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Impacts of farming advisory videos hinge on the goals of extension actors that share them

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Abstract
This study examined how and why extension workers shared farming videos with farmers, revealing divergent appropriation patterns and their implications for digitization in agriculture. 294 extension workers in Bihar (India) were asked to circulate three wheat agronomy videos with farmers. Extension workers' circulation of these videos was observed using link tracking, phone surveys, and follow-up interviews. Results were analyzed using a novel analytic framework based in affordance theory. Extension workers varied widely in how much, how, and why they shared the farming videos. This variation was underpinned by extension workers' differing incentives and goals. In other words, extension workers heterogeneously appropriated—rather than homogeneously deployed—the practice of sharing farming videos. Some but not all of these appropriations were desirable from the perspective of service managers. For theory, extension workers' appropriations of farming videos demonstrate that prevalent conceptualizations of digital agricultural technologies do not account for the adaptation of these technologies by farmers and other actors in agricultural innovation systems. For digital agriculture evaluators, the findings caution against the prevalent focus on averaging effects of interventions and highlight the need to examine the variability of these effects within and across interventions. For extension service managers, the findings emphasize the importance of engaging extension actors with farmer-aligned incentives and goals. This study was limited in focusing on the video-sharing behaviors of human extension actors and not on algorithmic extension actors, like YouTube or farming advisory chatbots powered by large language models. However, the findings have implications for both: just as human actors variably appropriate digital tools, algorithmic extension actors also embed implicit goals that shape how agricultural information circulates. Future research should examine the goals and behaviors of these algorithmic actors that have increasing influence in agricultural innovation systems.

Keywords ICT4Ag · Digital agriculture · Affordance theory · Agricultural extension · Agricultural advisory · Agricultural innovation systems

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Abbreviations

DET	Digital extension tool. "digital tool through which farmers or other extension actors share access or discuss agricultural information or knowledge" (Coggins et al. 2022)
JEEViKA	The 'Bihar Rural Livelihoods Promotion Society'
CSISA	The 'Cereal Systems Initiative for South Asia'

Introduction

People and other actors pursue numerous goals through food systems. These goals include ambitions to improve human nutrition, rural livelihoods, animal welfare, social equity, biodiversity, climate change mitigation, climate change adaptation, cultural conservation, and economic growth (Herrero et al. 2021). Achieving these food system goals commonly requires changes in farming practices (Bouwman et al. 2021; Buddle et al. 2021; Herrero et al. 2021).

Food system actors have long depended on agricultural extension to influence farmers' practices in pursuit of food system goals. Agricultural extension, commonly abbreviated to extension, has traditionally been framed as a formal state-led practice of educating farmers with scientific agricultural knowledge to 'improve' farming practices. State- and scientist-led extension programs have been critiqued for often neglecting the values, knowledge, and innovations of farmers and other actors in agricultural innovation systems (Leeuwis 2013; Klerkx et al. 2012), as well as neglecting the power dynamics formal extension programs engage in (Cook et al. 2021). Hence, this paper interprets extension using the Rickards (2018) definition of 'extension-like practices': "practices that are designed to help engage farmers and generate, disseminate and scale appropriate innovations in the rural sector". Importantly, this definition does not interpret extension as the exclusive role of formalized 'extension workers', but rather a practice that any 'extension actor' might perform, including extension workers, farmers, and input retailers (Nettle et al. 2018).

Extension actors, particularly formalized extension programs, generally interpret the effectiveness of extension activities in relation to how many farmers they engage (Fabregas et al. 2019; de Roo et al. 2019; Anderson and Feder 2007). For example, Nedumaran and Ravi (2019) lament the limited reach of India's government extension system, reporting more than 1,000 farmers per government extension official. This agenda for scalability is understandable given extension actors' aims to maximize the interpreted benefits of their activities.

In pursuit of scalability, extension actors increasingly look to digital tools, like phone calls, WhatsApp, text messages, videos, chatbots, and customized smartphone applications. These 'digital extension tools' (DETs) have been defined as "digital tool[s] through which farmers or other extension actors share, access or discuss agricultural information or knowledge" (Coggins et al. 2022). DETs can be interpreted as a subcomponent of 'digital agriculture', which has been defined as "expanded reliance on collecting, integrating, analysing, and applying digital data in agri-food systems" (Roeven et al. 2024). DETs can generally be replicated at low cost, making them attractive for formalized extension actors working to 'reach' large numbers of farmers (Fabregas et al. 2019). For example, the Government of India established the Kisan Call Centre (KCC) in 2004 "with an aim to improve awareness and knowledge efficiency of farmers" (Yashavanth et al. 2022). A review by India's National Academy of Agricultural Research Management found that "the KCC scheme became a hit with farmers", given that the call centre received more than five million calls in one year (Yashavanth et al. 2022). Importantly, farmers and other extension actors have also created their own DETs to access and share farming information using generic digital platforms like Facebook (Lee and Suzuki 2020), YouTube (Coggins et al. 2022), WhatsApp (Coggins et al. 2025a), and informal phone calls (Butt 2015). For example, a farmer from Punjab created the farming advisory YouTube channel Farming Leader, which had more than six million subscribers and 1.1 billion video views as of 21 February 2025 (Fig. 1). Faxon (2023) thereby developed the concept of 'appropriated agritech', defined as "the process of incorporating new digital technologies that are not originally intended for farming into agricultural systems".

