On-farm research network ecosystem increased awareness and use of digital agriculture

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Abstract

Digital agriculture (DA) can help meet the 2030 United Nation Sustainable Development Goals. In this study, a survey was deployed to characterize farmers' knowledge, adoption of DA technologies, barriers to their adoption, and perceived value of DA in the state of Nebraska (Nebraska Farmers) and among the Nebraska On-Farm Research Network (NOFRN) annual meeting attendees (NOFRN). The results were contrasted to understand the impact of NOFRN on DA understanding and adoption. The questions included the definition of DA, technologies adopted, barriers to adoption, and perceived value of DA. The results show that NOFRN attendees have a better understanding of what DA is (more unique words and words to define DA), and a larger proportion identifies and measures DA benefits. Of the 34 DA technology options, NOFRN attendees used 6% more technologies than Nebraska farmers. The NOFRN was shown to be an effective program to increase awareness and adoption of DA technologies for more sustainable farming systems.

Introduction

On-farm research can be defined as a process that brings together farmers, researchers, and other members of the agricultural value chain to conduct experimentation in farmers' fields to support their own management decisions (Lacoste et al., 2022). The University of Nebraska On-Farm Research Network (NOFRN) was established in 1989 and worked with 50–70 farmers per year, conducting experiments to answer farmers' questions in farmers' fields. The NOFRN used digital agriculture (DA) technologies to deploy and evaluate the experiments. DA refers to the integration of technology and data analytics in various aspects of agriculture to enhance the productivity, sustainability, and efficiency of the agricultural value chain.

The NOFRN has enabled farmers to answer their critical production, profitability, and sustainability questions using their fields and equipment for over 30 years. Seventy-five percent of the farmers mentioned that they put their research findings into practice (Thompson et al., 2019). Farmers in the NOFRN use DA tools and technologies to design, establish, manage, and harvest their experiments. Generating large amounts of

information (yield maps, crop index maps, and electroconductivity maps) that are analyzed by researchers to advise farmers on a specific practice under study. DA includes the use of sensors, drones, satellite imagery, robotics, the Internet of Things (IoT), precision agriculture, and artificial intelligence (AI) to optimize farming operations, increase yields, improve resource management, and enable data-driven decision-making (Puntel et al., 2022).

DA offers numerous benefits that can revolutionize farming practices and enhance the agricultural sector. The results of the NOFRN experiments are summarized in publications and shared with farmers at the end of the season. The hypothesis is that farmers attending the OFRN meeting have more knowledge/adoption of DA than average farmers in Nebraska. Our goal was to survey benchmark knowledge and use of DA tools as well as perceived benefits and barriers to adoption of DA in Nebraska, comparing an average Nebraska farmer with farmers attending the NOFRN meetings.

Material and methods

A survey with multiple choice questions and open-answer questions was deployed to characterize farmers' knowledge of DA, tools and technologies adoption, DA value, and barriers to adoption. The survey was coordinated by the Bureau of Sociological Research (BSR, University of Nebraska). The BSR deployed the survey and produced a database with a summary of the responses per group. Farmers were recruited in two different ways: a probability-based stratified random sample of 2,500 Nebraska farmers, and farmers who attended the 2023 On-Farm Research Extension Meetings (NOFRN Farmer, nonprobability base sample).

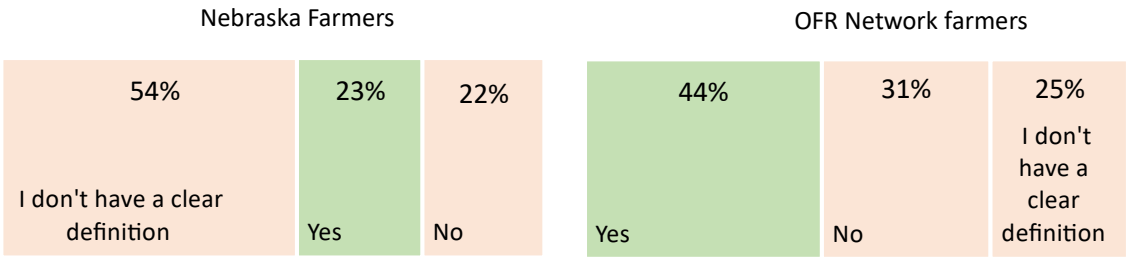
In the first case, the 2,500 farmers sample was drawn from counties proportionate to how many farms were in that county (e.g., Buffalo County contains 2% of farms in Nebraska, so 2% of the 2,500 sampled were from Buffalo County). Nebraska farmers had the choice to complete the survey in paper format (mail) or digital format; NOFRN farmers accessed a paper and a digital version of the survey during the NOFRN meeting. All responses were aggregated into two separate databases (keeping farmers' identities anonymous) and summarized with descriptive statistics to find evidence to support the hypothesis.

