



International Food and Agribusiness Management Review
Volume 19 Issue A, 2016

The Role of Wireless Broadband Connectivity on ‘Big Data’ and the Agricultural Industry in the United States and Australia

Tyler B. Mark[ⓐ], Terry W. Griffin[ⓑ], and Brian E. Whitacre[ⓒ]

[ⓐ]*Assistant Professor, University of Kentucky, Agricultural Economics,
417 Charles E. Barnhart Bldg. Lexington, KY 40546-0276, USA*

[ⓑ]*Assistant Professor, Kansas State University, Agricultural Economics
342 Waters Hall, Manhattan, KS 66506, USA*

[ⓒ]*Associate Professor, Oklahoma State University, Agricultural Economics
504 Ag Hall, Stillwater, OK 74078, USA*

Abstract

Big Data has the potential to change the fabric of agriculture as we know it today; but only with wireless connectivity sufficient to employ telematics and other precision agricultural technologies. The primary focus of this paper is on data transfer, specifically as an enabling technology to precision agriculture. Limited wireless internet connectivity impedes the full utilization and effectiveness of precision agricultural practices and subsequent agricultural big data system. These failures lead to potential differentiation of farmland values; those fields with adequate wireless connectivity commanding a premium. In the absence of wireless data transfer for download and upload, precision agriculture technologies such as telematics cannot be utilized efficiently. Improving wireless connectivity is a primary driver of the adoption of big data. Increased connectivity could also intensify the adoption of precision agricultural technologies leading to input cost savings and decreased input usage.

Keywords: wireless, internet, rural broadband, telematics, precision, connectivity

[ⓐ]Corresponding author: Tel: + 1 859.257.7283

Email: T. B. Mark: Tyler.Mark@uky.edu

T. W. Griffin: twgriffin@ksu.edu

B. Whitacre: brian.whitacre@okstate.edu

Introduction

The United States and Australia are global leaders in food production and agricultural technology adoption. For the 2014/2015 crop years the United States and Australia combined to produce 19%, 22%, and 15% of the world's coarse grains, oilseeds, and cotton, respectively (USDA/FAS 2016). These countries are also significant adopters of precision agricultural technologies, especially Global Navigation Satellite System (GNSS but formerly referred to as Global Positioning Systems or GPS) enabled yield monitors and automated section control, to name a few, are now standard on new equipment. This is a result of the continuous innovation that takes place in the agricultural sector. Humans have advanced from being hunters and gatherers to the point where we are annually increasing the yields of primary commodities, such as corn, soybeans, wheat, cotton, etc. via improved genetics and production practices (Fischer and Edmeades 2010). The increases seen in crop yields is a function of technology adoption starting with improved management of these crops, the adoption of precision agriculture technologies, and genetic modification (Evenson and Gollin 2003). To keep up with population growth it is expected that food production must double between 2014 and 2050 (FAO 2009). To accomplish this, production agriculture will have to continue efficiency improvements with respect to practices and inputs in order to optimize output per acre and limit the negative externalities created through production intensification. Success will depend on efficiently and effectively converting vast amounts of data that are generated into information and subsequently knowledge to make real-time decisions and justify the utilization of inputs.

Big Data has the potential to change the fabric of agriculture as we know it today. *Big Data* is data whose size, scale, and unstructured nature require the usage of new analytical tools and frameworks to be developed and employed (Sonka 2014). These frameworks need to be flexible enough to weave together data from millions of acres and from various sources, such as weather data, yield data, satellite imagery, small unmanned aerial systems (sUAS) imagery, planting prescriptions, and equipment diagnostics just to name a few. If this can be done, it has the potential to be the next agricultural revolution of smart products utilizing precision application of inputs, yield monitors, and other site-specific sensors, analogous to how smartphones changed popular culture, to a point where the system can be evaluated as a whole. However, this revolution requires a new or at least different mindset compared to the way most agricultural producers are operating today (Griffin et al. 2016). Many producers today are rightfully only focusing on their own operation and have reservations regarding several key questions including but not limited to:

- Data ownership: producer vs manufacturer vs landowner vs retailer;
- Data utilization, privacy, storage, and security: data access, utilization, sharing;
- Data value;
- Data transfer.

Each of these stated issues are substantial barriers to the technology (Ferrell 2016; Stubbs 2016); however, the primary focus of this paper is on the last topic, data transfer, specifically as an enabling technology to precision agriculture. This paper proceeds assuming data ownership, utilization, valuation, and especially data privacy have been satiated at least in the short run. Limited wireless internet connectivity impedes the full utilization and effectiveness of precision agricultural practices and the subsequent agricultural big data systems. In simplest terms, wireless connectivity is an enabling technology for precision agriculture; and lends itself to be the next infrastructure that may limit the usefulness of agricultural

technology. In the absence of wireless data transfer for download and upload, precision agriculture technologies such as telematics cannot be fully utilized. Whitacre et al. (2014) borrow their definition of telematics from Heacox (2008) as “transmitting of data through wireless communication links between the home base and field units”, however, an industry standard definition is likely to be offered by AgGateway as “the transmission and receiving of data over long distance communication links” (AgGateway 2016).¹ Wireless transmission of agricultural data, i.e. telematics, is seen as a necessary condition for the maturation of big data capabilities in agriculture. Telematics not only requires adequate wireless internet connectivity bandwidth, but this connectivity is required in non-residential areas where cellular services have not been offered at the same performance level as urban areas (Whitacre et al. 2014). Without sufficient internet connectivity, the transfer of agricultural data remains possible although with additional caveats.