Two concerns are commonly raised regarding the use of digital tools in agricultural extension. First, limited *usability* for some farmers, particularly for marginalised social groups (Tauzie et al. 2024; Porciello et al. 2022; Wyche and Olson 2018). To illustrate, a female farmer in India may be unable to watch a 'Farming Leader' video given limited access to time, smartphones, or affordable mobile networks. The second common concern regarding DETs is their limited *usefulness* for some farmers (Richards et al. 2024; Coggins et al. 2022; Lecoutere et al. 2023; Cai et al. 2019). For example, another female farmer in India may be able to access a 'Farming Leader' video, but its advice may be irrelevant to the farmer's values, existing knowledge, trust in 'Farming Leader', agroecology, social constraints, and economic constraints. Inequitable usability and usefulness of digital extension tools not only constrain their potential benefits but can also cause unintended harms, including disempowerment of marginalised social groups (Hidalgo et al. 2024; Tzachor et al. 2022).

In response to these concerns, formal extension workers and informal extension actors commonly rely on

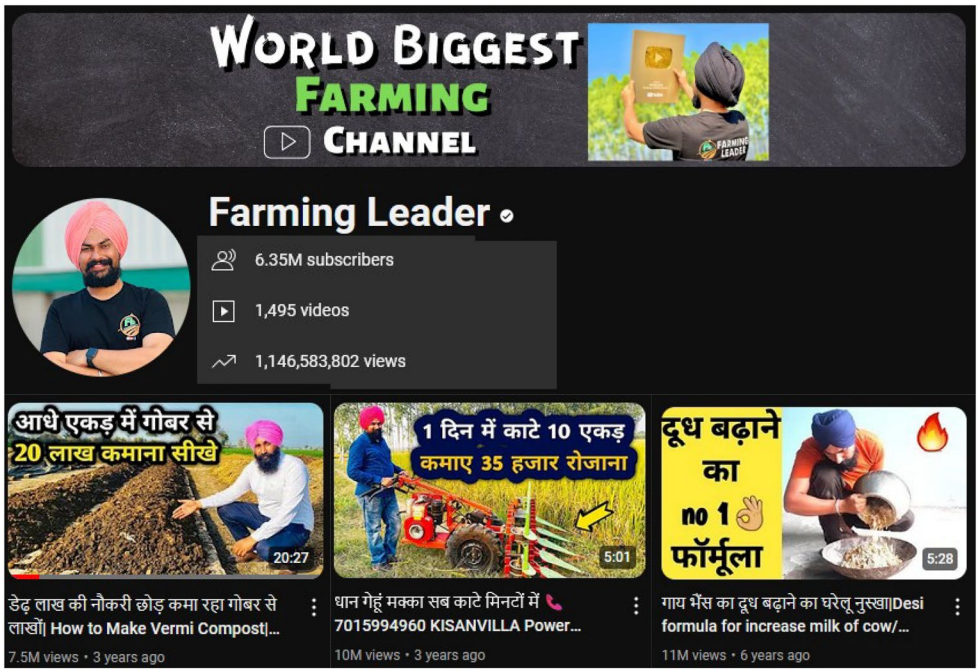

Fig. 1 Screenshots from the 'Farming Leader' YouTube channel on 22 June 2024 (YouTube 2025a). The channel was created by a farmer from Punjab, India. We received permission from YouTube and the owner of this YouTube channel to feature these images in this paper

person-to-person discussion to make digital extension tools usable and useful, not just scalable (Porciello et al. 2022; Munthali et al. 2018). For example, extension actors increasingly help farmers access and discuss farming videos, a practice termed 'video-assisted extension' (IDinsight 2023). Human-supported video viewings have sometimes made these farming videos more *usable* for marginalized farmers, such as facilitated video screenings using battery-powered projectors (Baul et al. 2024; Kadiyala et al. 2021). In addition, discussion of these farming videos has sometimes made them more *useful*, where farmers have collaboratively worked out if and how the farming advice was adaptable to local priorities and farming systems (Cai et al. 2019; Gandhi et al. 2007). It is important to note that video-assisted extension has not only been practiced by formal extension workers but also by informal extension actors, like farmers (Faxon 2023; Coggins et al. 2022; Maredia et al. 2018; Sousa et al. 2016). For example, farmers who engaged in a video screening in Uganda reported that learning "mainly occurred outside the video hall as they discussed and implemented what was shown in the video" (Karubanga et al. 2019).

