romaine lettuce) could trigger the removal of that variety from all store shelves across the country. Blockchain, by contrast, can enable industry to identity the farm and field from which the tainted produce was harvested, and recall only inventories from the affected acreage, thereby avoiding vast food waste and associated costs. As observed by an agronomist, blockchain tracing:

> . . . plays a significant role in helping businesses be competitive in the domestic and global marketplace. The ability to trace a product through all stages of production on farm, processing, distribution, transport and retail to the end point, or consumer, is becoming a standard business practice for all involved in today's food supply chain. . . . Adopting traceability is not a choice. It's a question of how do we do this in the best way possible, and how do we take advantage of the opportunities that are emerging.[32]

These principles have found Congressional expression in the Food Safety Modernization Act (FSMA).[33] FSMA rules, as promulgated by the Food and Drug Administration (FDA), allocate food safety responsibilities among specific steps on the food supply chain. These measures address, *inter alia,* preventative controls for human and animal food; produce safety; and third-party verification standards. In 2020, the FDA proposed new rules for food traceability.[34] The proposed rules are intended to address high-risk foods including eggs, leafy greens, and seafood.

B. LIVESTOCK

Ag tech can play an important role in livestock and dairy production. The value of potential efficiencies and gains in these sectors is evidenced by the role these industries hold in the national economy. Cash receipts for livestock and poultry total about $100 billion annually.[35]

---

[31] Estes.

[32] Folnovic, Tanja, "Traceability – What's It All About?," Agrivi Blog (https://blog.agrivi.com/post/traceability-what-s-it-all-about) (visited Mar. 22, 2021).

[33] Food Safety Modernization Act, P.L. 111-353, 111th Cong. (2011), codified at 21 U.S.C. § 301 *et seq.*

[34] *See, Requirements for Additional Traceability Records for Certain Foods: Proposed Rule*, Docket No. FDA-2014-N-0053, RIN 0910-A144, Food and Drug Administration, Department of Health and Human Service, 85 Fed. Reg. 59984 (2020).

[35] Animal Products, Economic Research Service, USDA (Aug. 21, 2019) (https://www.ers.usda.gov/topics/animal-products/) (visited Mar. 12, 2021).

U.S. livestock and dairy exports exceeded $20 billion in 2019.[36] Global demand for meat and animal products is anticipated to increase 70% by 2050.[37] Similar to crops, livestock production commonly operates on small margins; data collection and analytics can be critical to maximize efficiencies and profits. Ag tech for livestock and dairy farming is commonly referred to as precision livestock farming (PLF). Applications enable feed efficiencies and the ability to recognize sick or distressed animals. These functions are especially important because "the two major costs in animal farming are feed and disease management."[38] Ag tech can support livestock, dairy, and poultry production by monitoring feed consumption, animal health, and milk and egg production. Image processing can determine animal weight, as well as ". . . detect their sweat constituents, measure body temperature, observe behavior, detect stress, analyze sound, detect pH, and record[] cows' movements to aid in the detection [of] diseases and lameness in cattle."[39] Facial recognition technology can enable farmers to decipher animal health status.[40] Microphones can detect and distinguish among types of coughs.[41] These abilities are critical in an industry where, as noted above, the major cost factors are feed and disease.[42] Contagious diseases in confined conditions can devastate herds.[43] Cameras can help farmers with the critical task of identifying and isolating sick animals. On poultry farms, air sensors can detect concentrations that evidence the presence of avian intestinal disease.[44] PLF can also enhance worker safety. Large, open production areas are features of dairy and beef farms. In contrast, hog and poultry facilities generally operate at high biohazard ratings and have limited access from humans due to biological and contamination threats. These scenarios increase the value of remote monitoring technology. Overall, early detection can reduce the cost and time of

[36] "2020 United States Agricultural Export Yearbook," Foreign Agricultural Service, USDA, at 4 (2020) (https://www.fas.usda.gov/sites/default/files/2021-04/2020-ag-export-yearbook.pdf) (visited Apr. 7, 2021). This includes pork and pork products; beef and beef products; and dairy products.

[37] Neethirajan, Suresh, "The Role of Sensors, Big Data and Machine Learning and Modern Animal Farming," Sensing and Bio-Sensing Research 29, at 1 (2020) (https://reader.elsevier.com/reader/sd/pii/S2214180420301343?token=B602564370C602815736ED0D3610E8F2B313404BAAA7EAFD25129E21B1D56472EE9F980CE1FECCC7CC0335148D82EEB4) (visited Mar. 12, 2021) (Neethirajan).

[38] *Id.*

[39] DHS at 14.

[40] Neethirajan at 4. *See, also,* Morgan Rose, "406 Bovine Aims to Revolutionize Electronic Cattle Management," Ag Update (May 10, 2021) (https://www.agupdate.com/theprairiestar/news/livestock/406-bovine-aims-to-revolutionize-electronic-cattle-management/article_319d64e4-a938-11eb-aa6e-672d2753233b.html) (visited Jun. 16, 2021).

[41] DHS at 14.

[42] Neethirajan at 1.

[43] Neethirajan at 3.

[44] *Id.* Neethirajan explains as an example that sick pigs move up to 10% less during early stages of infection and describes how air sensors that measure the concentration of volatile organic compounds in the air can be used to identify the occurrence of intestinal infections in poultry.

treatment, and decrease the possibility of herd, passel, or flock/brood contamination by enabling early isolation of sick animals.