According to Erickson and Widmar (2015), one of the most notable changes over the last three surveys of agricultural service providers is the usage of telematics for field-to-home office communications. In 2011, only 7% of service providers offered telematics data services but the percentage increased to 15% by 2013, and to 20% in 2015. There were slightly more dealerships offering telematics in the Midwestern US (17%) than in other states (12%) in 2013, potentially due to the lack of broadband connectivity outside the Midwest (Whitacre et al. 2014). In addition, the common wireless carriers utilized by the leading equipment manufacturers have a larger presence in rural areas of the Midwestern US than they do in other regions. Holland et al. (2013) reported that two-thirds of service providers stated telematics are perceived to be an emerging technology with 30% suggesting an uncertain future and 37% suggesting a promising future; indicating uncertainty with respect to the future of the technology among service providers (Whitacre et al. 2014). Until wireless internet is sufficient to transfer agricultural data, the impedance of telematics and precision agriculture are likely to capitalize into substantial farmland value differences for internet-connected and internet-deficit fields (Griffin et al. 2016). Griffin et al. (2016) describe scenarios where the absence of biophysical and geo-spatial site-specific data could result in penalties during farmland sales or rental auctions. They also describe how farmers are not expected to pay similar rental rates for farmland without adequate wireless connectivity *ceteris paribus*. In part, it is the wireless connectivity that empowers farmers to securely archive the biophysical geospatial data in the former example.

The realization of the *Big Data's* full value will not happen until the wireless connectivity barrier is overcome. Expanding upon Whitacre et al. (2014) we have two objectives. First, given the new broadband definition for the United States, we explore the wireless coverage for the United States and Australia similar to Whitacre et al. (2014). We focus on examining broadband availability for crop production regions. These high-production broad acre areas are also the areas where precision agriculture adoption rates are expected to be the highest and where telematics most likely to be employed; therefore where the value of big data is initially expected to be fully realized. It should also be noted that some high value crops utilize various aspects of precision agriculture. For example, viticulture is a classic example of a high value crop that utilizes precision agriculture, especially yield monitors, irrigation, and other monitoring sensors (Bramley and Proffitt 1999; Bramley 2001; Bramley et al. 2003, 2005). However, without adequate access to wireless internet, the development of a big data system will lag behind potential development. Additionally, insufficient connectivity could

¹ AgGateway AgGlossary. Telemetry - The transmission and receiving of data over long distance communication links. <http://agglossary.org>.

limit the value of a big data system if the technologies used to populate the system are inefficient in data transfer.

Status of Broadband Connectivity in US and Australia

Broadband connectivity across the globe but specifically within the United States and Australia will have a significant impact on both big data utilization and on the agricultural industry at large. In the absence of broadband connectivity and wireless data transfer, the benefits of big data and telematics services are limited. In general the industry is experiencing effects related to network externalities. In addition to constraining the profitability of agricultural firms; lack of broadband connectivity limits the adoption and efficiency of precision agricultural technologies that make use of or rely upon near real time connectivity. Additionally, these precision agriculture technologies are the primary data collection methods populating this big data system.

In the United States, the National Broadband Map (NBM) provides data on wireless availability over a range of broadband speeds. Superimposing these data on top of publicly available crop production data from the United States Department of Agriculture (USDA) illustrates the need for increased wireless connectivity in nonresidential areas. Using analogous data from Australia including Australian Government Department of Communications and Australian Bureau of Statistics we compare and contrast these two nations known to be leaders in production agriculture and technology utilization.

Current Status of Broadband in US

The United States Federal Communications Commission (FCC) updated the definition of broadband in January 2015. The faster speeds required to be considered broadband brought light to connectivity barriers, especially with respect to broadband connectivity gaps in specific geographic areas such as agricultural production regions. Specifically, the 25 megabit per sec (Mbps) download speed requirement negates the majority of United States wireless connections from being classified as broadband. Figure 1 shows the discrepancy between the download and upload speeds required by the FCC to be considered broadband.