Person-to-person sharing and discussion of farming videos have thereby received significant traction with researchers, governments, and international development donors. The uses and impacts of video-assisted extension have been evaluated by more than fourteen empirical studies (Porciello et al. 2022), including numerous randomized controlled trials (Table 1; Lecoutere et al. 2023; IDinsight 2023). Notwithstanding some acknowledgement of heterogeneity (Baul et al. 2024; IDinsight 2023), researchers engaged in these evaluations have predominantly aimed to distil the average effects of video-assisted extension (Table 1). For example, IDinsight (2023) reviewed the five randomized controlled trials in Table 1 and generalized that "the available evidence suggests that the VMA approach is cost-effective" (VMA referring to video-assisted extension; IDinsight 2023). Relatedly, governments and international development donors have invested heavily in disseminating video-assisted extension across diverse contexts. For example, the Bill and Melinda Gates Foundation has provided at least US$36 million in grants to the NGO 'Digital Green' to scale out video-assisted agricultural extension in India and Ethiopia[1].

Existing research neglects the actors and processes involved in sharing and discussing farming videos (Carolan 2020). Almost all peer-reviewed studies of this practice evaluate narrow and pre-defined outcomes of video-assisted extension from pilot interventions implemented by formal extension programs (Table 1). A few qualitative studies have researched farmers' experiences of video-assisted extension (Cai et al. 2019; Karubanga et al. 2019; Gandhi et al. 2007). However, to our knowledge, no studies have examined the experiences and behaviors of extension workers tasked with sharing and discussing videos with farmers. Existing studies almost always assume that government extension workers passively disseminate video-assisted extension interventions as they were designed by service managers (Table 1). Existing evaluations of video-assisted

[1] See grant IDs INV-006978, INV-008086, INV-008788, OPP51526 in the Bill and Melinda Gates Foundation Grants data file (last accessed 5 April 2024).

Table 1 Randomized controlled trials (RCTs) of video-assisted extension that were included in the review by idinsight (2023)

RCT	Context		Video propositions and encounters				Mean outcomes	
	Location	Year	Video(s) length	Crop or livestock focus	Topic	Viewings and facilitated discussions per farmer	Practice change [a] (USD / practice changed)	Yield change
Baul et al. 2024[b]	India, Bihar	2014–2015	"Short"	Rice	System of rice intensification	3 group viewings & discussions	$0.5-$0.6	Mixed
Abate et al. 2023[c]	Ethiopia, four states	2017–2019	10–15 min	Teff, wheat, and maize	Planting and urea top-dressing	"Several" group viewings & discussions	Row planting: $30 Seeding rate: $16 Urea: $18	Nil
Van Campenhout et al. 2021	Uganda, eastern districts	2017	"Short"	Maize	Planting, weeding, nutrient management	2 private viewings without facilitated discussion	$9.24	Increase
Kadiyala et al. 2021	India, Odisha	2017–2019	No data	Goats, spinach, and others	Nutrition sensitive agriculture	32 group viewings & discussions & 32 private follow-ups [d]	$16–21	Mixed
Gandhi et al. 2007	India, Karnataka	2007–2008	10 min on average	Finger millet and banana	Mixed	13 group viewings & discussions [e]	$3.70	Not measured

[a] This refers to the estimated cost-effectiveness for service providers to facilitate farmer practice changes. All studies estimated the *marginal* cost for the intervention to facilitate one additional practice change, aside from Gandhi et al. (2007), which estimated the *total* cost per practice change

[b] IDinsight (2023) reviewed a 2023 version of the Baul et al. (2024) analysis

[c] Bernard et al. (2019) was also included in the IDinsight (2023) review, but not in this table, as it appeared to be based on the same RCT as Abate et al. (2023)

[d] "Two facilitated group meetings per month per group over 32 months… In at least half of the meetings… groups will view and discuss [nutrition-sensitive agriculture] videos on a pre-defined set of prioritised practices… Follow-up visits to all participating pregnant women and mothers of children aged 0–23 months after each video viewing"

[e] "An average of 280 farmers attended at least one screening each month"

extension typically do not even provide demographic information about the extension workers tasked with deploying video-assisted extension (e.g., Baul et al. 2024; Abate et al. 2023; Kadiyala et al. 2021). This neglect of the actors and processes involved in video-assisted extension leaves practitioners with substantial uncertainty regarding how much, how, and why different extension actors share and discuss different farming videos in the 'real world' (Tzachor et al. 2022). Addressing this research gap would offer video-assisted extension researchers, funders, and service providers a richer understanding of outcomes from video-assisted extension, their contextual dependencies, and thereby how to support or not support digitization in agriculture more beneficially (Beach et al. 2025). Also, from a theoretical perspective, addressing this research gap presents an opportunity to improve conceptual clarity regarding digital tools in agricultural innovation systems (Carolan 2020).