Research literature on PLF is not as abundant as that which exists for PA. Preliminary studies, however, suggest that similar to the efficiencies enjoyed in PA, PLF would enable gains. PLF includes, but is not limited to, robotic milking systems, livestock health monitoring, and associated hardware. One study focusing on dairy production found improved productivity among PLF adopters, but noted the relative lack of data in the field and concluded, "more empirical research[is] needed to better understand the effects of PLF technologies adoption on the productivity of heterogenous farms . . . ."[45] Another study is reported to estimate the U.S. PLF market to increase from $3.1 billion in 2020 to $4.8 billion in 2025.[46] Despite the nascent state of PLF data, it can be anticipated that technological advances in PLF and other applications aimed at poultry and egg production will continue, increasing productivity and driving additional demand for increased broadband connectivity in agricultural spaces.

IV. <u>AG TECH IN ACTION</u>

A. ADOPTION FACTORS

1. Farm Size and Costs

Several factors have been identified when assessing the rate and pace of ag tech adoption. Similar to factors affecting broadband adoption, generally, these can be presumed to include cost, perceived relevance/value, and age of user.[47] An analysis of farm demographics reveals positive indicators for increased ag tech adoption. As described above, U.S. farms are evolving. Although most farms are small, most production occurs on large farms.[48] Inasmuch as the cost of ag tech remains a barrier to adoption,[49] large farms may realize more beneficial economies of

---

[45] Carillo, Felicetta, and Abeni, Fabio, "An Estimate of the Effects from Precision Livestock Farming on a Productivity Index at Farm Level: Some Evidences from a Dairy Farms' Sample of Lombardy," Animals, MDPI, at 9 (2020) (Carillo and Abeni).

[46] "Precision Livestock Farming Market with COVID-19 Impact Analysis by System Type, Application, Offering, Farm Type, Farm Size and Geography – Global Forecast to 2025" (Nov. 2020) (https://www.reportlinker.com/p05812010/Precision-Livestock-Farming-Market-by-Functional-Process-Hardware-Application-And-Geography-Analysis-Forecast-to.html?utm_source=GNW) (visited Apr. 7, 2021).

[47] *See,* Schadelbauer, Rick, "Conquering the Challenges of Broadband Adoption," Smart Rural Community, NTCA–The Rural Broadband Association, Arlington, VA (2014) (https://www.ntca.org/sites/default/files/legacy/images/stories/Documents/Advocacy/CCBA_Whitepaper.pdf) (visited Apr. 7, 2021).

[48] ERS Farming and Farm Income.

[49] It bears mention, however, that these optimistic numbers must be analyzed alongside data indicating the growth of farm sizes and decreases in the number of farms; the proliferation of small farms where adoption may lag behind that of larger farms; and the potential impact of farmers who rely on off-farm income, and whether that might discourage investment in ag tech on small farms if the farm is not a primary source of income. Approximately half of U.S. farms are small farms, and "households operating these farms typically rely on off-farm sources for most of their household income." (ERS Farming and Farm Income.) At the same time, these trends may be counterbalanced

scale than small farms. Overall, farm size has been identified as a prevailing factor that determines adoption.[50]

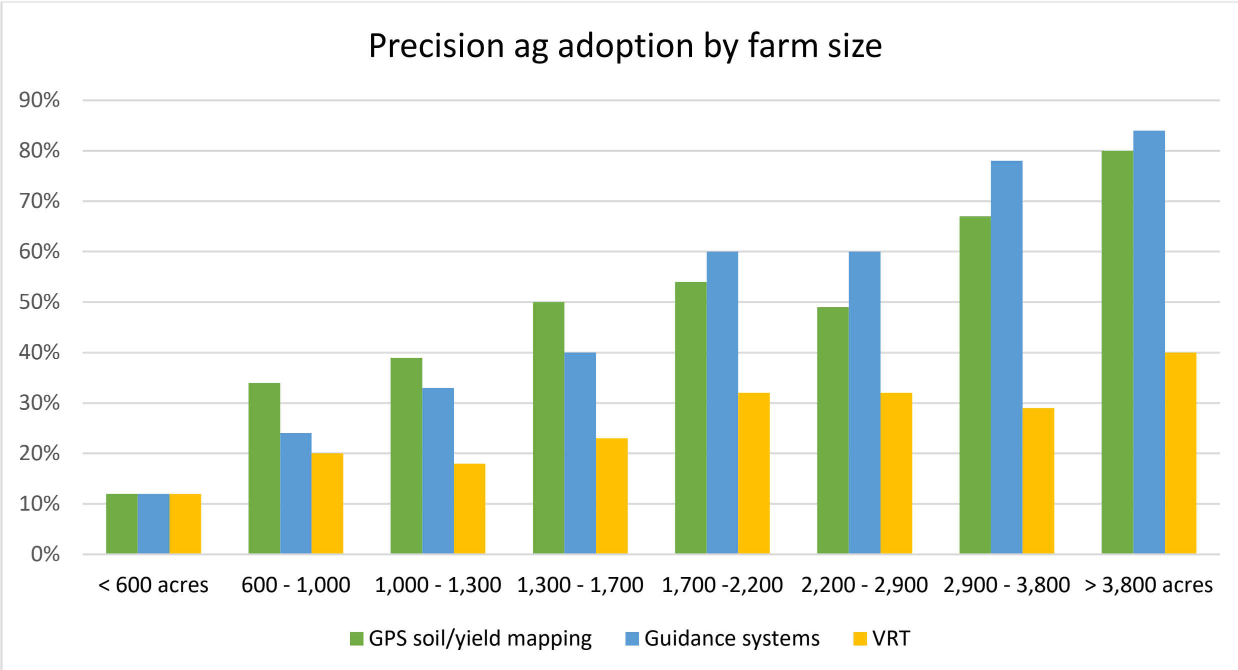
The efficiencies of ag tech, which intends to reduce input costs while increasing productivity and yields, may manifest differently on farms of various sizes. For example, a small, owner-operated dairy may deploy automated feed, milking, and manure management technology that can reduce the need to hire outside, non-family help. In contrast, a large crop farm may deploy a battery of sensors and automated equipment to drive VRT-enabled efficiencies that multiply across the many acres farmed. Overall, many factors will contribute to anticipated outcomes, and a simple comparison of adopters to non-adopters is difficult because the analysis must contemplate many variables such as size, crops, and sufficient broadband availability to support PA applications. Nevertheless, if farm size is identified as the prevelant factor that informs adoption, then it can be reasoned that overall adoption should increase as farm sizes increase. Adoption data provided by ERS bears this point, as illustrated in the graph below.[51]

