Survey of U.S. cow-calf producer access to and use of technology for cattle health and production record-keeping purposes

W. Isaac Jumper,[1] DVM; **Carla L. Huston**[1], DVM, PhD, DACVPM (Epidemiology); **Robert W. Wills**[2], DVM, PhD, DACVPM (Epidemiology); ***David R. Smith**[1], DVM, PhD, DACVPM (Epidemiology)

[1] Department of Pathobiology and Population Medicine, College of Veterinary Medicine, Mississippi State University, MS, 39762
[2] Department of Comparative Biomedical Sciences, College of Veterinary Medicine, Mississippi State University, MS, 39762
***Corresponding author:** Dr. David Smith, dsmith@cvm.msstate.edu

Abstract

The objective of this study was to describe U.S. cow-calf producer access to and use of technology for managing cattle health and production records (CHPR). We anonymously surveyed 14,294 cow-calf producers across the U.S. Multivariable logistic regression by manual forward variable selection was used to test demographic factors for association with CHPR-keeping technology outcomes. Overall, 92.9% of respondents had computer access for CHPR-keeping, 85.2% currently use a smartphone, and 88.7% had internet access at the cow-calf operation's office or headquarters. Factors associated with respondent interest in a smartphone-based CHPR-keeping system included: respondent uses a smartphone (OR = 7.7, 95%C.I. = 5.7-10.2; compared to not using a smartphone), respondent age (≤ 54 years: OR = 4.8, 95%C.I. = 3.7-6.2; 55-64 years: OR = 2.6, 95%C.I. = 2.0-3.3; 65-74 years: OR = 1.5, 95%C.I. = 1.2-1.9; compared to ≥75 years), survey response method (electronic: OR = 2.2, 95%C.I. = 1.7-2.9; compared to paper), respondent keeps any form of CHPR (OR = 2.0, 95%C.I. = 1.6-2.5; compared to not keeping CHPR), respondent education level (some college up to completed Bachelor's degree: OR = 1.4, 95%C.I. = 1.2-1.8; post-graduate or professional degree: OR = 1.5, 95%C.I. = 1.2-2.0; compared to high-school diploma or less), cow-calf operation is not primary income source (OR = 1.3, 95%C.I. = 1.1-1.6; compared to cow-calf operation being primary income source), region of the U.S. (midwest: OR = 1.1, 95%C.I. = 0.8-1.5; mountain: OR = 0.8, 95%C.I. = 0.5-1.1; northeast: OR = 1.4, 95%C.I. = 0.9-2.2; northern plains: OR = 0.9, 95%C.I. = 0.6-1.4; southeast: OR = 1.4, 95%C.I. = 1.0-1.9; southern plains: OR = 1.0, 95%C.I. = 0.7-1.4; compared to west) and respondent herd size (50-199 head: OR = 1.2, 95%C.I. = 1.0-1.4; ≥ 200 head: OR = 1.4, 95%C.I. = 1.1-1.8; compared to ≤ 49 head). Access to technology needed for electronic CHPR-keeping is common among U.S. cow-calf producers, however, individual demographic characteristics modified interest in using electronic CHPR.

Keywords: cow-calf, precision, technology, smartphone, beef

Introduction

Advancements in technology have increased the effectiveness and efficiency of data collection and analysis in many agricultural production systems. Precision agriculture techniques use data to apply the most appropriate level of input to specific areas of need, at specific times of need, within a crop or livestock production system. In row-crop production, precision agriculture began by using soil composition data to make real-time fertilizer rate and ingredient decisions during field application; this technology has led to improved soil conditions, crop production and plant and environmental health.[1,2] Precision agriculture concepts exist in livestock production as well. For example, the dairy industry has adopted remote sensing technologies to measure daily milk yield, milk components, cow activity, environmental conditions and other measures of individual animal health and production.[3,4] Radiofrequency identification (RFID) tags offer electronic identification and animal traceability options. Computer-controlled self-feeders and milking machines also use RFID tag technology to tailor management and nutrition plans to the individual animal.[1] Other examples of precision technologies used in the beef and dairy industries include estrus-detection systems that monitor physical activity, electrical resistance of reproductive tract secretions, and mounting behavior in order to more precisely coordinate artificial insemination.[5]

Opportunity exists for additional applications of precision agriculture concepts within the U.S. cow-calf industry, specifically in the collection, storage and use of electronic cattle health and production records (CHPR). Precision data management in the cow-calf sector involves collecting data to determine the type and amount of inputs or interventions needed to improve cattle health, nutrition, reproduction and carcass quality, as well as land and forage management. Cow-calf production in the U.S. varies greatly in size, geographical location, natural resource availability, and system of production. Electronic CHPR-keeping may allow cow-calf producers to more easily monitor health and production of the individual, as well as the herd, and design evidence-based animal management plans that fit resource availability and operational goals.

Historically, U.S. cow-calf producers have underutilized electronic CHPR-keeping systems. The 2007-2008 United States Department of Agriculture (USDA) National Animal Health Monitoring System (NAHMS) Beef Study found 19.9% of cow-calf producers kept CHPR on a computer, either on or off the operation. Handwritten records were kept by 78.6% of operation regardless of size.[6] Although handwritten records are common and convenient as a method of capturing CHPR, they are difficult to query, analyze and use for decision-making purposes. Technologies such as smartphones, tablets and personal computers offer tremendous potential and versatility in collecting, storing and analyzing electronic CHPR.

Additionally, internet-based electronic information storage systems (IBEISS) (e.g., iCloud, Google Drive, Microsoft OneDrive, Dropbox, etc.) are readily available and commonly used for many data storage purposes. Although these technologies are collectively believed to be more available today than at any point in history, U.S. cow-calf producer use of and access to these technologies for precision CHPR management is not well understood. The objective of this study was to describe U.S. cow-calf producer access to and use of technology necessary for precision beef production and electronic CHPR-keeping.

Materials and methods

Data reported in this study was collected as part of a survey of CHPR-keeping practices on U.S. beef cow-calf operations. A complete description of study design, survey implementation, data collection, and data analysis is reported elsewhere.[7] A brief description of the collection and analysis of data describing access to and use of technology for CHPR-keeping is provided here.

Sample

The target population of this study was U.S. beef cow-calf producers who are familiar with CHPR-keeping topics. Cow-calf producer members of the National Cattlemen's Beef Association (NCBA) were surveyed because the NCBA promotes the use of CHPR among its members through the National Beef Quality Assurance (NBQA) program. Investigators also empirically believed NCBA members would represent progressive, early adopters of technology that could be used for CHPR-keeping. A total of 14,294 NCBA cow-calf producer members were included in the study population.

Sample size calculations

Sample size calculations determined 2,860 responses would be sufficient to detect a difference between a 10% prevalence of a characteristic among 1 group of respondents (e.g., non-seedstock producers) and a 15% prevalence of the same characteristic among another group of respondents (e.g., seedstock producers) with 95% confidence if the ratio of these respondents (e.g., non-seedstock to seedstock producers) was 6:1. This number of responses would also provide 97% confidence with a margin of error of 2% around a probability estimate of 50% for a respondent characteristic (e.g., ownership of a smartphone).