In this paper, we research actors and processes involved in video-assisted extension in Bihar, a state in Eastern India. Two reasons make Bihar a particularly relevant context for researching video-assisted extension. (1) Bihar features large and diverse rural communities. Bihar is home to more than 130 million people, and 84% live in rural areas (Government of Bihar 2023, p.366). Most of these people depend on agriculture for their subsistence, livelihoods, communities, cultures, and lifestyles. These communities are highly diverse, with varied access to extension networks and other opportunities shaped by high rates of poverty and influential social structures, including gender and caste (Agarwal et al. 2022; Krishna et al. 2019; Eswaran et al. 2013). (2) In response to the perceived extension needs of Bihar's diverse rural communities, multiple actors are sharing and discussing farming videos in Bihar. These actors include farmers (Coggins et al. 2022), the Bihar Agricultural University (YouTube 2025b), YouTube's algorithms (Carolan 2020), agricultural advisory chatbots (Tzachor et al. 2022; Singh et al. 2024), extension workers employed by the Government of Bihar (JEEViKA 2013), international agricultural research institutes (YouTube 2025c), and the NGO 'Digital Geen' funded by the Bill and Melinda Gates Foundation (Baul et al. 2024). Insights regarding actors and processes involved in these video-assisted extension practices in Bihar would help practitioners navigate the challenges and opportunities presented by digital tools in agricultural extension in Bihar and other contexts.

To research actors and processes involved in video-assisted extension in Bihar, we implemented and observed a video circulation trial in collaboration with agricultural extension workers, specifically field technicians and agri-entrepreneurs, managed by the 'Bihar Rural Livelihoods Promotion Society' (JEEViKA) and the 'Cereal Systems Initiative for South Asia' (CSISA). JEEViKA is a program of the Government of Bihar. CSISA is a research and extension program led by CIMMYT and funded by international development donors, particularly USAID and the Bill and Melinda Gates Foundation.

Data from this study were also analyzed for two separate research papers: one on the circulation of farming videos with a gender perspective (Coggins et al. 2025b), and another on the opportunities and risks posed by WhatsApp in video-assisted extension (Coggins et al. 2025a). Each paper reports different analyses and implications with different uses and audiences in mind. The overlap with these other two papers is limited to their data collection methods.

Conceptual framework

The study was framed using affordance theory, an incisive analytic tool for observing and explaining technology use (Glover 2022; Evans et al. 2017; Davis and Chouinard 2016). Affordance theory is a relational theory of technology use, understanding that users value technologies based on the alignment between users and technologies, not the properties of technologies on their own. In this way, affordance theory differs from 'transfer of technology' frameworks, like 'Diffusion of Innovations' (Rogers 2003), which misleadingly conceptualize technologies as standalone objects that people only passively receive and deploy as fixed packages (Table 2; Glover et al. 2019; Glover et al. 2016). Affordance theory instead proposes that technologies present 'affordances' when the possibilities of a given material object *resonate* with the perceptions and capabilities of a given technology user. For example, a person named 'Chandani' may bite an apple she sees as a tasty fruit. Conversely, another person named 'Raymond' may throw an apple he sees as a ball. In these examples, Chandani and Raymond may use the same apple differently because of different perceptions, which are in turn underpinned by different goals, lived experiences, and cultural backgrounds (Glover 2022). In addition, both uses of the apple depend on the material capacities of the apple, Chandani, and Raymond (Davis and Chouinard 2016). In this case, Chandani may bite the apple given her strong front teeth, whereas Raymond may throw the apple given his physical capacity to throw. In summary, the affordances of the apple hinge on the perceptions of Chandani and Raymond *fitting* with the material capabilities of themselves and the apple (Evans et al. 2017).

Affordance theory was applied to the present study because the theory offers a 'way in' to analyze *how* extension actors circulate farming videos. Unlike the 'Diffusion of Innovations' theory, affordance theory creates room to observe and explain diverse uses of the same artefact (Table 2). This is needed when researching the circulation of farming videos because rural people routinely appropriate agricultural technologies in ways that their initial designers did not intend (Glover et al. 2016, 2019). For example, researchers have observed farmers appropriating practices of conservation agriculture (Bouwman et al. 2021; Brown et al. 2018), climate-smart agriculture (Smith et al. 2021), the system of rice intensification (Glover et al. 2017), and DETs (Faxon 2023; Coggins et al. 2022; Butt 2015; Patel et al. 2010; Gandhi et al. 2007).