---

by large farms that are managed by young farmers. In this regard, the core target for ag tech adoption would seem to be large farms that are farmed by young farmers.

[50] Schimmelpfennig at 26.

[51] The USDA Agricultural Resource Management Survey reports that precision ag was used on 30% to 50% of corn and soybean acres in 2010-2012. These data, however, do not account for other row crops and specialty crops. Overall, although different elements of precision are often used in tandem, GPS is more often used alone (17.2%) than in combination with other technologies. Guidance systems are used more often when adopted alone (6.1% corn farms). GPS is used with guidance systems on 5.7% of farms; with VRT on 4.3% of farms; and GPS, guidance and VRT are used together on 3.8% of farms. (Schimmelpfennig at 6, 10.) These figures refer to farms, but not farm acres.



Source: USDA ERS, 2016 (Schimmelpfennig, 2010 data)

Moreover, it should be noted that the need for broadband in rural areas to support ag tech is inelastic to farm size. Farms, whether large or small, are located primarily in rural regions, and large farms are not necessarily composed of contiguous acres. Rather, large farms often include operations that manage dispersed acreage across a range of many miles. This, too, increases the imperative for ubiquitous broadband deployment in rural agricultural regions. In sum, trends toward larger farms and data indicating higher ag tech adoption in larger farms demonstrate the need for rural broadband deployments to support increasing ag tech needs.

In addition to farm size, capital costs inform adoption. And, as noted above, most U.S. farms are small farms; many are owner-operator enterprises. Capital costs for small and medium farms can be mitigated by introducing ag tech with tailored applications. While rudimentary efficiencies can be gained through basic data collection and analysis, greater efficiencies are realized through more sophisticated and comprehensive data collection and analysis, *e.g.,* more expensive solutions. However, the benefits of PA, in addition to improved efficiencies and yield, can extend to quality-of-life improvements. For example, a farmer in a self-steering tractor can avoid fatigue as the machinery operates autonomously and use that time to monitor commodity prices. These labor efficiencies can benefit many small-scale farm operators who depend on off-farm income and who would benefit from that reclaimed time.[52]

Adoption trends can also be anticipated to correspond to developments in technology and relative pricing. As noted above, perceived value drives adoption. Value can be defined, generally, as the difference between cost and return. Stated differently, users can be expected to adopt ag tech when positive returns on investment outweigh capital costs, operating expenses,

[52] ERS Farming and Farm Income.

and intangible costs associated with acquisition and deployment. Notably, ag tech prices are declining over time.[53] This is consistent with technology prices, generally as (i) processing power grows exponentially in relatively quick cycles,[54] (ii) ongoing improvements change what is considered "state of the art," and (iii) increased demand results in higher production, leading to economies of scale that enable lower costs and pricing. A report explains, "Due to the evolution of technology, the size and shape of sensors is getting smaller and more sophisticated, while in parallel the general cost of the IoT devices is getting lower."[55] Decreasing prices for technology are often demonstrated in both lower constant-dollar and nominal dollar values. These overall decreasing costs would be anticipated to presage increased ag tech adoption over time. In this vein, tech adoption can be perceived as a steady incline punctuated by spikes as adoption rates increase; this may be visualized as a graph that features time on the X (horizontal) axis and adoption on the Y (vertical) axis. Innovative developments will be represented by spikes on the upward sloping X line that reflects action by early adopters, corresponding to a higher point on the Y (vertical/adoption) axis. That spike may then temper to a more moderate incline when initial excitement wanes but as the now-common technology is adopted by a broader community of users. The X line may then spike again when either (a) prices drop or (b) a new innovation that attracts early adopters is released.

2. Age and Educational Attainment

As farms change, farmers are changing, too. The average age of a U.S. farmer in 2017 was 57.5 years, 1.2 years older than the average age of a farmer in 2012.[56] Although data reveals that older users adopt technology at lower rates than younger users,[57] broadband adoption among "older users" is increasing over time as (a) perceived relevance among users increases as more aspects of daily life go "online," and (b) users who were in the 50-60 demographic a decade ago (and who were broadband adopters) now populate the 60-70 age group and *remain* broadband users.[58] Moreover, an analysis of ag tech, specifically, should also contemplate the correlative roles of education in broadband and tech adoption, specifically, increased broadband adoption that

[53] DHS at 9.