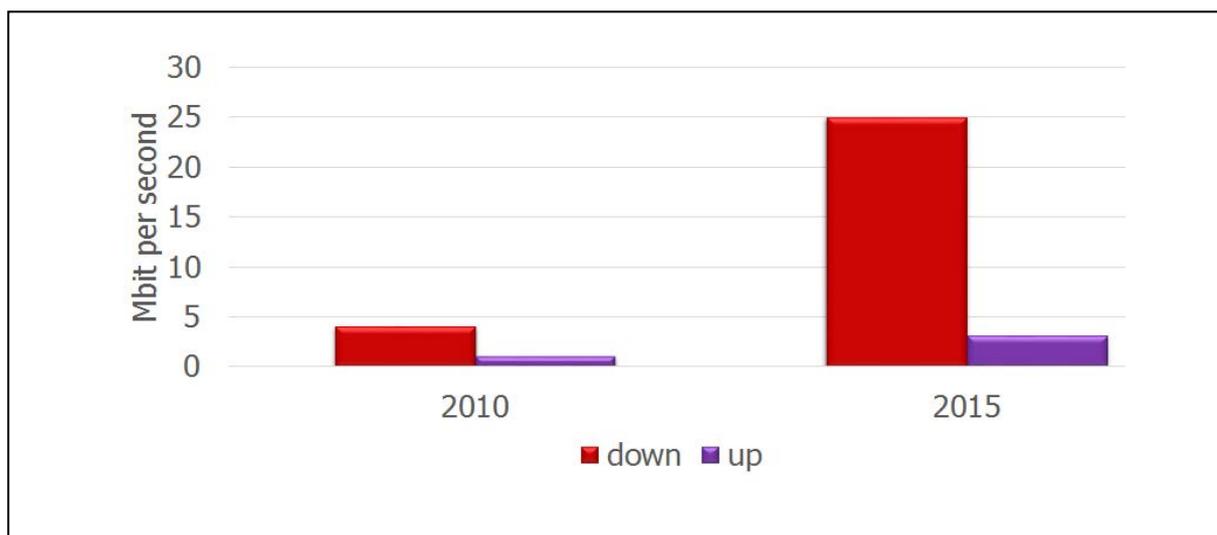


Figure 1. US FCC-defined broadband speeds

Recently passed state-level legislation, such as Iowa’s “Connect Every Acre” bill that was signed into law in June 2015, demonstrates the recognition of this topic by today’s policy makers. In addition, recent congressional hearings on internet connectivity in general and another specifically on big data in agriculture both discussed the ramifications of internet on agriculture (see Ferrell (2015), testimony to U.S. House of Representatives). Many producers currently employing precision agriculture technologies do not have access to broadband speed wireless internet. Figure 2 shows the relationship between corn and wheat production and download speeds. The dark black blocks represent areas where greater than 75% of the population meets the 25 mbps download requirements and the majority of these blocks are located in close proximity to major cities and not prime agricultural areas.

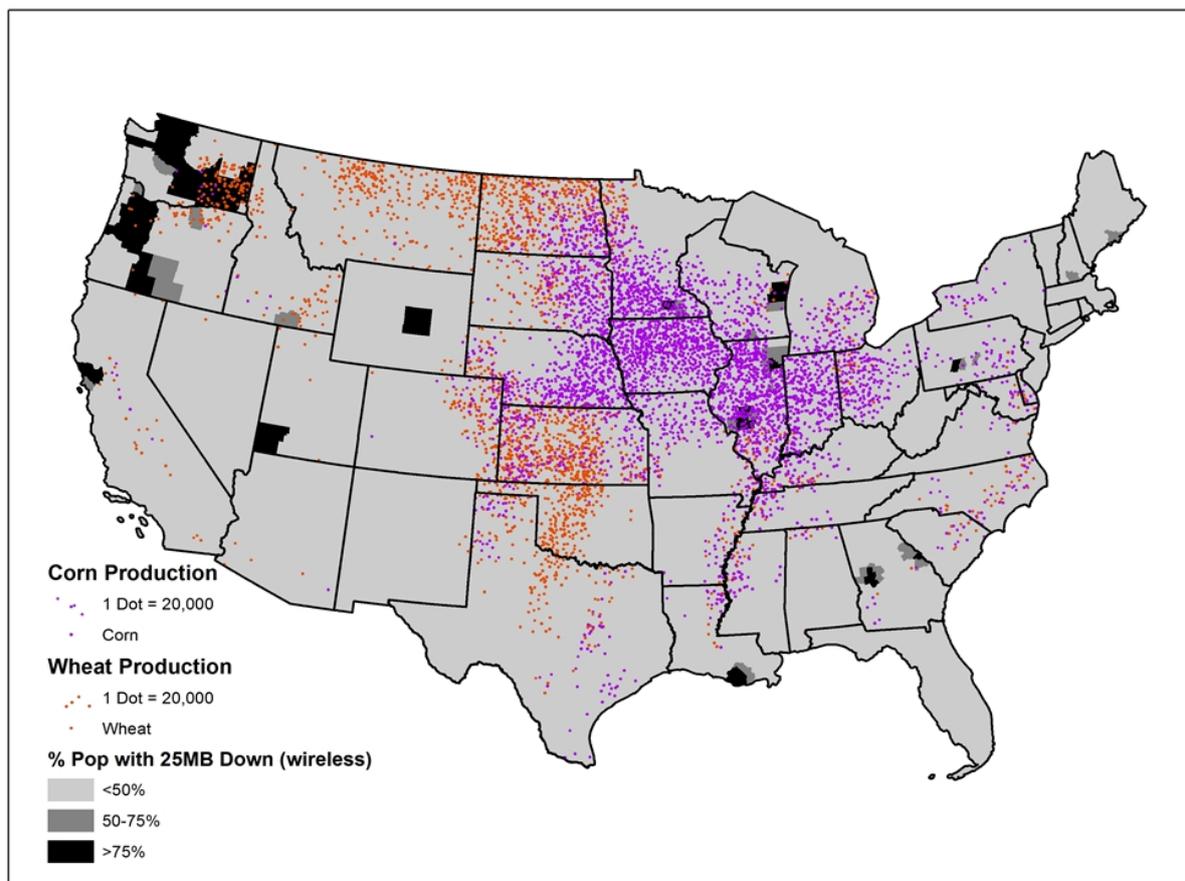


Figure 2. Wireless download availability for corn and wheat production, 2015.

Figure 3 shows the relationship between corn and wheat production and upload speed broadband speed requirements. The low hurdle of 3 mbps results in significant parts of the country achieving the hurdle to be considered broadband. Shearer (2014) points out that most precision agriculture data needs to be uploaded rather than downloaded; and given that upload speeds are substantially slower than download speeds, moving data such that real-time decisions can be problematic. For some types of data such as machine diagnostics, planting prescriptions, and the like the current speeds offered are probably adequate. However, yield data and specifically imagery data may require connectivity speeds in excess of what the industry currently offers. More importantly, these connectivity requirements may not be a cost effective method of data transfer, given labor and connectivity costs.