Results

Defining digital agriculture

The statewide survey was completed by 322 farmers, and the NOFRN reached 92 responses from meeting attendees. Fifty-four percent of Nebraska farmers said that they heard about the term DA but did not have a clear definition, while 24% of Nebraska farmers knew how to define DA. For the NOFRN farmers, the ability to define DA was higher (44%, Fig. 1).

Farmers were asked for five words to define DA. An average Nebraska farmer was able to provide two words, while a NOFRN farmer used 2.7 words (+35%). To evaluate vocabulary richness, unique words were identified when defining DA. An average Nebraska farmer provided 0.88 unique words per response, while the NOFRN farmers' vocabulary was richer, with 1.1 words (+25%, Table 1). At the state level, the top five mentioned words were computer, GPS, precision, technology, and variable rate, while the NOFRN farmers' most frequent words were variable rate, GPS, computer, data, and technology. It is important to highlight the word *data* that might reflect that this group of farmers is aware that one key element of DA is to collect large amounts of data and properly analyze it to generate information that can guide farm decisions.



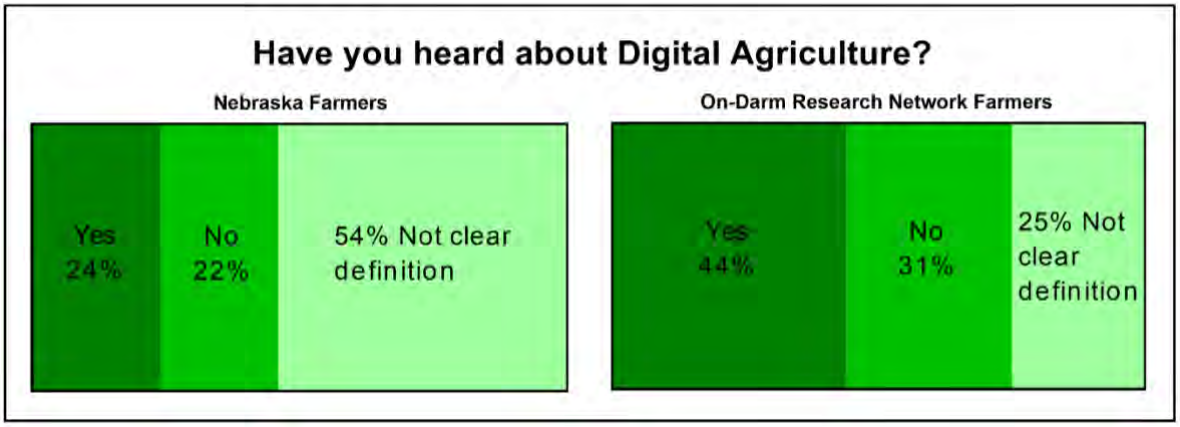


Fig. 1 I Have you heard about Digital Agriculture?

Nebraska farmers (left panel, n = 322) and On-Farm Research Network meeting farmers (right panel, n = 93) response to the question: Have you heard about Digital Agriculture?

Table 1 I Summary of words used to define DA at the Nebraska state level and by the Nebraska On-Farm Research Meeting attendees

Metric	Nebraska Farmer (State Survey)	On-Farm Research Network Farmer (Meeting Survey)
Responses	332	93
Total words (n)	601	249
Unique words (n)	295	101
Unique words per response	0.88	1.1
Total words per response	2	2.7
Top 10 words	Computer (48), GPS (37), precision (23), technology (21), variable rate (21), data (20), phone (16), expensive (13), internet (13), auto steer (12)	Variable rate (20), GPS (11), Computer (10), data (9), technology (8), precision (7), map (7), efficiency (6), satellite (6), sample grid (5)

Digital agriculture technologies adoption

The top six most adopted DA technologies among the 34 listed in the survey were phone apps, GPS, yield monitors, soil grid sampling, autosteer, and yield maps. While the top six less adopted technologies include robotics, LoRa networks, blockchain, virtual fencing, and automatic feeding and AI for decision-making (Fig. 2), technologies related to precision agriculture (GPS, yield monitor, variable rate, autosteer) showed greater adoption than other DA technologies, such as IoT, automation, and virtual feeding. The data showed that DA technologies related to livestock and dairy showed less adoption than technologies developed for crops. Overall, NOFRN farmers have a 6% greater adoption of DA technologies, with larger differences for autosteer (+23%), GPS (+21%), evapotranspiration (ET)gauge (+15%), soil moisture sensors (+14%), soil series maps (+13%), and digital platforms (+12%). The only category with low adoption by NOFRN farmers was soil grid sampling (-5%, Fig. 2).