[54] Commonly referred to as "Moore's Law," this principle predicts that the number of transistors on a circuit will double every two years. First forecast in 1965 by American engineer Gordon Moore, it has generally reflected engineering advancements for the past 50 years. The exponential growth of capability has been accompanied by decreasing prices per unit of capability, enabling more powerful chips to be deployed to "general purpose technology," *i.e.,* products that can be tailored to serve a variety of uses and industries.

[55] Konstantinos, et al., at 3.

[56] "2017 Census of Agriculture Data Release," National Agricultural Statistics Service, USDA, at 26 (Apr. 11, 2019) (https://www.nass.usda.gov/Newsroom/Executive_Briefings/2019/04-11-2019.pdf) (visited Apr. 7, 2021).

[57] Internet/Broadband Fact Sheet, Pew Research (June 12, 2019) (https://www.pewresearch.org/internet/fact-sheet/internet-broadband/) (visited Mar. 17, 2021) (Pew).

[58] *See, e.g.,* Greenwald, P., Stern, ME, Clark, S., Sharma, R., "Older Adults and Technology: In Telehealth, They May Not Be Who You Think They Are," International Journal of Emergency Medicine (2018) (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5752645/) (visited Sep. 14, 2020).

corresponds to increased educational attainment.[59] In these regards, then, it is instructive to assess trends surrounding young farmers. According to the USDA Farm Census, 321,000 farmers are "young farmers," *i.e.,* 35 years or younger.[60] This cadre of young farmers increasingly obtains more post-secondary education than their predecessors. In fact, it is anticipated that nearly 69% of young farmers in the near term will have a college degree.[61] These data correlate with increasing educational attainment in rural areas, generally. The ERS reports in 1970, more than half (56%) of rural adults 25 years and older did not have a high school diploma. That share dropped to 15% in 2015.[62] Currently, most rural adults have a high school diploma or equivalent (GED), and nearly 30% have a bachelor's degree or higher. In addition to data demonstrating increased adoption among users with higher rates of educational attainment, some suggest that educational attainment may correlate to adoption of new technologies, generally.[63] Together, the data bode well for the increasing incorporation of technology in agriculture; young farmers show greater favorability to PA than older counterparts.[64]

Moreover, today's farmers will find complete programs built around the evolving needs of the ag tech industry. For example, Wisconsin Indianhead Technical College (WITC) offers a two-year associates degree program leading to a technical diploma for Agricultural Power and Equipment Technician. Similarly, the Pennsylvania Department of Agriculture coordinates farming apprenticeship programs.[65] Programs like these are often only the beginning, as continuing education is necessary to keep pace with developing technology. Farm workers are transitioning to farm technicians. As described in a report published by the U.S. Department of Homeland Security,

> Where in the past farmers relied on mechanical skills to keep equipment operating, precision agriculture requires them to learn how to integrate computer

---

[59] Pew.

[60] Census of Agriculture: 2017 Census Volume 1, National Agricultural Statistics Service, USDA, at Table 68, (2017) (https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/st99_1_0068_0068.pdf) (visited Apr. 8, 2021).

[61] Wyant, *supra* n.6.

[62] "Rural Education at a Glance, 2017 Edition," Economic Information Bulletin 171, Economic Research Service, United States Department of Agriculture, at 2 (Apr. 2017) (https://www.ers.usda.gov/webdocs/publications/83078/eib-171.pdf?v=6364.1) (visited Apr. 8, 2021).

[63] *See, generally,* Mann, Bryan A., Smith, William C., and Baker, David P., "Schooling Attainment's Influence on Internet Adoption: Education's Role in the Cross-National Development of the Mass Media Knowledge Gap," FIRE: Forum for International Research in Education, Vol. 3, No. 3, at 47 (2016) (Mann, et. al.).

[64] Saiz-Rubio, Rovira-Mas at 2.

[65] "Wolf Administration Highlights Ag Apprenticeships Providing Hands-On, Paid Training for Jobs in Demand Among Pennsylvania Employers," Pennsylvania Department of Agriculture (Nov. 9, 2020) (https://www.media.pa.gov/pages/agriculture_details.aspx?newsid=993) (visited Apr. 9, 2021).

> systems and evaluate data integrity. . . Failure to adopt new technologies puts farmers into a competitive disadvantage. Being able to evaluate which technologies will return on their investment is a critical skill for today's farmers.[66]

Overall, trends reflecting age and educational attainment of farmers and farm size indicate opportunities for positive ag tech adoption growth and an ongoing need for rural broadband deployments.

B. RETURN ON INVESTMENT

Numerous studies have attempted to quantify the value of ag tech. Each estimate may rely on different data sets and approaches, and are further differentiated by farm size, crop and region. For purposes of this paper, some illustrative examples are offered:

- Auto-guidance systems can increase usable farm acreage from 3,000 to 3,335 acres.[67]
- VRT seeding enables gains of $12.53 per acre[68]
- VRT fertilization can enable gains of $36.00 to $88.00 per acre[69]

In addition to the different methodologies that guides various studies, it also bears mention that data gathered from farms of different sizes will represent different economies of scale. For example, large farms are found to adopt ag tech on a greater basis than smaller farms. Therefore, a greater proportion of data may be derived from large farms that rely on different economies of scale as compared to small farms; the average returns for ag tech may be proportionally higher on large farms than small farms. At the same time, certain operational expenses for large farms using PA may be higher than those incurred by small farms.[70]

Although crop and yield efficiencies should be expected with PA, it is not clear that labor costs necessarily decline. On the one hand, PA may support automation that reduces costs for hired labor. On the other hand however, more sophisticated equipment can require a higher-skilled work force for operation and maintenance. Service costs must be factored, as well, and a USDA report notes differences between large and small farm costs: "Custom service costs associated with the three PA technologies are substantially different between large and small farms, partly

---

[66] DHS at 14.