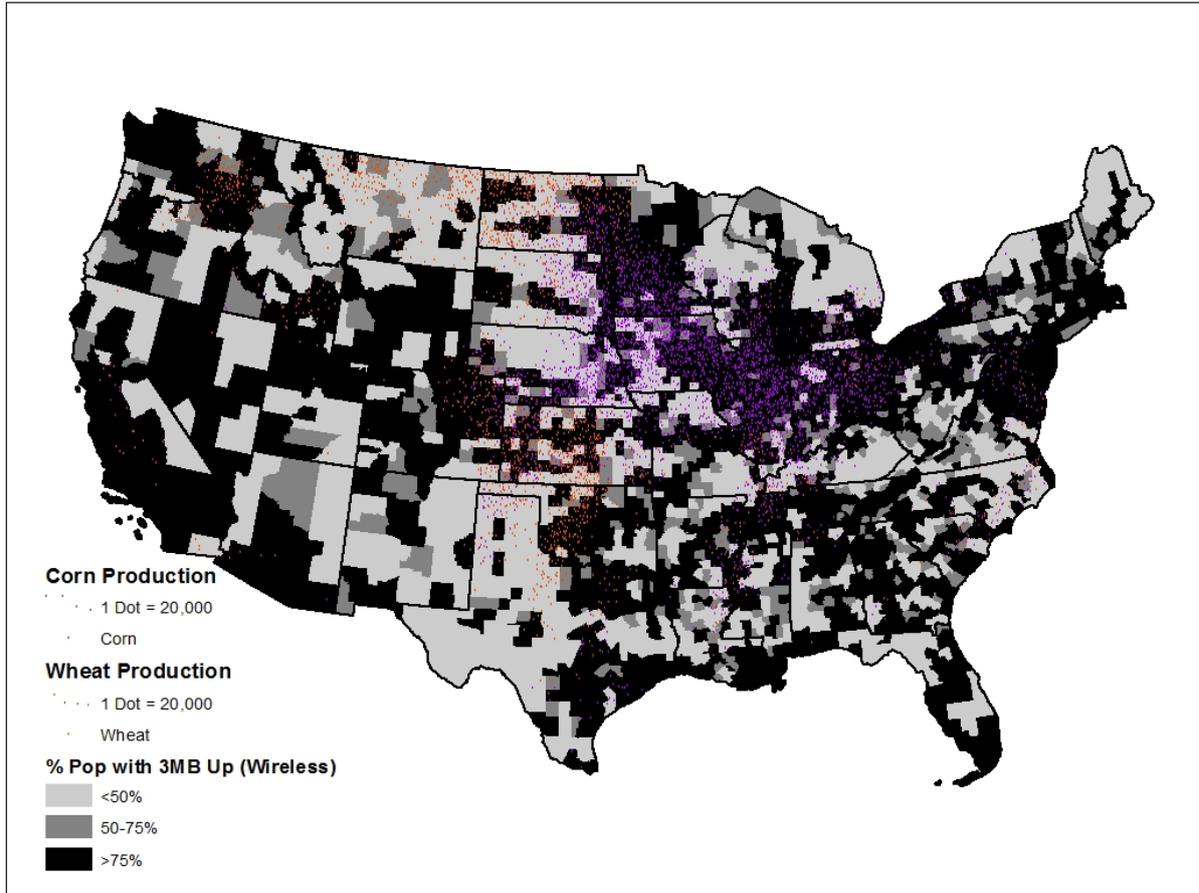


Figure 3. Wireless upload availability for corn and wheat production, 2015.

Current Status of Broadband in Australia

Similar to the United States, there are multiple mobile network providers in Australia. Existing coverage providers include Telstra, Optus, Vodafone, and National Broadband Network (NBN). The priority of these providers was initially voice coverage rather than data coverage especially in rural crop producing areas, just as in the United States. As an example Telstra (the largest Australian coverage provider) coverage areas is mapped in Figure 4. As expected, the cellular coverage area mirrors that of the residential population areas. A primary difference between the United States and Australia is that the Australian government provides internet infrastructure for resale by retailers. Australia’s NBN is a government owned wholesale provider of high speed coverage that sells via retail service providers. The NBN provides coverage through fiber optics, fixed wireless, and satellite.²