To analyze the affordances of video-assisted extension from the perspective of extension workers, we rely on the Glover et al. (2019) conceptual framework for understanding and evaluating technological change in smallholder agriculture. This framework delineates technological change into four aspects, which are explained comprehensively by Glover et al. (2019) and summarised below in the context of this research.

1. **Proposition**: put simply, the ***technology*** as initially designed, i.e., the material object and protocol for its use. Interpreted here as the material farming videos and instructions to share these videos with farmers.

Table 2 Contrasting assumptions underpinning 'Diffusion of Innovations' and 'affordance theory', two frameworks for Understanding the use of technologies like apples

	Diffusion of Innovations	Affordance theory
Users ***value*** technologies based on their:	***Objective*** functions intended by a technology ***designer***, given the material capabilities of the technology. E.g., *Desirability of an apple for eating given its sugar, flavonoid, and fiber content*	***Alignment*** between the functions perceived by a technology ***user***, in relation to the material capabilities of the user and technology. E.g., *Desirability of an apple for eating given taste preferences and dental health of the user, in relation to properties of the apple*
Users ***experience*** technologies as:	Fixed packages. E.g., *an apple to eat*	A set of possibilities and constraints. E.g., *an apple as a fruit to share, seeds to plant, an object to throw*
Users can be	Human.	Human or non-human. E.g., *an apple used by people, goats, apple harvesting machines*

2. **Encounter**: put simply, the ***occasion*** when an agent first perceives the technology. Interpreted here as an extension worker's experience of their manager's WhatsApp messages sending the proposition.
3. **Disposition**: put simply, the agent's ***interest*** in the technology. Interpreted here as an extension worker's interest in sharing the farming videos with farmers.
4. **Response**: put simply, the agent's ***adaptation*** of the technology to their circumstance. Interpreted here as the extension worker's farming video use, which may or may not align with extension managers' intentions.

To make the Glover et al. (2019) framework more practically applicable, its 'disposition' component was subdivided using the Unified Theory of Acceptance and Use of Technologies (UTAUT) (Venkatesh et al. 2003). This framework delineates five components of users' dispositions towards technologies, in this case, perceptions of extension workers towards the proposed practice of sharing farming videos (Fig. 2).

1. **Performance expectancy**: "the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al. 2003). Interpreted in this context as 'will sharing the farming video help?'
2. **Social influence**: "the degree to which an individual perceives that important others believe he or she should use the new system." Interpreted in this context as 'what will people in my community think of me if I share the farming video?'
3. **Effort expectancy**: "the degree of ease associated with the use of the system" (Venkatesh et al. 2003). Interpreted in this context as 'will sharing the video be difficult?'
4. **Facilitating conditions**: "the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh et al. 2003). Interpreted in this context as 'is it possible for me to share the farming video?'
5. **Moderating influences**: referring to the influence of user gender, age, voluntariness of use, and experience across the above dimensions. Interpreted in this context as any underpinning social structure influencing the other four dimensions.

The UTAUT framework is compatible with the 'disposition' component of the Glover et al. (2019) framework, given that both focus on an agent's attitude towards a given technology. The UTAUT framework was also deemed applicable to this study given UTAUT's well-cited explanatory power across various contexts, including for digital extension tools in low- and middle-income countries (Porciello et al. 2022). Moreover, the framework was developed to understand the use of information technologies within formal organisations (Venkatesh et al. 2003). This aligns with our study of the use of videos within extension organisations.

Nevertheless, applying the UTAUT framework in this study may be inappropriate given that the framework was developed in a different cultural context from this research context. UTAUT's 'moderating influences' dimension creates room to observe the influence of gender and other context-specific social structures on extension workers' perceptions of sharing videos. However, this 'moderating influences' component misses other influential social structures in this research context, such as caste and situated values. In view of this, the 'moderating influences' were interpreted with more flexibility than just user gender, age, voluntariness of use, and experience.