[67] Griffin, Terry, Lowenberg-DeBoer, and Lambert, D.M., "Economics of Lightbar and Auto-Guidance GPS Navigation Technologies," Precision Agriculture '05, at 581-587 (2005).

[68] Nafizger, Emerson, "Variable vs. Uniform Seeding Rates for Corn," farmdoc, Department of Agriculture and Consumer Economics, University of Illinois (Apr. 16, 2019) (https://farmdoc.illinois.edu/field-crop-production/uncategorized/variable-vs-uniform-seeding-rates-for-corn.html) (visited Apr. 5, 2021).

[69] "Big Savings from Variable Rate Fertilizer," Ohio Farmer (Dec. 15, 2008) (https://www.farmprogress.com/story-big-savings-from-variable-rate-fertilizer-9-20801) (visited Apr. 5, 2021).

[70] Individual users may avail themselves of predictive calculators. *See,* Dhuyvetter, Kevin; Smith, Craig; and Kastens, Terry, "Guidance and Section Control Profit Calculator," Agricultural Economics, Kansas State University (May 20, 2016) (https://www.agmanager.info/guidance-section-control-profit-calculator) (visited Apr. 5, 2021).

because providers' charges per acre decline as the number of acres serviced increases."[71] The report also explains:

> Hired labor costs are 60 to 70% lower with any of the three PA technologies on small corn farms (140-400 cropland acres), while hired labor costs are higher on large farms that have adopted precision mapping and guidance. The additional use of hired labor on larger farms may be for information management and field operation specialists that can help implement PA technologies. Larger farms have higher expenses for other inputs that these specialists can help control using PA. Custom service expenses are higher with mapping and guidance on both large and small corn farms under all three PA technologies. However, custom operation costs are five times larger, in percentage terms, on small farms than on large farms.[72]

PA applications may be combined in various permutations. Farmers can combine mapping, VRT and guidance systems. Both size of farm and the manner in which these technologies are combined affect costs. Overall, the rapid development of technology and emerging literature on ag tech at this time indicate that determining ag tech ROI for small farms will require individual analyses, while large farm economics may be evaluated against published literature. It can be expected that the body of research and literature on these topics will expand over time to reflect observations for a larger data set arising out of small farms. As an immediate issue, however, increasing ag tech adoption can be expected to drive demand for higher-skilled workers who demand higher wages. In this scenario, the farm sector will be forced to compete with other sectors demanding technology skills.[73]

On a national scale, the value of broadband for ag tech has also been demonstrated in economic studies offered by the FCC. A recent report correlated increased corn and soybean yields to increased broadband connections, specifically, 3.6% increase in corn yields and 3.8% increase in soy yields where broadband connections of 25+/3+ Mbps were doubled.[74] Several inputs to this study are notable and relevant to the instant discussion: (1) the study measured terrestrial and satellite broadband connections but not mobile wireless broadband; (2) the study measured only certain row crops but did not account for specialty crops, livestock/dairy or poultry/egg production; (3) the study measured *household* broadband adoption rather than *ag tech* or *PA* adoption. Nevertheless, the results indicate a causal relationship between broadband deployment

[71] Schimmelpfennig at 15.

[72] Schimmelpfennig at ii.

[73] For an overview of the increasing incorporation of technology into industry sectors, *see* Seidemann, Joshua, "Broadband and the Next Generation of American Jobs," Smart Rural Community, NTCA–The Rural Broadband Association (2019) (https://www.ntca.org/sites/default/files/documents/2021-03/SRC_whitepaper_the_next_generation_of_american_jobs.pdf) (visited Jun. 14, 2021).

[74] LoPiccalo, Katherine, "Impact of Broadband Penetration on U.S. Farm Productivity," OEA Working Paper 50, Office of Economics and Analytics, Federal Communications Commission, at 5 (2021) (https://docs.fcc.gov/public/attachments/DOC-368773A1.pdf) (visited Apr. 8, 2021).

and crop yields, allowing an inference that deployment enables adoption which in turn leads to increased usage for agricultural activities. The USDA estimates that the "full potential" of ag tech would increase gross U.S. economic benefits by $47-$65 billion.[75]

C. CYBER SECURITY

Industries across nearly all sectors are implicated by cyber security concerns. As ag tech comprises more applications for crops, livestock, and poultry, the potential threat to the ag industry increases. Threats to trade secrets, consumer privacy, and financial data are but several aspects that can be compromised by malicious actors. These threats arise at several points as data from sensors and equipment are uploaded to the cloud. Gateways for attacks include sensors; IoT gateways; cloud systems; and remote-control systems.[76] Malicious acts may include intentional theft from applications or devices that do not meet sufficient security standards; disruptions damage an individual farmer; or improper access by foreign actors.[77] Moreover, tactics such as ransomware or other intrusions can have debilitating impacts on affected entities. Cyber threats to ag tech are proportionally consistent with those that affect other industries. In June 2021, a ransomware attack resulted in disruptions at the world's largest meatpacking firm. The company paid an $11 million ransom.[78]

The increasing use of ag tech also implicates greater attention to cyber security in this sector. Intentional or unintentional interference can cause wide-reaching impacts; vast data sets create proportionate risk. Any systems that rely on data, sensors, or other monitoring equipment are subject to adversarial intrusion. For example, automated feed bins can be compromised; livestock data can be manipulated to portray false incidence of disease, prompting farmers to take unnecessary and potentially harmful action; irrigation systems can be hacked to either over- or under-water crops.[79] The threat to national food supplies that in turn can create significant national security consequences has been referred to as "agroterrorism."[80] Pricing information or other confidential data is subject to intrusion, and widespread attacks could skew land sale prices and crop insurance rates.[81]

---

[75] "A Case for Rural Broadband: Insights on Rural Broadband Infrastructure and Next Generation Precision Agriculture Technologies," USDA, at 23 (Apr. 2019) (https://www.usda.gov/sites/default/files/documents/case-for-rural-broadband.pdf) (visited Apr. 8, 2021).