² see <http://www.nbnco.com.au/> for more detail on NBN

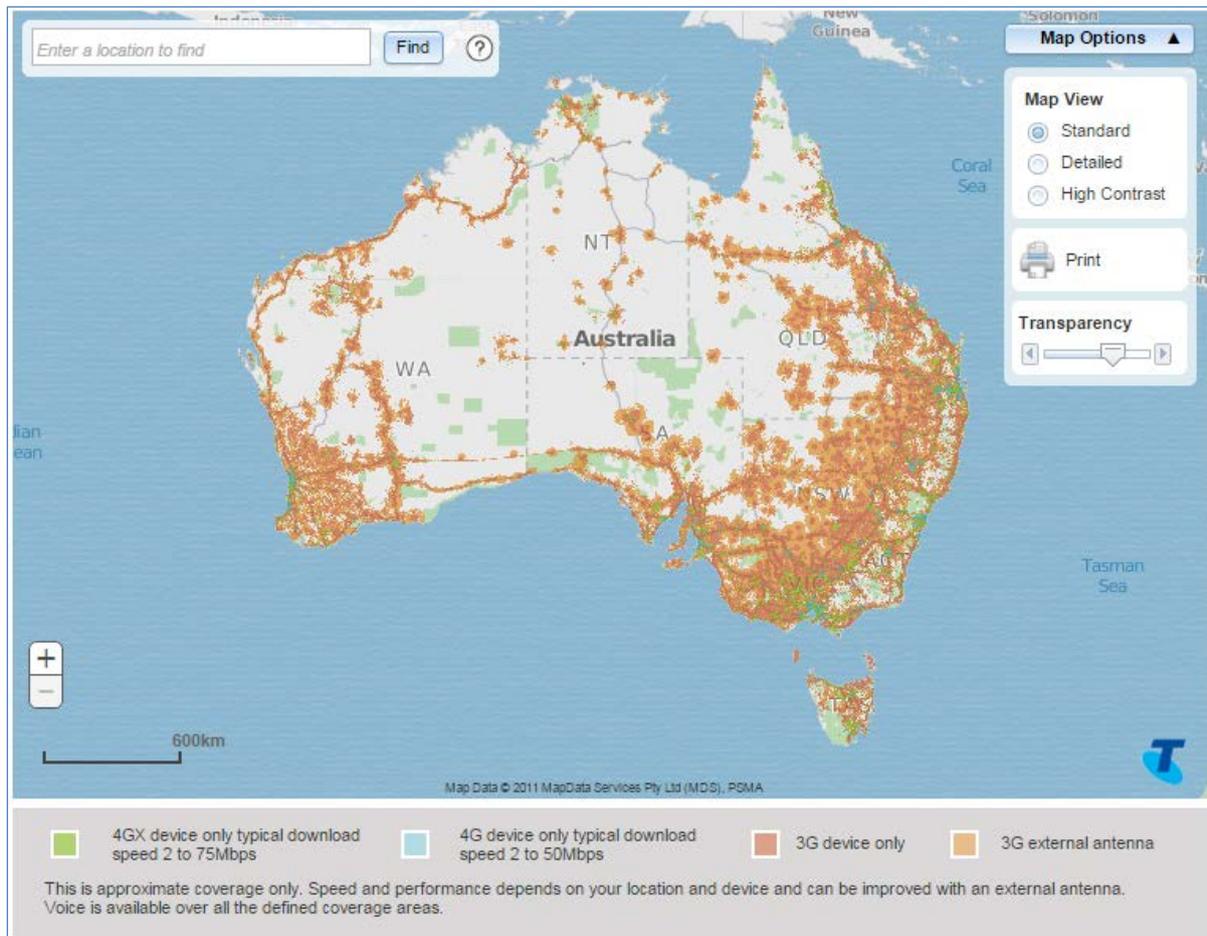


Figure 4. Wireless cellular coverage area from Telstra (the largest coverage provider in Australia).

Source. <https://www.telstra.com.au/coverage-networks/our-coverage>

The land use across Australia is presented in Figure 5. Similar to the United States, there are areas that are neither populated or cultivated. The areas of interest are the cultivated areas that have low population and therefore minimal if any wireless internet connectivity. For instance, the areas signified by the yellow, orange, and gold colors are agricultural production areas where *Big Data* are most likely to be adopted due to precision agricultural practices. The red and grey areas indicate urban and rural residential areas, respectively, to emphasize the relative location of populous and agricultural production.