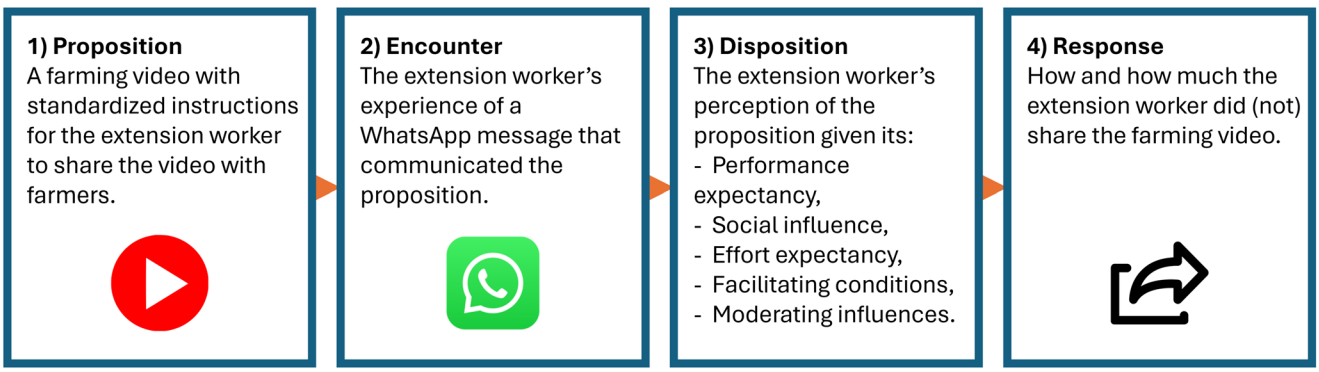

Fig. 2 The conceptual framework used in this study to interpret how, how much, and why different extension workers shared different farming videos. The framework synthesizes those published by Glover et al. (2019) and Venkatesh et al. (2003). All affordances are interpreted from the perspective of extension workers

Materials and methods

Methods overview

This study examined the dissemination processes of farming videos through an experimental intervention conducted in Bihar through partnerships with JEEViKA and CSISA from November 2022 to January 2023. The research engaged 294 extension workers from both organizations, tasking them with distributing three educational videos on wheat agronomy to farmers within their service areas. The study employed a Mixed Methods approach with a sequential explanatory design (Creswell, 2003). First, a quantitative assessment used link tracking technology and telephone surveys to measure both the frequency and methods of video sharing by extension workers. This was followed by a qualitative phase comprising twenty in-depth interviews with participating extension workers to provide contextual understanding and interpretation of the quantitative findings.

Ethical considerations

This research was approved by the Australian National University Human Research Ethics Committee on 11 October 2022 (Protocol 2022/511). Measures to protect participants included obtaining informed consent before conducting any telephone surveys or interviews with extension workers, keeping surveys and interviews brief to respect participants' time, maintaining confidentiality throughout the research process, and ensuring extension workers could continue accessing the wheat agronomy videos after the study concluded.

Research participants

The study involved 294 smartphone-equipped extension workers, comprising two main groups. The first group consisted of 251 agri-entrepreneurs supported by JEEViKA, a Government of Bihar program focused on the economic and social empowerment of people in rural Bihar. These agri-entrepreneurs, part of a larger network of approximately 400, provided multiple services to farmers: agricultural input sales, extension services, banking access, market linkages, and rice seedling nursery support. The second group included all 43 CSISA field technicians working in Bihar and eastern Uttar Pradesh. These technicians supported CSISA's broader mission of reaching eight million farmers through their agricultural research and extension initiatives, primarily by conducting on-farm trials and disseminating improved farming practices. The majority of participating extension workers operated in North Bihar, primarily in the districts of East Champaran and Muzaffarpur (Fig. 3). While most participants had previous experience receiving farming videos via WhatsApp from their managers, this was not a standard practice.

Experiment details

Videos

Each extension worker received three wheat cultivation advisory videos. The videos covered distinct agronomic topics: early sowing, irrigation timing, and weed management. They ranged from 3:30 to 3:48 min in length and were presented in Hindi. Each video featured two experts: a wheat agronomist and a successful Bihar farmer who had implemented the recommended practice. The video format was informed by nine preliminary key informant interviews with Bihar farmers and extension workers, who helped determine the most relevant aspects: wheat as the focus crop, specific agronomic topics, optimal duration, language choice, and the dual-expert presentation structure. The content was jointly developed by the featured farmers and a CIMMYT agronomist, working with a local agricultural video production specialist. For each topic, two versions were created: one featuring a successful male farmer and another featuring a successful female farmer. English-subtitled versions of all videos are available in Appendix 1.

Video dissemination

Extension workers were initially notified about the video-sharing initiative through a standardized Hindi message sent by their managers via WhatsApp groups (see Appendix 2). A dedicated WhatsApp account managed all subsequent communications and responded to participant questions. Each extension worker received individual videos through standardized WhatsApp messages containing a video link, content description, and a request to share with farmers in their community using their preferred method. All messages came from the same WhatsApp account and included consistent JEEViKA and CSISA signature information (see Appendix 3). Video distribution aligned with relevant crop calendar dates, with the wheat sowing video sent on 26–27 October 2022, the irrigation scheduling video on 9–11 December 2022, and the weed management video on 23 December 2022 (Fig. 4). All messages were sent during working hours (8:38 am −5:27 pm India Standard Time). Since simultaneous distribution was not possible, the order of video link delivery was randomized among participants. Four days after each video distribution, extension workers received a standardized reminder message through their WhatsApp groups (see Appendix 4 for the reminder message format).