Questionnaire development

The survey packet mailed to each NCBA cow-calf producer member included a 1-page letter of introduction, a 2-page questionnaire consisting of 44 multiple choice and fill-in-the-blank questions, and a self-addressed, metered business reply #9 envelope. The questionnaire included 4 sections: 1) producer demographic information, 2) current veterinary involvement in the operation, 3) current record-keeping methods, and 4) challenges to record keeping. Questions regarding producer access to and use of technology for collecting and analyzing CHPR were included in 1) producer demographic information, and 3) current record-keeping methods; only these data are reported here. The study was deemed "Not Human Subjects Research" by the Mississippi State University Institutional Review Board (MSU-IRB) due to the anonymity of respondents, exempting the study from the requirement for IRB approval.

Survey implementation

After mailing survey packets, responses were collected for 90 days. Recipients of the survey packet could respond by any one of the following methods: 1) return the paper survey using the included #9 business reply envelope, 2) use their smartphone to scan the QR code printed in the letter of introduction, or 3) use a web browser to visit the web link (URL) included in the letter of introduction. An article was published in the August 2020 edition of the *National Cattlemen* magazine creating awareness among NCBA members of the project and encouraging participation. No other reminders, incentives, or repeat mailings were used to enhance participation due to budget constraints.

Outcomes

Outcomes of interest in this study included: 1) survey response method, 2) respondent interest in a smartphone-based CHPR-keeping system, and 3) willingness of the respondent to use an IBEISS to store their CHPR. Explanatory variables tested for association with outcomes of interest included: 1) operation type, 2) if the cow-calf operation is the respondent's primary source of income, 3) respondent age, 4) respondent gender, 5) respondent herd size, 6) respondent education level, 7) region of U.S. where the cow-calf operation is located, 8) whether or not any CHPR are maintained for the cow-calf operation, 9) whether or not the respondent uses a smartphone, 10) whether or not the producer was familiar with IBEISS, and 11) survey response method.

Statistical analysis

Data collation and descriptive statistics were performed using spreadsheet software.[a] Inferential statistics were performed using commercially available statistics software.[b] Explanatory variables were assessed for correlation using Spearman correlation coefficients in PROC CORR. No highly correlated variable combinations were identified. Explanatory variables were further screened for collinearity using collinearity diagnostics and variance inflation factors within PROC REG. No collinearity was detected, making all variables eligible for inclusion in multivariable models.

Univariable models were assembled using PROC LOGISTIC for the outcomes of survey response method and respondent interest in a smartphone-based record-keeping system. Contingency tables of responses for each univariable model were examined to identify variable levels with few responses. For explanatory variables with more than 2 levels, the LSMEANS statement and Tukey's HSD test were used to examine differences in least square means between variable levels. When an explanatory variable with more than 2 levels had few responses in a level, or when Tukey's test revealed variable levels that did not differ statistically, variable levels were collapsed. Explanatory variables with more than 2 levels were modified as follows: QR code and URL combined to form an "electronic" category, making response method either "paper" or "electronic"; respondent age levels collapsed to ≤54 years, 55-64 years, 65-74 years, and ≥75 years; herd size levels collapsed to ≤ 49 head, 50-199 head, and ≥200 head; education level collapsed to high-school diploma or less, some college up to completed Bachelor's degree, and post-graduate or professional degree. A description of states included in each U.S. region is provided elsewhere.[7]

Multivariable models were assembled by manual forward variable selection, with Wald Type III p-values and Akaike's Information Criterion (AIC) values used to determine variable inclusion or exclusion from the model at each step. The LSMEANS statement and Tukey's HSD test were used to evaluate differences in least square means between explanatory variables with more than 2 levels in each multivariable model.

Because the outcome of producer willingness to use an IBEISS to store their CHPR had 3 inherently ordered levels (i.e., Yes, I need more information to decide, and No), ordinal logistic regression with a cumulative logit model was used for inferential analysis. The assumption of proportional odds was tested in univariable models for each explanatory variable using the Chi-square Score test, as well as through visual assessment of empirical cumulative logits.[8,9] Not all explanatory variables met the assumption of proportional odds, therefore a partial proportional odds multivariable model was assembled by manual forward variable selection using the UNEQUALSLOPES option to specify explanatory variables that violated the assumption of proportional odds during the model building process. Type 3 *P*-values and Akaike's information criterion (AIC) values were used to determine variable inclusion or exclusion from the model, as well as model fit when including explanatory variables in the UNEQUALSLOPES option.[10,11] Within the model, cumulative logits were modelled using the outcome level of "No" (i.e., respondent is not willing to use an IBEISS to store their CHPR) as the reference. Data used in this model was limited to respondents who indicated they currently kept some type of CHPR. For all analyses, statistical significance was set a priori at alpha = 0.05. Within the model of survey response method, the following 2-way interactions were tested: respondent age and respondent uses a smartphone, respondent uses a smartphone and respondent education level, region and cow-calf operation is primary income source, and respondent education level and cow-calf operation is primary income source. Within the model of respondent interest in using a smartphone-based CHPR-keeping system, the following 2-way interactions were tested: respondent uses a smartphone and respondent age, survey response method and respondent education level, respondent age and respondent keeps any form of CHPR, region and respondent herd size, and cow-calf operation is primary income source and respondent herd size. Within the model of respondent willingness to use an IBEISS to store their CHPR, the following 2-way interactions were tested: respondent familiar with IBEISS and respondent age, respondent age and respondent education level, respondent uses a smartphone and respondent education level, and cow-calf operation is primary income source and respondent herd size.

Results

Data regarding survey respondents' access to and use of technology for CHPR-keeping purposes is reported here. Additional descriptive statistics for respondent demographics, current CHPR-keeping methods, and veterinary involvement in CHPR-keeping are reported elsewhere.[7,12] Of the 14,294 survey packets mailed, 3,741 (26.2%) responses were received, with 3,641 (97.3%) meeting the study inclusion criteria of being actively involved in cow-calf production. Table 1 displays descriptive survey results for respondent access to and opinions of technology related to electronic CHPR-keeping systems. The majority of responses (88.3%) were paper, with a combined 11.7% of responses being electronic (i.e., URL and QR code). Overall, 85.2% of producers used a smartphone, 92.9% had access to a computer that could be used for cattle record-keeping purposes, and 88.7% had internet access available at the office or headquarters of the cow-calf operation with which they were associated. Most respondents (72.4%) were familiar with IBEISS, and 34.5% of respondents were willing to use an IBEISS to store their CHPR (Table 1). Internet access was common among producers across all regions of the U.S.; the midwest had the largest number of respondents without internet access available at the cow-calf operation's office or headquarters (15%) (Figure 1). Cell-phone signal was available where cattle are processed (i.e., in the calving pasture, chute-side at their processing facility, etc.) least commonly in the west (46%) and mountain (50%) regions (Figure 2). The 75 years of age and older category of respondents had the fewest respondents with access to a computer for CHPR-keeping purposes (82%), and fewest respondents who had a smartphone (67%) (Figure 3). Figure 4 displays the distribution of survey responses by age and response method. Producers less than or equal to 54 years of age represented 50.7% of all QR code and URL responses, while 22.1% of paper responses were from producers less than or equal to 54 years of age.