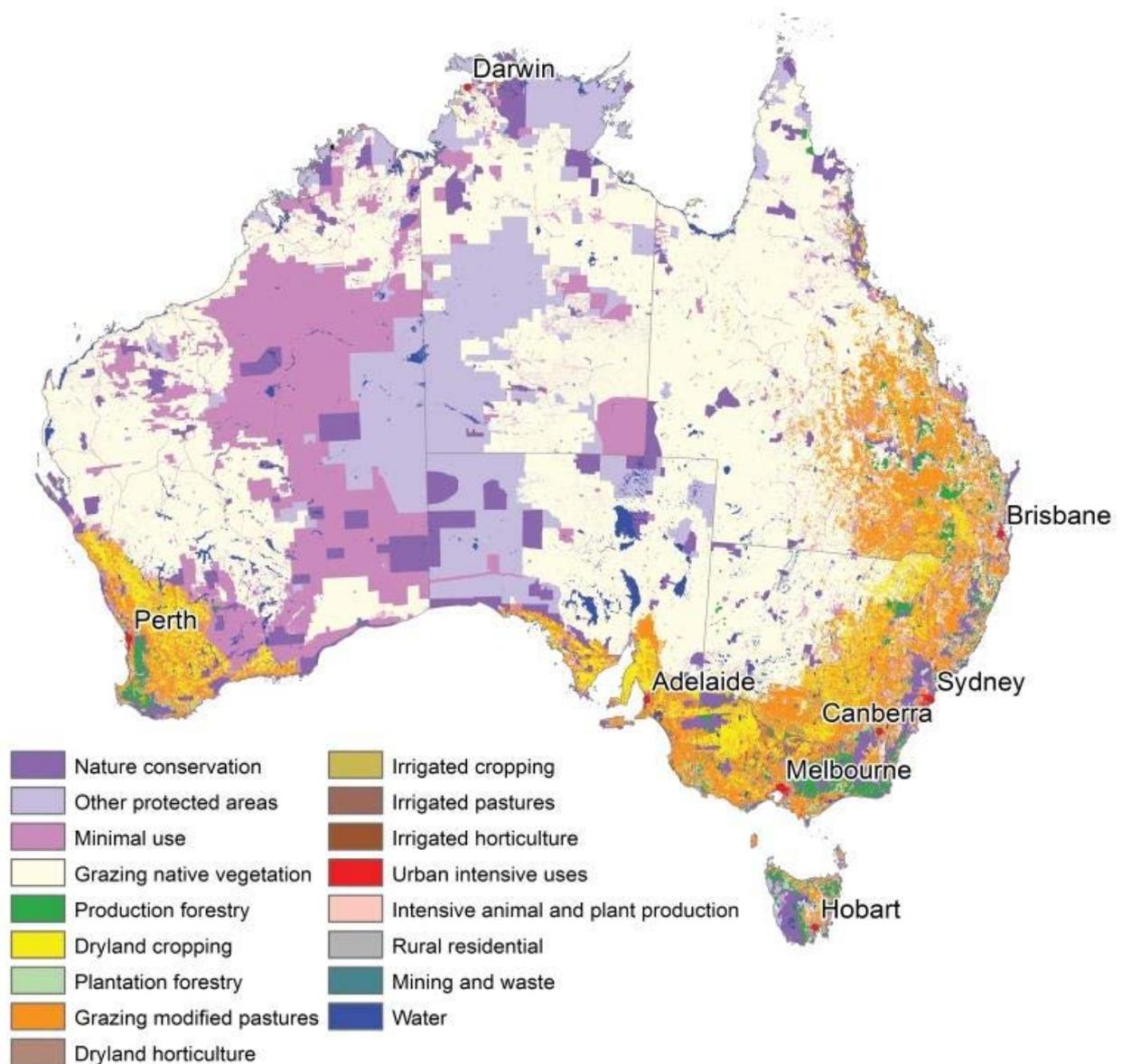


Figure 5. Land use in Australia, 2005-2006.

Source. Australian Government Department of Foreign Affairs and Trade

Rest of World and Global Initiatives

The US and Australia are not unique across the globe in providing high speed internet. In Germany, the government is pushing a 50 Mbps target up from the existing threshold of 11 Mbps for all users (Woods 2015). This doubles the currently highest global average speed of South Korea of 24 Mbps (Woods 2015). Wireless internet providers have only started to provide wireless connectivity sufficient to move data from crop producing regions far from residential areas. These providers have been encouraged and supported by the efforts of Google and Facebook to connect the world’s population. Facebook has been reported to evaluate drones (Lee 2015), satellites, and high-altitude balloons (Patterson 2015) for providing internet access in developing regions. Google has similar goals; to make internet connectivity ubiquitous for every global citizen.

To this point this study has focused on two heavily developed countries. However, this is not to say that information gleaned from the adoption of telematics and big data analytics cannot be transferred to developing countries. First, most likely the types of technologies that Facebook and Google are developing will be needed for developing countries who lack the capital to build the infrastructure needed for increased connection speeds. This could even be said for some part of the United States. In the meantime, as we start to populate and gain a deeper understanding of the agricultural systems both farmers in developing countries and small farms in developed countries will benefit. Historically, precision agricultural technologies have had economies of scale barriers to entry. With the introduction of big data farmers in developing countries and small farmers will have the opportunities to benefit from the findings. We suspect that the gains from farmers in developing countries and small farmers will be relatively greater than those who are already utilizing precision agricultural technologies. This would simply be a function of now being able to make better management decisions with the newly acquired information.

Data Transmission Needs

Current forms of data transmission (i.e. cellular, wireless, and satellite) are lagging behind the needs of production agriculture (Griffin and Mark 2014). CoBank (2016) just released an infrastructure briefing where they interviewed producers about their data usage and needs. They found that during peak harvest large producers can utilize 30 plus gigabytes of data per month. This is more than double what they were using three years ago and the need is only growing. There has been a significant push to increase availability of broadband internet connectivity in rural areas, where the majority of agricultural production takes place. This has been a very slow process that is not keeping pace with demand to the point that connectivity is a barrier to the full utilization of current precision agriculture technologies or at least the internet is seen as an enabling technology. Cellular and hard-wired providers have not been incentivized to expand their services in rural areas due to the lack of sufficient voice service customers needed to justify the investment. However, satellite based internet connectivity could provide an effective solution over larger geographic areas. However, one of the downsides to satellites is the signal can be interrupted and that can cause issues with applications, such as John Deere Machine Sync, that require uninterrupted connectivity to function properly (John Deere 2015)

The typical setup for producers today involves utilizing cellular connectivity to transfer data or the *status quo* of manually transferring data. Current 4G cellular connections only allow up to a 10 Mbps download speed, and upload speeds that range from 2 to 5 Mbps. Historically, differences between upload and download speeds were several magnitudes different due to residential uses relied more on download than upload. This is evident if one considers watching streaming video via Netflix, i.e. downloaded data; however more recent phenomena such as uploading 'selfies' to Facebook require relatively more upload. This has increased wireless providers desire to improve upload speeds. Anecdotal evidence suggests wireless connectivity has a 2:1 ratio of download to upload speeds in the US (Speedtest 2016). Increasing the upload speed would provide the agriculture sector with a much needed boost in capacity.

