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Digital Agriculture Infrastructure in the USA and Germany †

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Abstract: The USA and Germany have compared the issues that surround the adoption of digital technology on the farm that will foster more environmentally sustainable food production/processing systems. Both countries lack robust broadband internet pathways to foster the adoption of these technologies. The problem is currently relevant to making this data technology available on every farm and field. The implementation of this infrastructure is even more important as society demands more and more information on the product and production process of agriculture and industry.

Keywords: data availability; rural regions; smart farming

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1. Introduction

Agriculture worldwide is undergoing a transformation process toward the integration of digital process and production chains. The development of the necessary infrastructure for data transmission will be compared and analyzed using the examples of Germany and the USA (Corn Belt). The current development of smart farming is also strongly characterized by the fact that data and information can be easily shared between different partners. This can be control data for fully autonomous tractors, results from in situ sensors in the field, application rates for implements derived from satellite data, or the transmission of production data to trading partners.

The fact that data is collected directly on the working machine and processed there, and the information is converted directly into decisions is less and less the case, due to increasing complexities and amounts of data, on the one hand, and the need for third-party information and complex algorithms for decision making, on the other hand. Data is increasingly being collected at different points and times, blended with existing data, processed by different parties, then forwarded as information to different points for later analysis. To enable this development, the infrastructure for data transmission plays a crucial role.

2. Materials and Methods

In this study, we focus on three subareas of this infrastructure network. The first part is between the cloud and the farm. The second subarea is data transmission between farm and field/tractor. Here the discussion is between data rate, range, penetration, cost, and energy demand of different transmission technologies. Low-power, wide-area network (LPWAN) systems (e.g., LoRa, mioty, Sigfox, etc.) are on the rise. They combine low-power and low data rates with high range, therefore making them effective for many use cases of stationary sensor deployment in agriculture. A third category blends in between the mentioned technologies. In the US, these transmission technologies (e.g., TV whitespace) are suitable to build a bridge/backbone between regional locations of a farming operation. With medium data rates and very high ranges, they are suitable to connect LPWAN-based wireless sensor networks from remote locations to an internet backbone on a farmer's home base. Streaming technologies, such as what is used by Netflix, are being adopted in the USA by some precision agriculture vendors, but many farmers in the USA gather data via an iPad while in the field and upload this data after they return to their home office.

3. Digital Agriculture Infrastructure

3.1. USA

The deployment and adoption of digital technology by agriproducers is expected to enhance food production in the USA as in other parts of the world to meet the increasing population of the world with more than 9.5 billion people by 2050. Digital devices and sensors, such as satellite remote sensing, UAV imaging systems, Internet of Things (IoT) sensing systems, and ground-based robotic systems, are rapidly becoming more common in agriculture for collecting high-resolution temporal and spatial big data of crops, animals, environment, and farm equipment. With the advance of big data analytic technologies and artificial intelligence, digital data are able to be used to monitor production, improve efficiency, and increase agricultural sustainability. In addition, these advanced systems allow farms to be more profitable, efficient, safe, and environmentally friendly, conserving our natural resources.

To successfully adopt and implement these advancements, wireless connectivity is an enabling technology. However, the wireless network infrastructure for data transfer in agriculture is still lacking. We feel that there are three layers of networks that need consideration in the US: (i) backbone connectivity ("to the internet"), (ii) regional network infrastructure (wireless transfer of data from the farm to the nearest backbone, e.g., TV whitespace, private 4G LTE, or cellular hotspot), and (iii) local sensor networks (e.g., low-power, wide-area networks or LPWANs) for collection of sensor/machine data.

Companies, such as Farmobile, The Climate Corporation, Trimble, Farmers Edge, Ag Leader, and John Deere, are establishing proprietary networks, some with the assistance of companies, such as Trilogy, a company that advocates the use of a private 4G LTE network on the farm. Why 4G? Data would be more secure and faster, since a private 4G LTE network does not use the more traditional cell phone network. Data is collected directly via the CAN bus on the tractor, combine, or sprayer. Data transfer to the cloud varies as The Climate Corporation (Bayer) first transfers that data from the CAN bus via Bluetooth to the iPad. The iPad later connects to the Internet via Wi-Fi, and the data is transferred to The Climate Corporation cloud. Farmobile uses traditional cell phone networks (when available) to immediately transfer the data to the Farmobile cloud.

Data analysis is more efficient via artificial intelligence systems after being placed on cloud-based servers. Companies have also adopted data transfer systems similar to those used by Netflix and Hulu (for TV viewing). Why are multiple and different data transfer systems used and not a single common system? Because 80% of the 24 million American households do not have reliable, affordable, high-speed broadband in the rural areas (Federal Communications Commission's report). Digital technology and understanding this data will change the way the American farmer works; however, the USDA [1] recently noted that digital row crop technology is being adopted, yet the livestock and special crop production remains at the early innovator stages. According to the same article, "90 percent of the people do nothing with the data that they collect. They don't know what to do with it." It seems we have two challenges: (i) the USA needs an agricultural workforce that understands the best use of digital technologies, and (ii) as stated earlier, there is a lack of Internet access in rural communities. According to the Leichtman Research Group [2], broadband is penetrating the USA home in many cities. However, this is not the case for rural areas in US.