Multivariable logistic regression model results for the outcomes of survey response method and interest in a smartphone-based CHPR-keeping system are displayed in Tables 2 and 3, respectively. No significant 2-way interactions were detected within any multivariable model. Factors associated with respondents replying electronically to the survey included respondent age (≤ 54 years: OR = 7.0, 95% C.I. = 4.3-11.3; 55-64 years: OR = 3.5, 95% C.I. = 2.1-5.7; 65-74 years: OR = 1.6, 95% C.I. = 1.0-2.7; compared to ≥75 years), respondent uses a smartphone (OR = 7.1, 95% C.I. = 3.1-16.2), respondent education level (some college up to completed Bachelor's degree: OR = 2.6, 95% C.I. = 1.7-4.0; post-graduate or professional degree: OR = 2.9, 95% C.I. = 1.9-4.6; compared to high-school diploma or less), region of the U.S. where the cow-calf operation is located (midwest: OR = 1.3, 95% C.I. = 0.7-2.2; mountain: OR = 2.8, 95% C.I. = 1.6-5.1; northeast: OR = 1.8, 95% C.I. = 0.9-3.5; northern plains: OR = 1.7, 95% C.I. =0.9-3.3; southeast: OR = 1.9, 95% C.I. = 1.1-3.3; southern plains: OR = 1.6, 95% C.I. = 0.9-2.7; compared to west), and the cow-calf operation not being the respondent's primary income source (OR = 1.5, 95% C.I. = 1.1-1.9) (Table 2). Factors associated with respondents being interested in using a smartphone-based CHPR-keeping system included: respondent uses a smartphone (OR = 7.7, 95%C.I. = 5.7-10.2), respondent age (≤ 54 years: OR = 4.8, 95%C.I. = 3.7-6.2; 55-64 years: OR = 2.6, 95%C.I. = 2.0-3.3; 65-74 years: OR = 1.5, 95%C.I. = 1.2-1.9; compared to ≥ 75 years), survey response method (electronic: OR = 2.2, 95%C.I. = 1.7-2.9; compared to paper), respondent keeps any form of CHPR (OR = 2.0, 95%C.I. = 1.6-2.5; compared to not keeping CHPR), respondent education level (some college up to completed Bachelor's degree: OR = 1.4, 95%C.I. = 1.2-1.8; post-graduate or professional degree: OR = 1.5, 95%C.I. = 1.2-2.0; compared to high-school diploma or less), cow-calf operation is not their primary income source (OR = 1.3, 95%C.I. = 1.1-1.6; compared to the cow-calf operation being their primary income source), region of the U.S. where the cow-calf operation is located (midwest: OR = 1.1, 95%C.I. = 0.8-1.5; mountain: OR = 0.8, 95%C.I. = 0.5-1.1; northeast: OR = 1.4, 95%C.I. = 0.9-2.2; northern plains: OR = 0.9, 95%C.I. = 0.6-1.4; southeast: OR = 1.4, 95% C.I. = 1.0-1.9; south plains: OR = 1.0, 95%C.I. = 0.7-1.4; compared to west) and respondent herd size (50-199 head: OR = 1.2, 95%C.I. = 1.0-1.4; ≥ 200 head: OR = 1.4, 95%C.I. = 1.1-1.8; compared to ≤ 49 head) (Table 3).

Table 4 displays results of the multivariable cumulative logits partial proportional odds model for the outcome of respondent willingness to use an IBEISS to store their CHPR. Explanatory variables included in the multivariable model that met the assumption of proportional odds included respondent uses a smartphone (OR = 2.9, 95% C.I. = 2.3-3.6), respondent age (≤54 years: OR = 2.3, 95% C.I. = 1.8-3.0; 55-64 years: OR = 1.6, 95% C.I. = 1.3-2.0; 65-74 years: OR = 1.0, 95% C.I. = 0.8-1.3; compared to ≥ 75 years), seedstock operation (OR: 1.3, 95% C.I. = 1.1-1.5; compared to non-seedstock production), male respondents (OR = 1.3, 95% C.I. = 1.1-1.6; compared to female respondents), and cow-calf operation is not their primary income source (OR = 1.3, 95% C.I. = 1.1-1.6; compared to cow-calf operation being their primary income source). Because the explanatory variables of respondent familiarity with IBEISS, respondent education level, survey response method, and respondent herd size were included in the multivariable model, but violated the assumption of proportional odds, separate parameter estimates for each cumulative outcome level are reported. Model results for respondents who said "Yes" when asked about their willingness to use an IBEISS to store their CHPR included respondents familiar with IBEISS (OR = 4.7, 95% C.I. = 3.6-6.1; compared to not being familiar with IBEISS), respondent education level (some college up to completed Bachelor's degree: OR = 1.2, 95% C.I. = 1.0-1.6; post-graduate or professional degree: OR = 1.8, 95% C.I. = 1.3-2.3; compared to high-school diploma or less), electronic response method (OR = 1.6, 95% C.I. = 1.3-2.0; compared to paper response method), and respondent herd size (50-199 head: OR = 1.1, 95% C.I. = 0.9-1.4; ≥ 200 head: OR = 1.2, 95% C.I. = 1.0 - 1.6; compared to ≤ 49 head). Model results for respondents who said "Yes" or "I need more information to decide" when asked about their willingness to use an IBEISS included being familiar with IBEISS (OR = 1.5, 95% C.I. = 1.2-1.8; compared to not being familiar with IBEISS), respondent education level (some college up to completed Bachelor's degree: OR = 1.5, 95% C.I. = 1.2-1.9; post-graduate or professional degree: OR = 1.8, 95% C.I. = 1.4-2.4; compared to high-school diploma or less), electronic response method (OR = 2.5, 95% C.I. = 1.7-3.7; compared to paper response method), and respondent herd size (50-199 head: OR = 1.5, 95% C.I. = 1.2-1.9; ≥ 200 head: OR = 1.6, 95% C.I. = 1.3-2.1; compared to ≤ 49 head).

Discussion

The results of this study describe factors related to the access to and use of technology by U.S. cow-calf producers for CHPR-keeping purposes. The large difference in the number of paper and electronic responses was interesting (Table 1); method of response to the survey may indicate how familiar the respondent is with technologies (e.g., computers and smartphones) that could be used for CHPR-keeping. A similar difference in response types was noted in a previous survey of cow-calf producer members of the Mississippi Cattlemen's Association.[13] Because the study population was initially contacted by mail, investigators may have selected for producers who are more willing to fill out a paper survey. If survey recipients had been initially contacted by electronic methods (i.e., email) only, respondents who prefer to fill out paper surveys or who do not regularly use electronic platforms of communication may have been less likely to respond. Previous surveys of U.S. cow-calf producers and members of the Iowa Cattlemen's Association conducted exclusively by email resulted in response rates of 3.43% and 18.6%, respectively, both of which are lower than the response rate of the present study.[14,15] Additionally, a recent email survey of beef and dairy producers and veterinarians achieved a cumulative response rate of 3.8%.[16] Investigators recognize that because recipients of the survey packet were not contacted by email first, respondents may have found it easier to fill out and mail in the paper survey, rather than manually enter the short URL address in order to answer the web version of the questionnaire. If the URL had been provided by email in the form of a clickable link directing the recipient to the questionnaire, more URL survey responses may have been received.