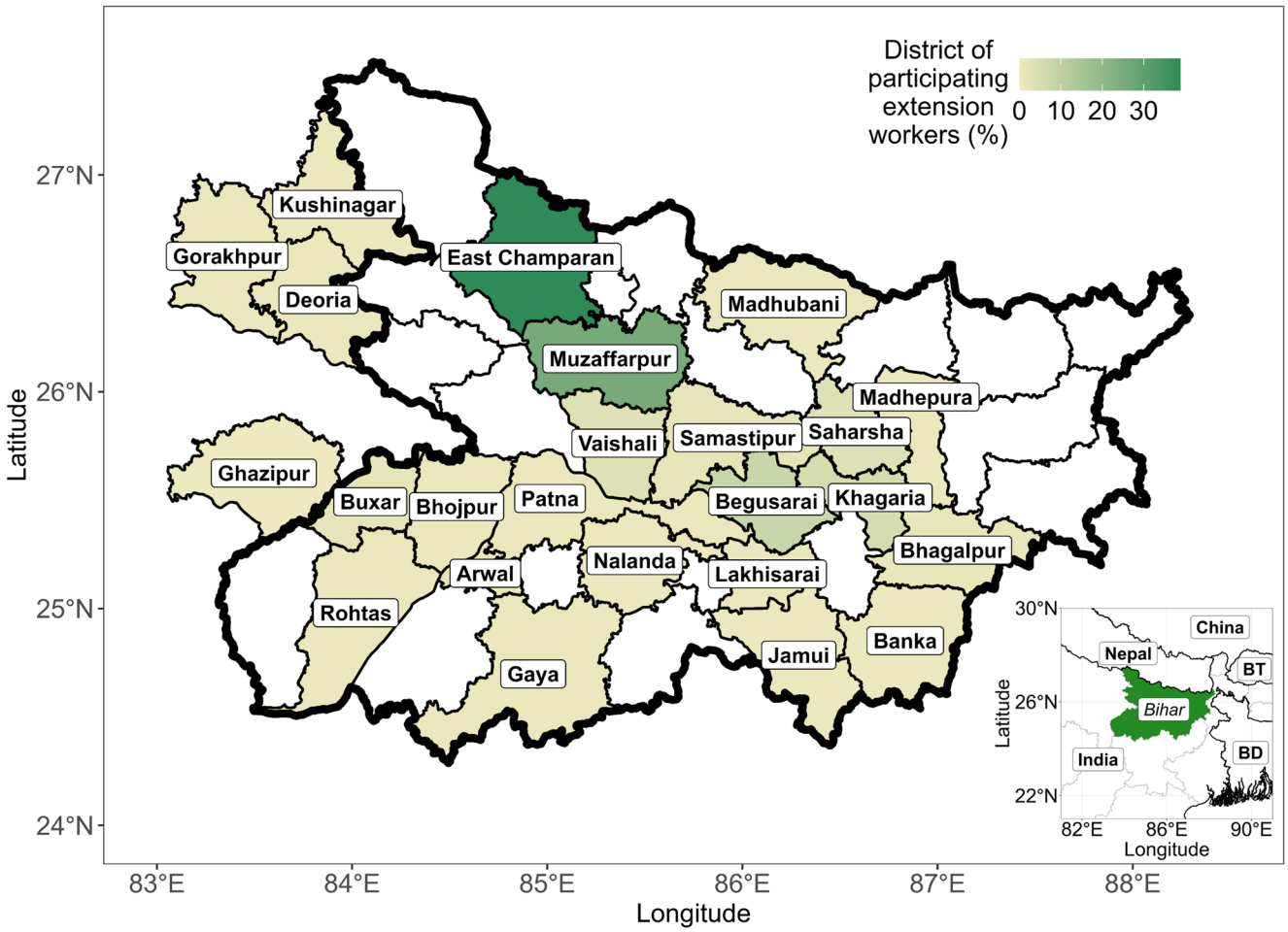

Fig. 3 Districts of Bihar in which the extension workers who participated in this study were employed. Additionally, a small proportion of participating CSISA field technicians were based in neighbouring districts of Uttar Pradesh, specifically Deoria, Kushinagar, Ghazipur, and Gorakhpur. The figure also includes a map indicating the location of Bihar (bottom-right corner). This map abbreviates Bangladesh as BD and Bhutan as BT.