Little information actually exists or is not publically available on file size by type. Additionally, precision agriculture provider has proprietary software used to package and move the data. However, Shearer (2014) estimated that row crop producers potentially

generate 0.5 kilobytes of data per plant. In other words, a corn producer with a plant population of 30,000 seeds per acre could produce 15 megabytes of data per acre each year; and if this were a 1,000 acre corn farm, they could potentially produce 15 gigabytes of data per year that would need to be transferred. Extrapolating this out to the approximately 88.9 million acres of corn planted in 2015 there would be approximately 1,333.5 terabytes of data produced. This estimate does not include the usage of drone or UAV imagery data that is increasing in popularity in agriculture; the reliance on imagery from drones greatly increase these data transfer requirements. The amount of data generated from drones will depend on the type, frequency, and quality of images that are being taken (Buschermohle 2014). Recently commercialized technology allows multiple automated section control (ASC) enabled vehicles to share a coverage map so that each vehicle is instructed to turn application on or off to prevent over application or gaps. Bennett (2016) reports economic implications of shared coverage map technology and how satellite ping rates are not sufficient; suggesting that cellular connectivity is the only viable option for coverage map sharing.

A key for most producers will be deciding which data layers will require real-time transfer and analysis. Data layers that might require real-time transfer are yield data and equipment diagnostics. However, some data layers could be wirelessly transferred after the fact once a connection is achieved. Furthermore, without sufficient wireless data transfer service, producers rely on manual data transfer which may not happen until after the season is over and furthermore cause suspicion with third parties. Many third-parties require data in real time from the sensor-based equipment to prevent data from being corrupted either intentionally or unintentionally. By the time data are manually moved to the analytics, opportunities to adjust management practices are missed, significantly affecting farm profitability, productivity, and environmental impact. In addition, real-time communication between farm equipment and online servers is not possible. Finally, land that lacks adequate connectivity leads to geospatial data not being sufficiently backed-up in a timely manner, therefore increasing the risk of this valuable data being lost, destroyed, or otherwise not used.

Discussion

These findings suggest that opportunities exist for the private and/or public sectors to increase wireless connectivity infrastructure. This could be in the form of improved satellites, increased wireless cellular infrastructure, or high altitude balloons. The primary criteria for their usage will be upload capacity and reliability. Improving wireless connectivity could be one of the primary drivers of the adoption of big data, or at least not to impede adoption. The increase in connectivity could also increase the adoption of precision agricultural technologies that can lead to input cost savings and decreased input usage. Without adequate connectivity to allow efficient and cost effective data transfer, the value of the big data system will be limited for both direct and indirect users, such as producers and consumers, respectively. In the U.S., internet service providers, especially wireless providers, are all private sector firms as opposed to Australia where the federal government provides basic internet infrastructure for resale.

These results are of interest to public policy makers, environmental groups, private sector satellite internet service providers, and members of the agricultural industry including farmers, equipment manufacturers, and software companies. Quantifying the magnitude of the problem and providing guidance toward a feasible solution will aide in maintaining a sustainable production agriculture industry now and for years to come.

Moving Forward

It is expected that over the next five years there will be an increased desire and demand for producers to collect and analyze data in an effort to increase the efficiency of their operation. This will be even more important during time periods of low commodity prices and increased scrutiny over chemical and nutrient usage. If producers are able to track and verify usage of these inputs, it could help minimize perceived environmental impacts and legal costs for producers. Wireless data transfer technologies including satellite, cellular, hard-wired, and potential balloon based systems are suitable candidates to fill the connectivity void and all need to be explored. All of these technologies have the potential to be used for agricultural data transfer but none are universally perfect for the task. However, specific characteristics are sought to move forward with the increased data collection requirements within the agriculture sector. The first and most important characteristic is reliable access. As seen in Figure 2 and Figure 3 there are significant gaps in current broadband offerings and most of these voids exist in prime agricultural areas. Currently, upload and download speeds are a significant bottleneck for farmers depending on the file type and size, in terms of receiving real-time feedback. This does not mean that internet connectivity is required for planting or harvest. However, if the upload or download speeds are too slow, field efficiency can be decreased and in turn decrease the number of acres covered in a given day. This can be especially true in fields that are running multiple units and are requiring them to communicate in real time where the other unit has been in the field. During planting season slow internet speeds can mean the difference in getting the crop in before a weather event or suffering yield penalties for an untimely planting, thus translating into potentially decreased income for the operation. There have been substantial pushes by state governments to increase broadband access to help increase business development in rural areas. However, the expansion of broadband access has been very slow and is not keeping pace with the demands of the industry.

References

- Australian Government Department of Foreign Affairs and Trade. Land Use in Australia, 2005–2006. <https://www.telstra.com.au/broadband/nbn/nbn-rollout> [accessed Feb. 2016].
- Bennett, J.D. 2016. Value Of Map Sharing Between Multiple Vehicles In The Same Field While Using Automated Section Control. MAB Thesis, Manhattan, KS, Kansas State University.
- Bramley, R.G.V. and A.P.B. Proffitt. 1999. Managing variability in viticulture production. *Grapegrower and Winemaker* 427: 11–16.
- Bramley, R.G.V. 2001. Progress in the development of precision viticulture – variation in yield, quality and soil properties in contrasting Australian vineyards. In *Precision Tools for Improving Land Management*, edited by L.D. Currie and P. Loganathan, 25-43. Occasional report No. 14. Fertilizer and Lime Research Centre, Massey University, Palmerston North.
- Bramley, R., B. Pearse and P. Chamberlain. 2003. Being profitable precisely – a case study of precision viticulture from Margaret River. *Australian Grapegrower and Winemaker*. (473a):84–87.