Access to a computer that could be used for record-keeping purposes was common among respondents (Table 1). Similarly, a 2021 study of cow-calf producer members of the Mississippi Cattlemen's Association found 73% of respondents had readily available access to a computer for CHPR-keeping purposes on their operation.[13] A 2007 study of U.S. cow-calf producers with 100 head or more found that approximately 55% used a personal computer on their operation. In this study, 65% of those study participants using a personal computer on their cow-calf operation used the computer for maintaining livestock records.[c] The larger percentage of respondents with access to a computer on their operation for CHPR-keeping purposes may be attributed to the increasing availability and affordability of personal computers over the last 15 years. However, access to a computer that could be used for CHPR-keeping purposes does not always mean the producer is utilizing the computer for that purpose. This is evident when data from the present study regarding respondent access to a computer for CHPR-keeping purposes is compared to data describing respondents who keep handwritten records reported elsewhere; 92.9% of respondents had access to a computer, while 62.8% of all respondents who kept any form of CHPR used handwritten records.[7]

Interestingly, internet access was common across all regions of the U.S. (Figure 1). Investigators speculated that large regional differences in internet access would exist, however, this did not appear to be the case. According to the 2017 Census of Agriculture, approximately 73% of beef cattle ranching and farming operations had internet access either on the operation or at the owner's residence.[17] Continual efforts to expand internet availability and improved methods of delivering internet access in rural areas likely contribute to the widespread respondent internet access in the present study. The importance of internet access in rural areas of the U.S. became readily apparent during the height of the COVID-19 pandemic, as schools and businesses relied on videoconferencing, email and other internet-related applications for daily functions.[18]

Compared to internet access, more disparity by region was observed for availability of a cellphone signal where cattle are worked on the cow-calf operation (Figure 2). Inconsistencies in cellphone signal availability among respondents can be seen in the mountain and northern plains regions where over one-third of respondents indicated cellphone signal was "sometimes" available. The differences in cellphone signal and internet availability seen in the present study may be attributed to question wording. Investigators recognize that personal computers are most likely to be used for CHPR-keeping purposes when the operator is at the cow-calf operation's office or headquarters. Although many personal computers are very portable, data entry in the calving pasture or when treating animal chute-side may be better suited for smartphones or tablets. Investigators specifically asked about internet access at the operations headquarters, and cell-phone signal where

cattle are worked in order to determine the feasibility of using the smartphone as a primary data collection tool, while reserving more detailed procedures and analysis of CHPR for when the operator is working from their personal computer at the office or headquarters. Had respondents been asked if cellphone signal was available at the cow-calf operation's office or headquarters, investigators speculate more respondents may have said "Yes".

Smartphones are perhaps one of the most commonly owned and used pieces of technology in our culture today, and as can be seen from Figure 3, smartphone use was common across all respondent age categories. Previous studies have found smartphone use to be common among "millennials", or those individuals born from approximately 1980 to 2000.[19] Results of the present study suggest smartphone use among respondents who belong to the "millennial" generation (i.e., respondents under the age of 45) is nearly ubiquitous (Figure 3). Smartphone use was very common among respondents in older age categories as well. This common use of smartphones was also seen in a 2021 survey of cow-calf producer members of the Mississippi Cattlemen's Association, where 75% of respondents used a smartphone.[13] Lower rates of smartphone use among cattle producers have also been reported. A 2020 survey of Iowa Cattlemen's Association members found only 50.5% of respondents owned a smartphone.[15]

The smartphone holds potential as an efficient and easy to use data collection tool for cow-calf producers. Whereas many respondents to the present study currently use some form of handwritten notebook or notepad to capture data[7] (e.g., writing down calving information in a pocket notebook), smartphones can also be easily carried with the producer, allowing data to be immediately entered electronically, rather than relying on the conversion of paper to electronic records. In the present study, over half (55.2%) of all respondents were interested in a smartphone-based CHPR-keeping system (Table 1); similarly, 58.3% of respondents to a 2021 survey of cow-calf producer members of the Mississippi Cattlemen's Association were interested in using a smartphone to capture CHPR.[13] Understanding how to use commercially available CHPR-keeping software is an important challenge in electronic record-keeping for cow-calf producers.[7] This may be a reason why 44.8% of respondents said they were not interested in a smartphone-based CHPR-keeping system. Other reasons may include unreliable cellphone signal in rural or isolated regions, such as in the mountain region of the present study (Figure 2). This obstacle may be overcome by developing a smartphone-based CHPR-keeping tool that is able to store data locally (i.e., on the device) when no cellular service is available, then backing-up the data to an IBEISS when the device comes in range of internet or cellular service. Internet-based electronic information storage systems (e.g., iCloud, Dropbox, Google Drive, etc.) are common today, with many smartphones backing-up personal information (e.g., contacts, photos, music, etc.) in such systems. The advantages to this type of data storage include 1) data accessibility from any place where internet connection is available, 2) limited storage space required locally on the device, and 3) protection against data loss if the device is lost or malfunctions in any way. A large portion of respondents to the present study indicated they needed more information to decide whether or not they would use such a data storage system for their CHPR (Table 1). Investigators speculate that concerns for the confidentiality, security, and accessibility of data may contribute to respondent reluctance to use an IBEISS to store their CHPR.

The survey response method chosen by respondents likely provides information on the respondent's familiarity and overall comfort level with using technology on a daily basis

Figure 1: Respondents with and without internet access at the cow-calf operation's office or headquarters by region of the U.S. where the cow-calf operation is located.