[76] *See,* Konstantinos, et al., at 8.

[77] *See,* Konstantinos, et al., at 5.

[78] "JBS Paid $11 Million to Resolve Ransomware Attack," Jacob Bunge, Wall Street Journal (Jun. 9, 2021) (https://www.wsj.com/articles/jbs-paid-11-million-to-resolve-ransomware-attack-11623280781) (visited Jun. 14, 2021).

[79] DHS at 18.

[80] *See, i.e.,* Konstantinos, et al., at 6 (2020).

[81] DHS at 4, 17.

A growing body of work is examining the need for rigorous attention to cybersecurity for ag tech. From the perspective of an individual farmer, interference with systems designed to maximize planting could reduce efficiencies at the outset, ultimately leading to smaller yields and reduced revenues. Compromises to systems designed to monitor and maintain livestock environments could generate adverse impacts on an entire herd; by way of example, disruptions to climate control systems designed to maintain optimal environments could make facilities too cold or too hot. Moreover, disruptions in systems intended to enable monitoring of herd health could lead either to false reports of herd disease or failures to report actual adverse conditions. These, too, could affect value and pricing.

The Federal Bureau of Investigation has recognized these threats, citing 18 U.S.C. § 1831 (Economic Espionage) and § 1832 (Theft of Trade Secrets) as laws that could be violated through either the targeting or theft of a trade secrets.[82] In 2019, the U.S. District Court for Eastern Missouri indicted a foreign national who worked for a U.S. company that estimates soil quality based on satellite imaging.[83] Other instances of agricultural espionage include theft of modified seed samples and corn growing strategies.[84]

Cybersecurity accordingly warrants consideration among costs of ag tech implementation.

V. BROADBAND NEEDS

Broadband demand, both domestically and internationally, has grown significantly over the past 30 years as devices and applications proliferate in volume, sophistication, and complexity. Accordingly, the demand for broadband connectivity on farms should be anticipated to grow proportionally to broadband demand across other connected industries. To illustrate growth in broadband demand, the following data is instructive: According to CISCO, it is expected that by 2023, North America will have five billion networked devices/connections in service, up from three billion in 2018. Average fixed broadband speeds during this period are expected to reach 141.8 Mbps, two-and-half-times higher than the 2018 average (56.6 Mbps).[85]

---

[82] "Agricultural Economic Espionage: A Growing Threat," Federal Bureau of Investigation, U.S. Department of Justice (https://ucr.fbi.gov/investigate/counterintelligence/agricultural-economic-espionage-brochure) (visited Mar. 19, 2021).

[83] *See,* Edwards, Julia, "In Iowa Corn Fields, Chinese National's Seed Theft Exposes Vulnerability," Commodities News (Apr. 11, 2016) (https://www.reuters.com/article/us-usa-china-seeds/in-iowa-corn-fields-chinese-nationals-seed-theft-exposes-vulnerability-idUSKCN0X80D6) (visited Mar. 22, 2021).

[84] *See,* "Chinese National Who Worked at Monsanto Indicted on Economic Espionage Charges," U.S. Department of Justice, U.S Attorney's Office, Eastern District of Missouri (Nov. 21, 2019) (https://www.justice.gov/usao-edmo/pr/chinese-national-who-worked-monsanto-indicted-economic-espionage-charges#:~:text=LOUIS%E2%80%93%20Haitao%20Xiang%2C%2042%2C,of%20theft%20of%20trade%20secrets) (visited Mar. 22, 2021). *See, also,* Clayton, Chris, "China Caught Stealing Ag Tech," Ohio's Country Journal/Ohio Ag Net (Nov. 25, 2019) (https://ocj.com/2019/11/china-caught-stealing-ag-tech/) (visited Mar. 22, 2021).

[85] Cisco Annual Internet Report (2018-2023) White Paper (Mar. 9, 2020) (https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html) (visited Mar. 16, 2021).

A study conducted in the Netherlands illustrates how advanced connectivity, robotics, cloud computing and AI can be combined. In many instances, sugar beets are rotated with potato crops. Dutch law requires the removal of "volunteer potatoes," namely, potatoes that grow from remnant potato seeds during a season in which the field is dedicated to sugar beets. Removal of the volunteer potatoes is necessary to protect the sugar beets since the potatoes grow faster and would block light from reaching the sugar beets. In a trial, images of plants were captured by a robot traversing fields. These images were sent to a cloud-based server where an algorithm aided comparison of field images to 6,000 stored images of potatoes at different growing points and in various seasons. Once identified, the status of the plant was transmitted to the robot which could apply herbicides to kill invasive volunteer potatoes. The complete field-to-cloud-to-application cycle took about 250 milliseconds: 20-25 milliseconds from the robot to the cloud and back and 200-230 milliseconds for processing.[86] This type of application requires about 120 Mbps wireless upload.[87]