- Bramley, R.G.V., A.P.B. Proffitt, C.J. Hinze, B. Pearse, and R.P. Hamilton. 2005. Generating benefits from precision viticulture through selective harvesting. In *Proceedings of the 5th European Conference on Precision Agriculture*, edited by J.V. Stafford, 891–898. Wageningen Academic Publishers, The Netherlands.
- Buschermohle, M. 2014. Enhancing the Value of Precision Ag Data with Unmanned Aerial Systems. Paper presented at 2014 Crop Management Seminar. November. <http://www.plantmanagementnetwork.org/edcenter/seminars/2014CottonIncCropMgtSeminar/>.
- CoBANK. 2016. Farmers Harvest Gigabytes with Broadband and Wireless Technologies. *Rural Infrastructure Briefings*. March. <http://www.cobank.com/Knowledge-Exchange/Research-Reports.aspx> [accessed March 17, 2016].
- Erickson, B., and D.A. Widmar. 2015. Precision Agricultural Services Dealership Survey Results. <https://www.agecon.purdue.edu/cab/ArticlesDatabase/articles/2013PrecisionAgSurvey.pdf> [accessed May 25, 2016].
- Evenson, R.E. and D. Gollin. 2003. Assessing the impact of the green revolution, 1960-2000. *Science*. 300:758-762. DOI: 10.1126/science.1078710.
- Food and Agricultural Organization (FAO). 2009. FAO's Director-General on how to feed the world in 2050. *Population and Development Review*. 4(35):837-839.
- Ferrell, S.L. 2015. Testimony to U.S. House of Representatives Big Data and Agriculture: Innovations and Implications. http://agriculture.house.gov/uploadedfiles/10.28.15_ferrell_testimony.pdf [accessed May 25, 2016].
- Ferrell, S.L. 2016. Forthcoming. Legal Issues on the Farm Data Frontier, Part I: Managing First-Degree Relationships in Farm Data Transfers. *Drake Journal of Agricultural Law*. 20(1): Spring.
- Fischer, R.A. and G.O. Edmeades. 2010. Breeding and Cereal Yield Progress. *Crop Science* 50:S85-S98. DOI: 10.2135/cropsci2009.10.0564.
- Griffin, T.W. and T.B. Mark. 2014. Value of Connectivity in Rural Areas: Case of Precision Agriculture Data. Paper presented at International Conference on Precision Agriculture. July. Sacramento, CA.
- Griffin, T.W., T.B. Mark, S. Ferrell, T. Janzen, G. Ibendahl, J.D. Bennett, and J.L. Maurer. 2016. Big Data Considerations for Rural Property Professionals. *Journal of the American Society of Farm Managers and Rural Appraisers*. 167-180
- Heacox, L. 2008. Time for Telematics. *CropLife*. Sept. 10. <http://www.croplife.com/equipment/precision-ag/time-for-telematics/>.
- Holland, J.K., Erickson, B., and D.A. Widmar. 2013. Precision Agricultural Services Dealership Survey Results. <http://agribusiness.purdue.edu/files/resources/rs-11-2013-holland-erickson-widmar-d-croplife.pdf> [accessed May 25, 2016]

- John Deere. 2015. Satellite Module Theory of Operation. http://manuals.deere.com/omview/OMPFP14775_19/AE77568,0000024_19_20150303.html [accessed March 9, 2016]
- Kelly, H. 2014. Facebook looks to drones, lasers and satellites for Internet access. <http://www.cnn.com/2014/03/27/tech/innovation/facebook-drones-lasers-connectivity/> March 28, 2014.
- Lee, D. Facebook builds drone for internet access. <http://www.bbc.com/news/technology-33728704>. [accessed May 25, 2016]
- Patterson, Thom. 2015. Google, Facebook, SpaceX, One Web plan to beam Internet everywhere. <http://www.cnn.com/2015/10/30/tech/pioneers-google-facebook-spacex-oneweb-satellite-drone-balloon-internet/> [accessed May 25, 2016].
- Shearer, S.A. 2014. Big Data: The Future of Precision Agriculture. Presented at The InfoAg Conference. St. Louis, MO, June. http://past.infoag.org/abstract_papers/papers/paper_233.pdf
- Sonka, S. 2014. Big Data and the Ag Sector: More than Lots of Numbers. *International Food and Agribusiness Management Review* 17(1): 1–20.
- Speedtest. 2016. Americas Fastest ISPs and Mobile Networks 2015. <http://www.speedtest.net/awards/us>. [accessed May 26, 2016].
- Stubbs, M. 2016. Big Data in U.S. Agriculture. Congressional Research Service. 7–5700 R44331. <http://www.fas.org/sgp/crs/misc/R44331.pdf> [accessed February 28, 2016]
- U.S. Department of Agriculture, Foreign Agricultural Service. 2016. *Production, Supply and Distribution*. USDA/FAS. Reports: Field Crop-Production.
- Whitacre, B.E., T.B. Mark, and T.W. Griffin. 2014. How Connected are Our Farms? *Choices* 29(3). www.choicesmagazine.org/UserFiles/file/cmsarticle_392.pdf.
- Woods, B. 2015. Germany promises 50Mbps broadband for all, 10 times faster than global average speeds. <http://thenextweb.com/eu/2015/09/08/germany-promises-50mbps-broadband-for-all-10-times-faster-than-global-average-speeds/>. [accessed October 15, 2015].