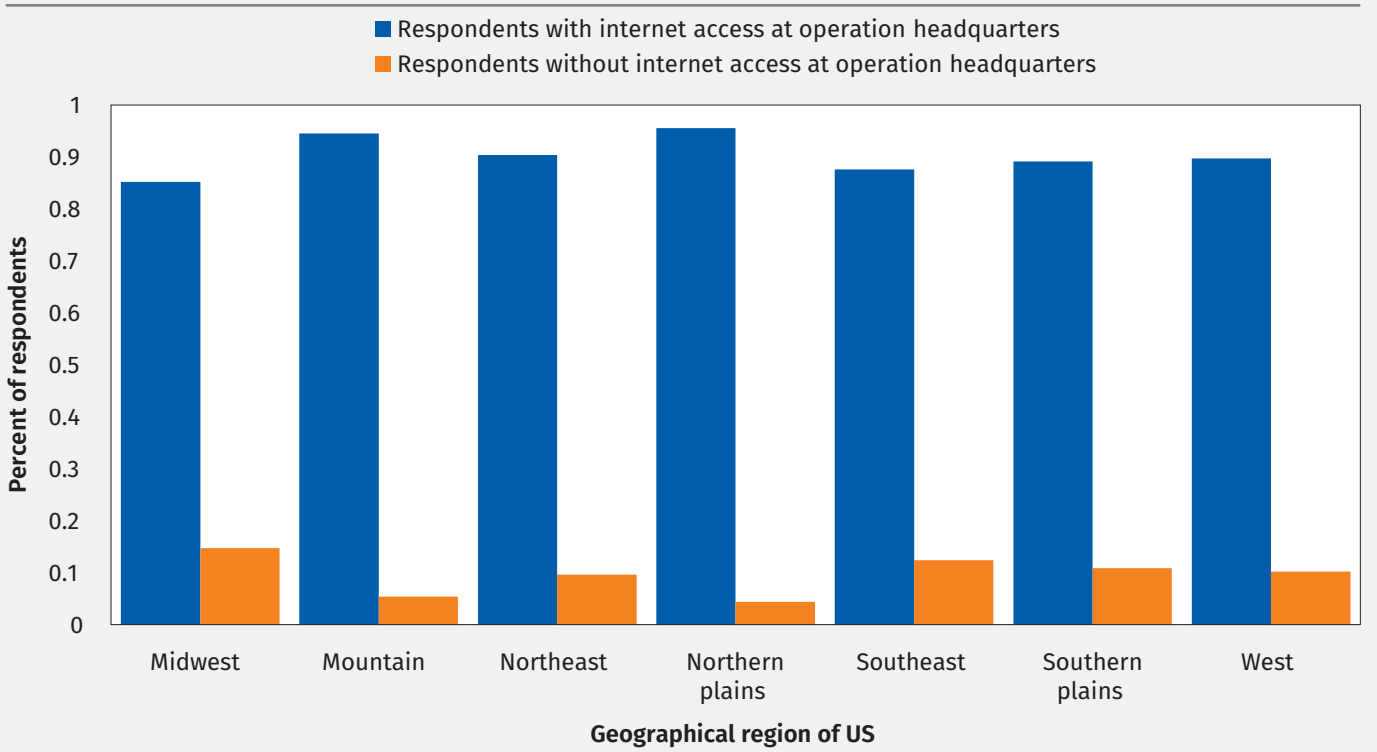


Table 1: Descriptive survey results for U.S. cow-calf producer access to technology to be used for electronic CHPR-keeping.

Question	Number of responses	Percent, %
Survey response method	3741	
Paper	3303	88.3
URL	258	6.9
QR code	180	4.8
Do you have access to a computer (desktop, laptop, tablet, etc.) that could be used for cattle record-keeping purposes?	3610	
Yes	3354	92.9
No	256	7.1
Is internet access available at the cow-calf operation's office or headquarters?	3600	
Yes	3192	88.7
No	408	11.3
Do you have a "smartphone" (iPhone, Android, etc.)?	3606	
Yes	3074	85.2
No	532	14.8
Is a cellphone signal available where you work cattle (e.g., in the calving pasture, chute-side at your processing facility, etc.)?	3611	
Yes	2425	67.2
No	248	6.9
Sometimes	938	25.9
Are you interested in using a cattle health and production record-keeping system from a "smartphone"?	3532	
Yes	1950	55.2
No	1582	44.8
Are you familiar with "the Cloud" or other internet-based electronic information storage systems (e.g., Dropbox, Google Drive, iCloud, etc.)?	3594	
Yes	2602	72.4
No	992	28.6
Would you use an internet-based electronic information storage system such as "the Cloud" to store your cattle health and production records?	3584	
Yes	1235	34.5
No	980	27.3
I need more information to decide	1369	38.2

(Table 2). Younger producers are likely more accustomed to using technology (e.g., smartphone, tablet, personal computer, etc.) daily in other areas of their lives, and therefore were more likely to find answering the electronic form of the questionnaire convenient. Similarly, owning a smartphone imparts familiarity with using a smartphone for purposes such as web browsing, taking pictures, or answering emails, all of which are functions that non-smartphone cellular devices cannot perform; therefore, answering the survey electronically (i.e., from their smartphone or by web URL) is likely not a new concept to smartphone users. Investigators speculate that producers with higher levels of education (i.e., some college up to completed Bachelor's degree or post-graduate or professional degree) may occupy roles within the cow-calf operation or outside the cow-calf operation that require regular use of technology such as smartphones and computers, making those producers more likely to answer the present study by electronic means. Interestingly, the regional differences in odds of responding to the present study by electronic means may suggest regional differences in respondent familiarity with technology. Curiously, respondents in the mountain region (i.e., Arizona, Colorado, Idaho, Montana, Nevada, Utah, Wyoming) had the greatest odds of answering the survey electronically. Cellphone signal availability where cattle are

Table 2: Multivariable logistic regression model for survey response method (i.e., paper or electronic response) to the questionnaire. Outcome modeled as the probability that responses were received electronically (i.e., QR code or URL).

Explanatory variable	Level	Responses*	Parameter	Standard error	Odds ratio	95% C.I.		*P*-value
Intercept			-6.68	0.56				<.0001
Respondent age								
	≤ 54 years[a]	900	1.94	0.25	7.0	4.3	11.3	<.0001
	55-64 years[ab]	937	1.24	0.25	3.5	2.1	5.7	
	65-74 years[bc]	1114	0.49	0.26	1.6	1.0	2.7	
	≥ 75 years[c]	574	Ref.	Ref.	1.0	Ref.		
Respondent uses a smartphone								
	Yes	3013	1.96	0.42	7.1	3.1	16.2	<.0001
	No	512	Ref.	Ref.	1.0	Ref.		
Respondent education level								
Post-grad. or Prof. degree[a]	739	1.07	0.23	2.9	1.9	4.6		<.0001
Some college up to completed Bachelor's degree[b]	2226	0.96	0.21	2.6	1.7	4.0		
High-school diploma or less[b]	560	Ref.	Ref.	1.0	Ref.			
Region								
	Midwest[a]	826	0.22	0.29	1.3	0.7	2.2	0.0012
	Mountain[b]	329	1.04	0.30	2.8	1.6	5.1	
	Northeast[ab]	217	0.60	0.34	1.8	0.9	3.5	
	Northern plains[ab]	205	0.55	0.33	1.7	0.9	3.3	
	Southeast [ab]	883	0.65	0.28	1.9	1.1	3.3	
	Southern plains[a]	822	0.45	0.28	1.6	0.9	2.7	
	West[a]	243	Ref.	Ref.	1.0	Ref.		
Cow-calf operation is the respondent's primary income source								
	No	2345	0.38	0.13	1.5	1.1	1.9	0.0028
	Yes	1180	Ref.	Ref.	1.0	Ref.		