Robust broadband is necessary at the farm office/homestead, as well. By way of example, low latency applications support livestock operations.[88] Online cattle auctions are quickly enabling performance improvements. In recent years, drastic price swings (in 3Q16, for example, cattle futures prices dropped nearly 33%) have cut into rancher earnings and prompted discussions about how pricing might be better guided in a market that in 2019 was valued at $48.2 billion.[89] Although the USDA publishes price indices, the delay in disseminating price data reported by traders may result in indices that do not reflect actual market positions. In contrast, online cattle auctions direct trading to a cash market that offers near-instant dissemination of pricing information which, when aggregated across hundreds of producers using the broadband-enabled platforms, provides a more current picture of pricing. This, in turn, is proposed to potentially reduce uncertainty in the futures market. Online auctions offer cattlemen several distinct benefits: (1) the ability to participate in a process that is more economically efficient than traveling to live auctions for both the cattle and the buyers; (2) the ability to participate in hundreds of distant auctions; (3) reduced risk for animals that avoid travel and potential exposure to disease and biohazards These broadband-enabled benefits combine to serve greater economic efficiencies and opportunities for the agriculture industry. Connectivity can also inform farmers' decisions regarding where, and what, to farm. A lack of connectivity may discourage efficient use of arable land if ag tech applications cannot be used.

[86] "Smart Farming: Weed Elimination with 5G Autonomous Robots," GSMA, at 4 (Feb 2020) (https://www.gsma.com/iot/wp-content/uploads/2020/02/Smart-Farming-weed-elimination-final-for-web-170220.pdf) (visited Apr. 8, 2021).

[87] *Id.*

[88] For a comprehensive comparison of latency characteristics among broadband services, *see* Enga, Brian, and Thompson, Larry, "Satellite Broadband Remains Inferior to Wireline Broadband," Vantage Point Solutions, Mitchell, South Dakota, at 3-5 (Sep. 2017).

[89] *See,* "Statistics and Information," Economic Research Service, USDA, Table 1 – U.S. Beef Industry (Jan. 22, 2021). This reflects "total live weights of animals marketed, farm slaughter, and customer slaughter consumed on farms where produced," less various adjustments. Total receipts for cattle marketed for slaughter in 2019 were valued at $66.2 billion, and the value of beef offered for retail was $111.2 billion.

Wired and wireless facilities are necessary to support the full complement of ag tech solutions. As described above, mobile sensors in the field rely on wireless solutions, while data intensive, high-capacity applications demand low-latency and security provided by fiber networks.[90] Moreover, wireless communication services rely on terrestrial wired facilities; stated differently, "wireless needs wires." Wireless communications networks include a mobile switching center (MSC) facility at some point in the communications path. The MSC connects wireless antennae facilities to the wired network. By way of example, a mobile signal transmits from the device to a tower antennae or base station, and then to an MSC that accepts the spectrum-based signal and redirects it along terrestrial wired facilities. If the final destination is a wired location, then the signal stays on the wired network; if the final destination is wireless, then the signal will route to the MSC closest to the destination for emergence and reentry to the wireless network. Accordingly, the deployment of wireless communications services, whether 3G, 4G or 5G, requires wired facilities along the general path of communications.[91] To this end, the role of terrestrial wired broadband facilities must be contemplated as comprehensive ag tech solutions are examined.

With these examples, it stands to reason that farmers' demand for and use for broadband will continue to increase in-step with consumer and industrial trends, generally. Accordingly, anticipated broadband needs on the farm should be expected to reflect generally increasing demands among other users. These will reflect demands for increased volume, velocity (the ability to capture, analyze and act on data "on the go"), and variety among wired and wireless services.[92] Therefore, the collective interest of the ag and tech industries, alongside policymaker interest in supporting U.S. farm markets and expanded broadband deployment, should drive actions to develop and maintain robust, future-proof scalable broadband networks throughout rural and agricultural regions.

VI. CONCLUSION

The U.S. farm economy and related industries play a critical role in the national economy. Evolving literature and developing data demonstrate efficiencies enabled by ag tech, leading to production and economic gains for U.S. farmers. These benefits are essential to maintaining global competitiveness as U.S. food import/export balances shift. Factors leading to increased ag tech adoption, including age of farmers, farmers' educational attainment, and farm size, alongside declining costs of technology, favor increased ag tech adoption. However, robust, future-proof scalable wired and wireless broadband systems are necessary to support a growing range of ag tech platforms. Accordingly, continued development of ag tech and its role in

[90] For a comparative overview of terrestrial and wireless broadband, *see* "Future Proof: Economics of Rural Broadband – Comparing Terrestrial Technologies and Investment Considerations to Meet Increasing Consumer Broadband Demands," Vantage Point Solutions (2021) (https://www.ntca.org/sites/default/files/documents/2021-05/Future%20Proof%20--%20Economics%20of%20Rural%20Broadband%20FINAL_0.pdf) (visited Jun. 17, 2021).

[91] *See, generally,* "The Truth About Wireless Broadband," John Staurulakis, Inc., Monte R. Lee & Company, and Palmetto Engineering & Consulting (2011) (https://ccofkansas.com/resources/Documents/truthaboutwirelessbroadband.pdf) (visited Jun. 17, 2021).

[92] Saiz-Rubio, Rovira-Mas at 3.

maintaining U.S. global competitiveness, alongside sustaining economic inputs to the U.S. economy, will demand the deployment and ongoing development of robust, scalable fiber-supported wired and wireless broadband networks throughout rural and agricultural regions of the nation.