3.2. Germany

Citizens in Germany and Europe are increasingly demanding information on the product and process quality of their food. Smart farming is one way to satisfy these demands [3]. Data exchange is necessary for this. In Germany, the data rate between the farm and the Internet cloud is strongly influenced by the transmission technology. Germany is relatively densely populated and therefore has a historically good network infrastructure based on copper cables. In the meantime, however, significant problems can be observed with the upgrade to fiber-optic networks. The expansion rate is only 4.7% and is mostly limited to the conurbations [4]. In rural areas, the network infrastructure is therefore only weakly developed. The data rate for downloads in landline networks at the district level is relatively low, especially in rural areas. The median for the worst-served areas is 15.5 Mbps. Most rural areas are in the 35–55 Mbps range, but with sometimes large differences between providers. The available data download in the landline network is less than 15 Mbps for 20% of all users; in 50% of all users less, than 50 Mbps; and in 20% of all users, more than 100 Mbps [5].

For the second area, field-to-farm data exchange, the quality of the mobile data networks is crucial. Although the 4G network is fairly widespread, there are still gaps in rural and sparsely populated northeastern Germany. The 5G network is mostly only developed in densely populated regions and along long-distance routes. There are still large gaps in rural regions [6]. Due to this structure, download rates between only 6.8–8 Mbps are possible in some districts. The majority of agricultural districts have a download rate of 8–18 Mbps. In large cities, on the other hand, 82 Mbps is possible. If one analyzes one level deeper and looks at agricultural areas and villages separately, data availability drops even further. Here, if a network is available at all, download rates of only 3 Mbps are usually possible. The available data download in the mobile network is less than 3.8 Mbps for 20% of all users, less than 14.3 Mbps for 50% of all users, and greater than 44.1 Mbps for 20% of all users. Since many smart farming applications in the field also require data to be uploaded to the cloud, the upload data rate is also important. The available data upload in the mobile network is less than 0.9 Mbps for 20% of all users, less than 4.4 Mbps for 50% of all users, and greater than 14.8 Mbps for 20% of all users.

The analysis of the transmission technology favored in Germany shows that it is mostly oriented towards consumer applications in large cities and along long-distance traffic routes. In contrast, rural areas and fields still face selective availability of even 3G connectivity. However, the requirements of agriculture are more diverse. On the one hand, some mobile machinery requires a remote broadband connection from time to time. On the other hand, local wireless sensor networks prefer long functional life, low energy consumption, and transmission ranges typically closely related to the geographic extension of a farm, that can be provided by a local LPWAN gateway.

4. Discussion

In the studies in the USA and Germany, the various problems of the data transmission infrastructure for low, medium, and high data rates were analyzed. It is evident in both countries that the quality of the data network infrastructure is still insufficient. Ultimately, political support (social support) are needed before the USA invests in robust rural broadband, thus enabling the adoption of digital technology and the use of more sustainable/efficient food production and processing systems needed by society. In some ways, rural broadband needs to mirror the adoption of electricity in the USA. The electric light bulb was invented in 1880. On 3 June 1889, the first North American electric power transmission line went online. On 11 May 1935, President Roosevelt created the Rural Electrification Administration, and by 1950, most of rural America had electricity. However, things are much different now, especially after the COVID-19 pandemic; society is better informed of the value of rural broadband for the USA. We believe that rural broadband will be deployed much quicker than electricity in rural USA.

The development of network infrastructure in Germany is such that, in the case of the railroad, electricity, and telephone networks, this was also started by private companies at the beginning, but was then soon transferred by the state to state or semipublic companies. The reason for this development was to ensure network expansion in rural regions as well. From the 1980s onward, the state withdrew more and more from the infrastructure networks and privatized the networks. In the implementation of the individual data networks, it can now be seen very clearly that companies are concentrating on urban areas with a high return on sales. In the case of 4G and 5G licenses, the contracts stipulate that rural regions in particular are to be expanded, but this is not apparent in the analysis. It is therefore evident in both study areas that there is still a need for action.

Another aspect that the study has shown is that, in some cases, there are no systems that are adapted to the needs of agriculture. Many applications for smart farming in agriculture require continuous and long-term data transmission with only low data rates. Examples are moisture sensors in the soil or position data for cattle. Low-power, wide area networks (LPWAN), such as LoRaWAN, offer solutions for these applications. Although only limited amounts of data can be exchanged via this system, they can be exchanged within a radius of 10 to 20 km (depending mostly on topography) and with low energy requirements. The distribution of these networks in Europe is not uniform. In Switzerland, nationwide use is possible via the major telephone companies. In Germany, on the other hand, there is little interest on the part of commercial providers, and there is only 70% coverage, which is mostly organized via citizens' networks. The question remaining is whether technologies, such as LPWANs, will really become so user friendly that farmers deploy their own networks on a farm level in contrast to relying on network providers like in the past. Another interesting trend, to cover the network availability gaps worldwide, are satellite communication systems. With companies, such as Starlink and Inmarsat, expanding their satellite constellations and connectivity services, this could become an important pillar for farms in remote areas, not only as a broadband connection backbone, but also for the collection of low-power and low-data rate wireless sensor networks.

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