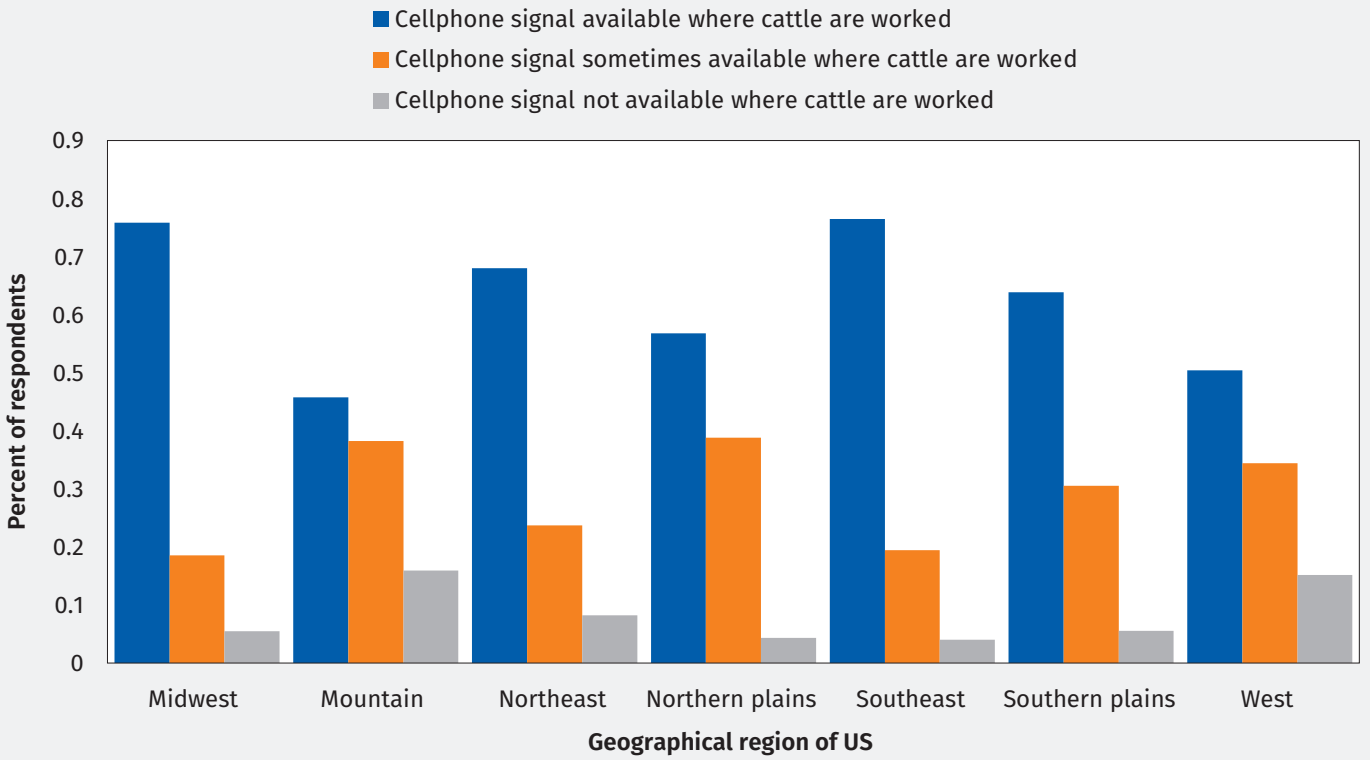
***** = 3,525 total responses were used in this model

[a,b,c] = levels with a common letter were not statistically different by Tukey's HSD test for multiple comparisons among variable levels

worked was the lowest in the mountain region (Figure 2). However, internet access appears to be abundant to respondents in the mountain region (Figure 1), which may explain their ability to respond to the survey electronically.

Respondent characteristics associated with interest in using a smartphone-based CHPR-keeping system likely represent many of the characteristics of early adopters of new technology (Table 3). Current use of a smartphone conveys familiarity with smartphone utility and functionality, and likely means the respondent has some understanding of the versatility of smartphones for data capture and management. Although smartphone use was common in the present study across age categories as previously discussed, investigators speculate younger respondents likely had greater odds of being interested in using a smartphone-based CHPR-keeping system because they are well-versed in the extensive utility of smartphones, whereas older respondents may tend to use smartphones for more basic functions (i.e., call, text, web browsing, etc.). Answering the survey by scanning the QR code included in the letter of introduction is likely also a more advanced smartphone function, and respondents who can perform this function are likely more familiar with smartphones and more interested in their use for CHPR-keeping. Respondents who

Figure 2: Respondents who indicated that a cellphone signal was available, was sometimes available, or was not available where cattle are worked on the cow-calf operation (i.e., in the calving pasture, chute-side at processing facility, etc.) by region of the U.S. where the cow-calf operation is located.



already keep some form of CHPR likely are inherently more interested in new options for record-keeping compared to those producers who do not keep any records. Investigators speculate that respondent education level is representative of their familiarity with the value of data collection and use; respondents with a post-graduate or professional degree may have participated in research as part of their training that required some form of data collection, making them more aware of the value of data for evidence-based decision-making. This additional education may also convey familiarity with data and technology that predisposes the respondent to interest in using their smartphone for CHPR-keeping. Interestingly, respondent's whose primary income source was not the cow-calf operation had the greatest odds of being interested in a smartphone-based CHPR-keeping system. This association may be due to a perception by respondents whose primary income source is the cow-calf operation that they do not have time to learn a new method of record-keeping, that they do not perceive any financial or other benefits, or that there is risk associated with using a smartphone-based CHPR-keeping system that they are not willing to accept with their primary source of income. Regional differences in respondent interest in a smartphone-based CHPR-keeping system were observed as well, although differences were small. Fewer responses from regions such as the northeast and northern plains likely led to limited power to detect differences between regions (e.g., northeast and mountain) (Table 3).

When an outcome has more than 2 levels with an inherent order, such as the outcome of producer willingness to use an IBEISS to store their CHPR, a cumulative logit model may be used if the assumption of proportional odds is met. Proportional odds models assume the change in explanatory variable values are proportional across each outcome variable level, when accounting for all other explanatory variables in the model. When this is true, odds ratios for explanatory variables can be interpreted as proportional across cumulative levels of the outcome (i.e., the odds of a respondent saying "Yes" or "I need more information to decide" compared to "No" are equal to the odds of a respondent saying "Yes" compared to "I need more information to decide" or "No"). For example, in Table 4 the explanatory variable "respondent uses a smartphone" met the assumption of proportional odds, therefore respondents who used a smartphone had 2.9 times the odds of saying "Yes" or "I need more information to decide" when asked about their willingness to use an IBEISS to store their CHPR, compared to respondents who said "No". However, if a variable included in the model did not meet the assumption of proportional odds, separate parameter estimates for each explanatory variable are provided at each outcome level (i.e., respondent familiar with IBEISS in Table 4). In these cases, the odds are not proportional and must be defined across each outcome level. For example, respondents who were familiar with IBEISS had 4.7 times the odds of saying "Yes" when asked about their willingness to store their CHPR in such a system compared to those respondents who said "I need more information to decide" or "No". However, respondents who were familiar with IBEISS had 1.5 times the odds of saying "Yes" or "I need more information to decide" when asked about their willingness to store their CHPR in such a system compared to those respondents who said "No". A partial proportional odds model allows for the construction of a model with superior fit when some but not all explanatory variables violate the assumption of proportional odds.[9,10]

Internet-based electronic information storage systems are prevalent today. These information storage systems allow the user to store large amounts of data in a location that is external to the device, allowing local storage on the device to remain free, while allowing access from any location where internet services are available. Many smartphones, tablets, personal computers and other mobile devices today utilize IBEISS such as iCloud, Dropbox, Google Drive or Microsoft OneDrive. In the current study, factors such as respondent age, education level and smartphone use that were associated with interest in using a smartphone-based CHPR-keeping system (Table 3) and electronic survey response methods (Table 2), were also associated with respondent willingness to use an IBEISS to store their CHPR. These factors may be characteristic of innovators or early adopters of technology. These innovators and early adopters need little to no incentive or motivation to adopt a new technology, even going so far as to adopt new technologies that may involve risk (e.g., data loss).[20] The primary risks of IBEISS technologies include lack of internet services precluding access to data, and data loss, theft or manipulation from security issues or system malfunction. Factors such as trust, perceived privacy and security cost, and perceived benefit have been shown to be influential in a user's willingness to store personal information in cloud-based storage systems, with perceived cost becoming more important as the sensitivity of the information increased.[21] This may explain why respondents whose primary source of income was not the cow-calf operation had greater odds of answering "Yes" or "I need more information to decide" when asked about their willingness to use an IBEISS compared to those respondents whose primary income source was the cow-calf operation. Similarly, larger herd sizes often correspond with larger financial investments and operational costs, which may explain the greater amount of hesitancy to use an IBEISS by respondents with greater herd sizes. Respondents with larger herd sizes had greater odds of answering "I need more information to decide" or "No" compared to "Yes" when asked about their willingness to store their CHPR in an IBEISS.