APPENDIX

This section shares examples of ag tech "in action" in areas served by small, locally operated rural broadband provider members of NTCA.

Bruce Telephone, Bruce, Miss. (pop. 2,250): The rural ISP provides symmetrical 100 Mbps via fiber to a 10,000-acre sweet potato farm. Working with farm staff, the company assists with technical needs to support systems that monitor temperature and humidity for production. The farm employs 50 year-round employees and an additional 500-600 seasonal employees and produces more than 900,000 bushels annually.

CTC Comcell Community, Scotland, Tex. (pop. 463): A fully robotic dairy relies upon broadband connectivity to control robots, monitors, fans, and soakers. Cattle are tagged for electronic tracking of movement, productivity, and temperature. Livestock data is transmitted overseas for analysis and then transmitted back to the farm. The dairy produces more than 2.9 million gallons of milk annually.

Green Hills Communications, Breckenridge, Mo. (pop. 3,000): A special fiber build connects a railway loading point that is accessible to farmers in north central Missouri and southern Iowa. Corn and grain are transported, stored, and delivered with advanced broadband-enabled logistics. Automated scanning and weighing systems allow an average load to be delivered in less than 10 minutes. The connected facility can load nearly 400,000 bushels into a 110-railcar train in less than eight hours.

Lynxx Networks, Camp Douglas, Wis. (pop. 500): A 60-year-old multi-generational dairy farm tracks livestock via monitor collars and tags. Broadband connectivity enables staff to pinpoint location, and maternity pen surveillance provides real time alerts to the office computer and mobile apps. Calf feeding is monitored and machines can be adjusted remotely to assure proper feeding and consumption.

Premier Communications, Sioux County, Iowa (pop. 9,000): In 2017, Sioux County was ranked 12th among U.S. counties for market value of agricultural products sold ($1.69 billion) (2017 Census of Agriculture, Country Profile, National Agricultural Statistics Service, USDA). Broadband-powered cameras enable producers to monitor livestock through live video feeds. At the same time, advanced alarm systems issue mobile and email alerts. Broadband-enabled sensors in feeding bins can measure and dispense the exact amount of feed. Broadband-enabled soil sensors monitor conditions and track rainfall, enabling farmers to calibrate planting and create a mapping database of crop harvest by the acre.

Tri-County Communications Cooperative, Merrillan, Wis. (pop. 600): Broadband-enabled monitoring systems and apps regulate temperature and irrigation systems at a 200-acre nursery. Greenhouse conditions are relayed to mobile phones and can be adjusted remotely, relieving staff of weekend travel to the farm to change environmental settings. Fiber-optic internet supports both backhaul mobile wireless facilities as well as wired infrastructure for business and operational functions.

About NTCA–The Rural Broadband Association: *NTCA–The Rural Broadband Association is the premier association representing approximately 850 independent, community-based telecommunications companies that are leading innovation in rural and small-town America. NTCA advocates on behalf of its members in the legislative and regulatory arenas, and it provides training and development; publications and industry events; and an array of employee benefit programs. In an era of exploding technology, deregulation, and marketplace competition, NTCA's members are leading the IP evolution for rural consumers, delivering technologies that make rural communities vibrant places in which to live and do business. Because of their efforts, rural America is fertile ground for innovation in agriculture, economic development and commerce, education, health care, government services, and public safety. Visit us at www.ntca.org.*

About Smart Rural Community: *Smart Rural Community*[SM] *is an initiative of NTCA–The Rural Broadband Association. Smart Rural Community comprises programming relating to and promoting rural broadband networks and their broadband-enabled applications that communities can leverage to foster innovative agricultural, economic development, education, health care, government services, public safety and other vital services. Smart Rural Community administers award and best practices programming as well educational resource through original research and white papers that investigate issues relating to rural broadband deployment, adoption and use. For information, please visit www.smartruralcommunity.org.*

About the Author: *Joshua Seidemann is vice president of policy of NTCA–The Rural Broadband Association. He focuses on Federal regulatory issues as well as technology and economic factors affecting the rural telecom industry. Seidemann holds a B.A. degree in Economics and Speech/Drama and a law degree from Yeshiva University. He is admitted to practice in New Jersey, New York and the District of Columbia and is certified corporate counsel in the Commonwealth of Virginia.*

Additional Smart Rural Community White Papers:

"Beyond Rural Walls: A Scholars' Conversation About Rural and Urban Spaces," Joshua Seidemann, Editor, NTCA–The Rural Broadband Association (2016).

Schadelbauer, Rick, "Anticipating Economic Returns of Rural Telehealth," NTCA–The Rural Broadband Association (2017).

Schadelbauer, Rick, "Conquering the Challenges of Broadband Adoption," NTCA–The Rural Broadband Association (2014).

Seidemann, Joshua, "Beyond Rural Walls: Identifying Impacts and Interdependencies Among Rural and Urban Spaces," NTCA–The Rural Broadband Association (2015).

Seidemann, Joshua, "Rural Broadband and the Next Generation of American Jobs," NTCA–The Rural Broadband Association (2019).

"Steel Sharpens Steel: A Conversation About Regional Thinking for Rural America," Joshua Seidemann, Editor, NTCA–The Rural Broadband Association (2017).

Ward, Jesse, "The Smart Rural Community," NTCA–The Rural Broadband Association (2012).

NTCA THE RURAL BROADBAND ASSOCIATION

4121 Wilson Boulevard, Suite 1000 • Arlington, VA 22203-1801
Phone/703-351-2000 • Fax/703-351-2001 • www.ntca.org