Benefits and barriers

Only 28% of Nebraska farmers who used DA technologies measured their benefits. This number rises to 39% for NOFRN farmers. Reduction of inputs and increase in profits were the top two benefits identified by both groups of farmers. An increase in production quality and better commodity input prices were the categories with fewer responses (Fig. 3). Overall, responses from both groups followed the same trend, but NOFRN farmers reported more value for all categories (an average 8% greater value). Larger differences were reported by NOFRN farmers for increasing production quality (+12%), generation of own data (+ 12%) and increasing profits (+11%, Fig. 3).

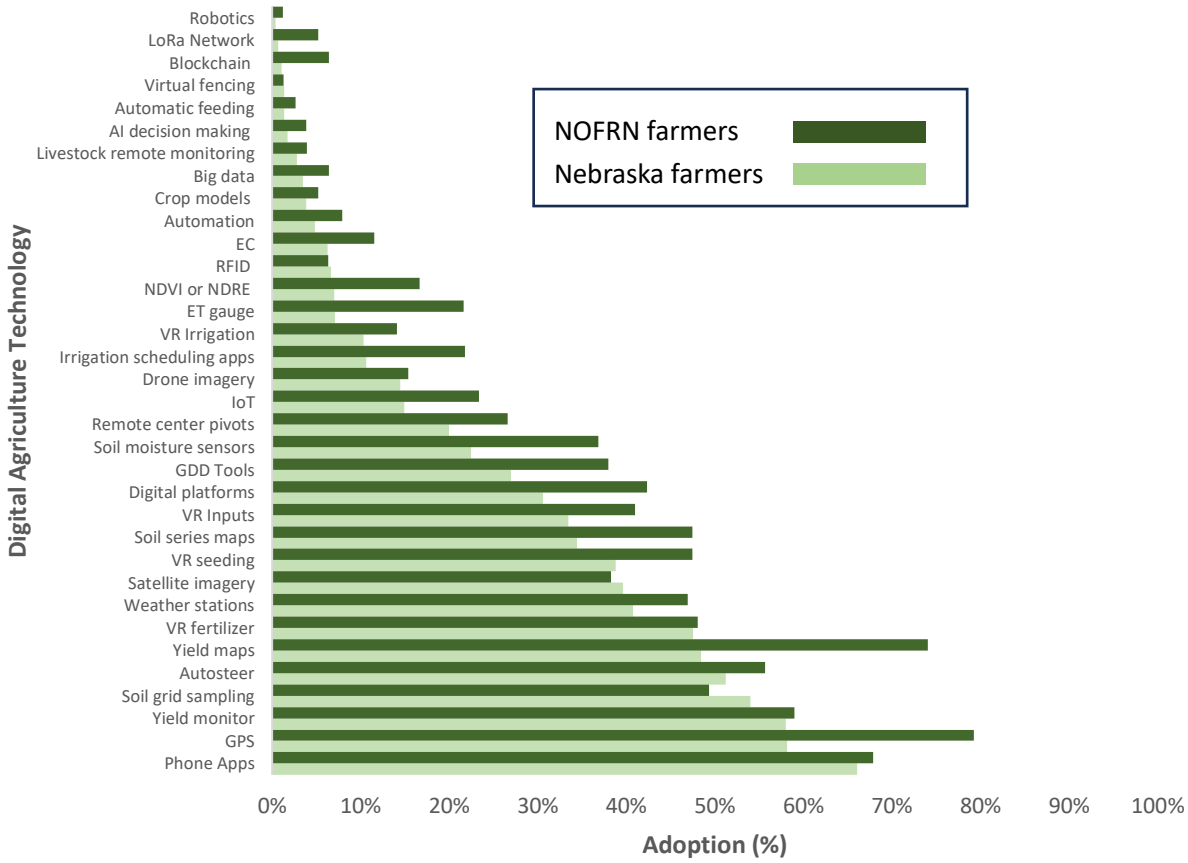


Fig. 2 I Digital agriculture technology adoption by farmers in Nebraska
List of DA technologies (y-axis) and % of adoption (x-axis) by farmers from the statewide survey (light green, n = 332), and for farmers attending the NOFRN meetings (dark green bars, n = 93) organized by the University of Nebraska Extension. EC, electroconductivity; RFID, radio frequency identification; NDVI, normalized difference vegetation index; NDRE, normalized difference red edge index; ET, evapotranspiration; VR. variable rate; IoT, internet of things; GDD, growing degree days; GPS, global position system; apps, applications