Responses to the present study may not be representative of the opinions and practices of all U.S. cow-calf producers. The target audience of this study was cow-calf producers who are familiar with CHPR-keeping topics. Investigators believe that producers who are familiar with and currently using CHPR may be more likely to adopt new technologies to aid in the efficiency and effectiveness of data collection, compared to producers who currently are not collecting or using CHPR. Investigators empirically believe that members of the NCBA are likely familiar with the importance of CHPR, and as a result, may be more willing to adopt new technologies related to CHPR management compared to non-NCBA members. The results of the present study would likely differ if non-NCBA members had been included in the sample population. Budget constraints and the anonymity of the study prevented methods of contacting survey non-responders; therefore, the results of this study must be interpreted with the understanding that those producers with strong opinions of CHPR, or those who were willing to respond, likely composed the respondent population.

Technology continues to shape livestock production by offering convenient and efficient ways to collect data that is both meaningful and needed. Respondents in this study commonly had access to electronic data collection and management tools. A large percentage of respondents currently have a smartphone, and more than half of respondents are interested in using a CHPR-keeping system from their smartphone. Respondents were largely familiar with IBEISS, and one-third of respondents were willing to use such systems to store their

Figure 3: Respondents by age group who indicated they used a smartphone and had access to a computer that could be used for CHPR-keeping purposes.

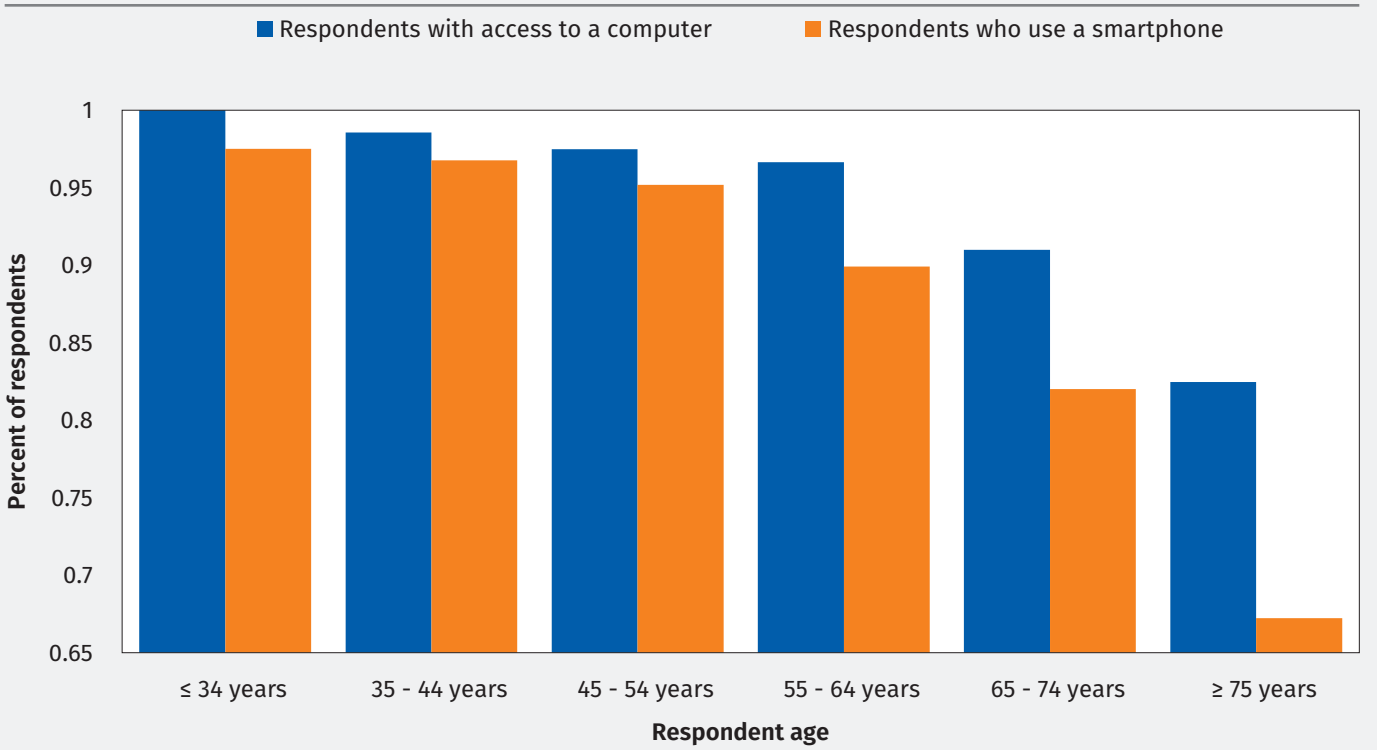


Table 3: Multivariable logistic regression model for the outcome of respondent interest in using a smartphone-based CHPR-keeping system. Outcome modeled as the probability that the respondent was interested in using a smartphone record-keeping system.

Explanatory variable	Level	Responses*	Parameter	Standard error	Odds ratio	95% C.I.		*P*-value
Intercept			-3.77	0.28				<.0001
Respondent uses a smartphone								<.0001
	Yes	2933	2.04	0.15	7.7	5.7	10.2	
	No	498	Ref.	Ref.	1.0	Ref.		
Respondent age								<.0001
	≤54 years [a]	886	1.56	0.13	4.8	3.7	6.2	
	55-64 years [b]	921	0.95	0.13	2.6	2.0	3.3	
	65-74 years [c]	1076	0.42	0.12	1.5	1.2	1.9	
	≥75 years [d]	548	Ref.	Ref.	1.0	Ref.		
Survey response method								<.0001
	Electronic	420	0.78	0.14	2.2	1.7	2.9	
	Paper	3011	Ref.	Ref.	1.0	Ref.		
Respondent keeps any form of CHPR								<.0001
	Yes	3000	0.69	0.12	2.0	1.6	2.5	
	No	431	Ref.	Ref.	1.0	Ref.		
Respondent education level								0.0021
	Post-grad. or Prof. degree[a]	718	0.42	0.13	1.5	1.2	2.0	
	Some college up to completed Bachelor's degree[a]	2160	0.37	0.11	1.4	1.2	1.8	
	High-school diploma or less[b]	553	Ref.	Ref.	1.0	Ref.		
Cow-calf operation is the respondent's primary income source								0.0048
	No	2291	0.27	0.1	1.3	1.1	1.6	
	Yes	1140	Ref.	Ref.	1.0	Ref.		
Region								0.0029
	Midwest [ab]	802	0.05	0.17	1.1	0.8	1.5	
	Mountain [a]	318	-0.25	0.19	0.8	0.5	1.1	
	Northeast [ab]	212	-0.36	0.22	1.4	0.9	2.2	
	Northern plains [ab]	201	-0.08	0.22	0.9	0.6	1.4	
	Southeast [b]	866	0.33	0.17	1.4	1.0	1.9	
	Southern plains [ab]	796	0.03	0.17	1.0	0.7	1.4	
	West [ab]	236	Ref.	Ref.	1.0	Ref.		
Respondent herd size								0.0207
	≥200 head[a]	966	0.34	0.12	1.4	1.1	1.8	
	50-199 head[ab]	1563	0.15	0.1	1.2	1.0	1.4	
	≤49 head [b]	902	Ref.	Ref.	1.0	Ref.		

***** = 3,431 responses were used by this model

[a,b,c] = levels with a common letter were not statistically different by Tukey's HSD test for multiple comparisons among variable levels

Table 4: Multivariable cumulative logit partial proportional odds model for respondent willingness to use an IBEISS to store their CHPR. The outcome had 3 levels: "Yes, I need more information to decide", and "No". Cumulative logits modeled using outcome level "No" as reference.

Explanatory variable	Variable level*	Outcome level†	Parameter	Standard error	Odds ratio	95% C.I.		*P*-value
Intercept		Yes	-4.1	0.24				<.0001
Intercept		More info	-1.6	0.19				<.0001
Respondent familiar with IBEISS‡								<.0001
	Yes (2287)	Yes	1.5	0.14	4.7	3.6	6.1	
		More info	0.4	0.10	1.5	1.2	1.8	
	No (758)	Ref.	Ref.	Ref.	1.0	Ref.		
Respondent uses a smartphone				< .0001				
	Yes (2635)		1.1	0.12	2.9	2.3	3.6	
	No (410)		Ref.	Ref.	1.0	Ref.		
Respondent age								<.0001
	≤54 years (832)		0.84	0.12	2.3	1.8	3.0	
	55-64 years (827)		0.47	0.12	1.6	1.3	2.0	
	65-74 years (922)		0.03	0.11	1.0	0.8	1.3	
	≥ 75 years (464)		Ref.	Ref.	1.0	Ref.		
Respondent education level								<.0001
	Post-grad or Prof. degree (659)	Yes	0.58	0.14	1.8	1.3	2.3	
		More info	0.60	0.15	1.8	1.4	2.4	
		Ref.	Ref.	Ref.	1.0	Ref.		
	Some college up to completed Bachelor's (1910)	Yes	0.21	0.13	1.2	1.0	1.6	
		More info	0.41	0.12	1.5	1.2	1.9	
	High-school diploma or less (476)	Ref.	Ref.	Ref.	1.0	Ref.		
Survey response method								<.0001
	Electronic (378)	Yes	0.47	0.12	1.6	1.3	2.0	
		More info	0.91	0.20	2.5	1.7	3.7	
	Paper (2667)	Ref.	Ref.	Ref.	1.0	Ref.		
Operation type								0.0013
	Seedstock (969)		0.24	0.08	1.3	1.1	1.5	
	Non-seedstock (2076)		Ref.	Ref.	1.0	Ref.		
Respondent gender								0.0107
	Male (2613)		0.26	0.1	1.3	1.1	1.6	
	Female (432)		Ref.	Ref.	1.0	Ref.		

Table 4 continued on next page

Table 4 Continued:

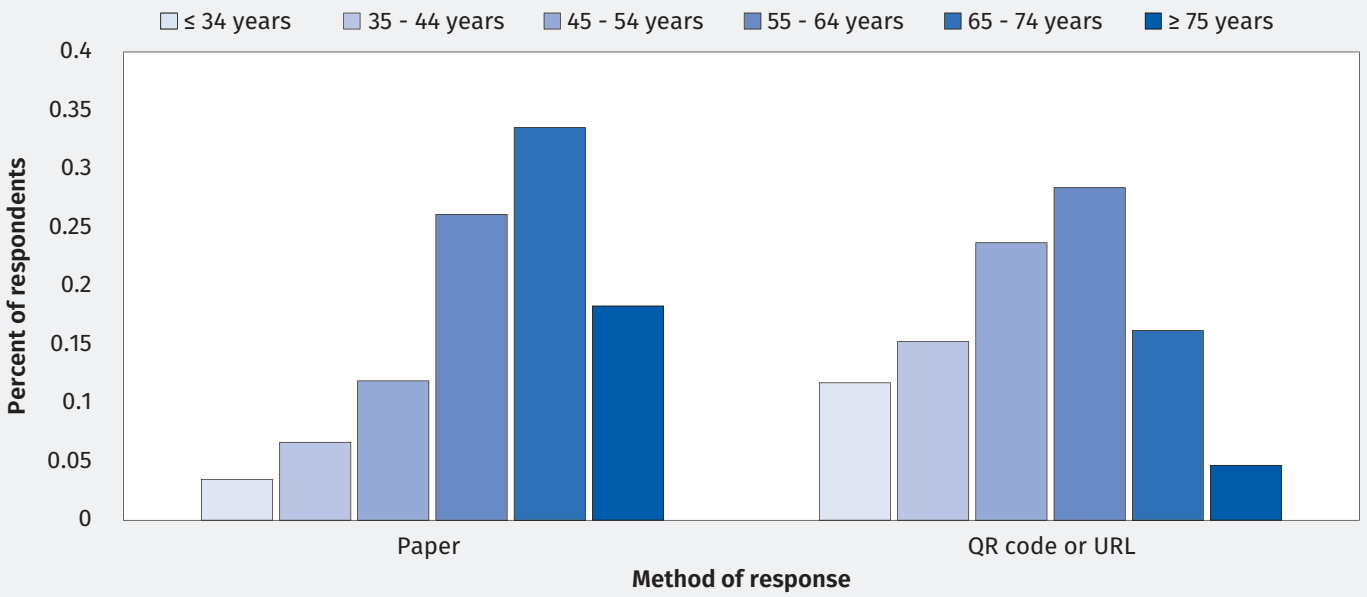
Explanatory variable	Variable level*	Outcome level†	Parameter	Standard error	Odds ratio	95% C.I.		*P*-value
Cow-calf operation is the respondent's primary income source								0.0005
	No (2004)		0.29	0.08	1.3	1.1	1.6	
	Yes (1041)		Ref.	Ref.	1.0	Ref.		
Respondent herd size								0.0009
	≥ 200 head (881)	Yes	0.21	0.12	1.2	1.0	1.6	
		More info	0.48	0.13	1.6	1.3	2.1	
		Ref.	Ref.	Ref.	1.0	Ref.		
	50-199 head (1368)	Yes	0.11	0.10	1.1	0.9	1.4	
		More info	0.42	0.11	1.5	1.2	1.9	
	≤ 49 head (796)	Ref.	Ref.	Ref.	1.0	Ref.		

***** = 3,045 responses were used by this model; parentheses indicate number of responses by explanatory variable level; data limited to respondents who kept some form of CHPR

† = Parameter estimates for each outcome variable level provided for explanatory variables that violated proportional odds assumption

‡ = Internet-based electronic information storage systems

Figure 4: Distribution of responses by survey response method and age of respondent. Percentages are based on the total number of responses by each method.



CHPR. Access to a computer for record-keeping purposes, internet-availability on the cow-calf operation, and cellphone signal availability were common among respondents. Age of producer, producer education, and survey response method were all associated with both interest in using a smartphone-based CHPR-keeping system and willingness to use an IBEISS to store their CHPR. Many U.S. cow-calf producers have access to the technology needed to collect and store electronic CHPR for precision beef production.

Conflict of interest

The sampling frame for this study was provided by the National Cattlemen's Beef Association (NCBA). The authors declare no conflict of interest.

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Endnotes

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[b]SAS for Windows v9.4, SAS Institute, Inc., Cary, NC

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