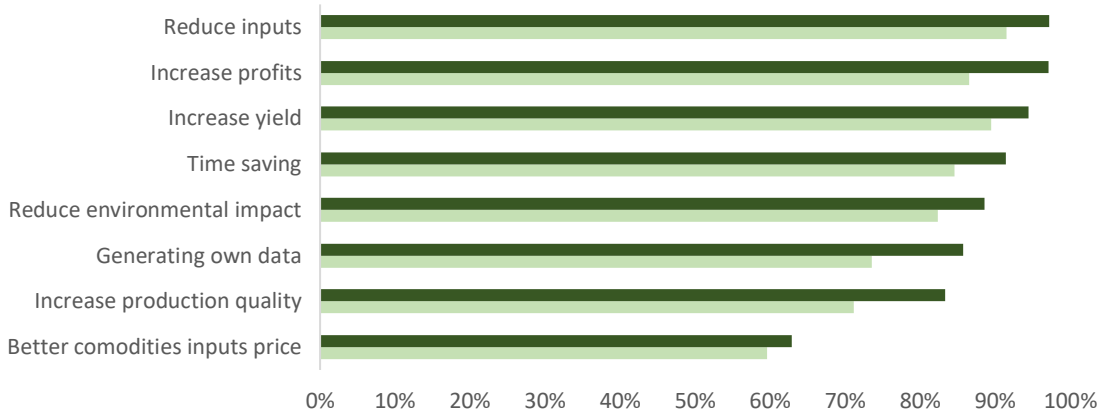


Fig. 3 I DA perceived benefits by Nebraska farmers

List of DA technologies (y-axis) and % of adoption (x-axis) by farmers from the statewide survey (light green, n = 332), and for farmers attending the NOFRN meetings (dark green bars, n = 93) organized by the University of Nebraska Extension.

Regarding barriers to DA adoption, the two most frequently cited barriers were technology cost for both groups (average 78% moderate + high barrier) and an overwhelming number of technologies (68% moderate + high barrier). NOFRN farmers were more concerned (+13%) about the lack of information regarding the DA value. (Table 2). These results can guide future extension actions to address these barriers and increase the adoption of DA.

Table 2 Levels of barriers to adoption of Digital Agriculture technologies selected by Nebraska Farmers (Nebraska, n=332) and the Nebraska On-Farm Research Network Meeting attendees (NOFRN, n=93).

	No Barrier		Moderate		High		Unsure	
Barrier	Nebraska	NOFRN	Nebraska	NOFRN	Nebraska	NOFRN	Nebraska	NOFRN
Technology cost	5%	3%	37%	42%	38%	38%	20%	16%
Lack of time	14%	16%	33%	41%	30%	27%	24%	15%
Available training	13%	17%	36%	50%	22%	13%	29%	21%
Number of service provider	18%	18%	33%	46%	20%	11%	29%	25%
Lack of information about DA value	15%	12%	33%	53%	23%	16%	29%	19%
Lack of qualified labor to manage DA	12%	14%	31%	38%	29%	29%	28%	19%
Not enough field days to access information	16%	22%	28%	42%	16%	10%	40%	26%
An overwhelming number of technologies	8%	15%	27%	38%	38%	32%	26%	15%

Conclusion

Our goal was to characterize farmers' knowledge, adoption of DA technologies, barriers to adoption, and perceived value of DA in the state of Nebraska (Nebraska farmers) and among NOFRN annual meeting attendees. Farmers participating in the NOFRN meetings were able to use more words to define DA. The level of adoption of DA tools was higher (+6%) for NOFRN farmers in all categories, and they reported a greater value (+8%) of DA benefits. The NOFRN farmers reported a greater value (+11%) in generating their data when using DA tools. The ecosystem generated by the NOFRN (farmers directly participating in experiments and farmers attending the meetings) shows more knowledge, value, and adoption of DA tools and technologies.

Acknowledgments

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