Quantitative measurement of video circulation

Video engagement was monitored using 'Wistia', a commercial video tracking platform. Each extension worker received unique links to the three videos, allowing the software to track view counts, viewing duration, and unique IP addresses accessing each link. This monitoring was conducted without explicitly informing the extension workers, an approach that received ethical approval from the Australian National University Human Research Ethics Committee on October 11, 2022 (Protocol 2022/511), following consultation with JEEViKA and CSISA partners. Telephone surveys complemented the link tracking, with surveys conducted 8–17 days after each video's distribution. These surveys examined how extension workers shared the videos, achieving response rates of 68%, 65%, and 81% for the sowing, irrigation, and weed management videos, respectively. The complete survey instrument is available in Appendix 5.

Follow-up qualitative interviews

Twenty semi-structured interviews were conducted between 5 and 11 November 2022 to explore extension workers' video-sharing decisions and practices in more depth. Interviewed participants were selected through purposive sampling to ensure diversity across work location, gender, age, religion, and video-sharing engagement levels, as indicated by 'Wistia' tracking data (Table 3; Robinson 2014). Interviews were conducted in Hindi, predominantly in person, with audio recording (with one telephone interview and one unrecorded exception). The interview protocol, detailed in Appendix 6, guided consistent topic coverage and sequencing. Interview data were analyzed using inductive coding and thematic analysis methods (Braun and Clark, 2006) using NVivo version 14 software.

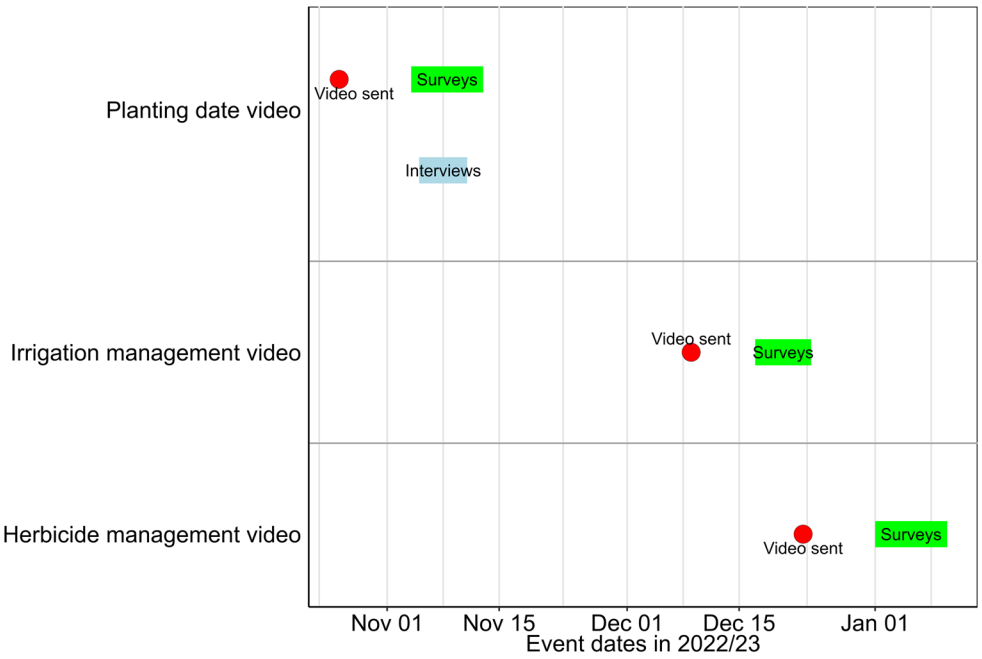

Fig. 4 Timeline for dissemination of videos to extension workers, and subsequent observation of their video-sharing behaviors through link tracking, telephonic surveys, and in-depth interviews

Table 3 Demographic characteristics and video-engagement patterns of extension workers who participated in at least one of the three data collection methods: link tracking, phone surveys, and semi-structured interviews

	Link tracking	Phone surveys	Semi-structured interviews
Average number of data collection participants per video	270	179	20 (only following the first video)
Extension role	85% agri-entrepreneur, 15% field technician	83% agri-entrepreneur, 17% field technician	80% agri-entrepreneur, 20% field technician
Gender	23% women, 77% men	24% women, 76% men	20% women, 80% men
Age (median)	32 years	32 years	35.5 years
Age (range)	20–55 years	20–55 years	23–50 years
District	40% East Champaran, 24% Muzaffarpur, 36% other	39% East Champaran, 25% Muzaffarpur, 36% other	60% East Champaran, 28% Muzaffarpur, 12% other
Video views	75% zero, 11% one, 14% multiple	61% zero, 11% one, 16% multiple, 12% missing data	15% zero, 20% one, 45% multiple, 20% missing data

The sample sizes for each method are lower than the total research population ($n=294$) due to technical issues with video links (8% failure rate) and voluntary participation in the phone surveys. Even so, the consistent distributions of extension roles, gender, age, and district representation across methods suggest that each subsample effectively reflects the research participants. The participant representation data for link tracking and phone surveys have been averaged across the three videos, since link tracking and phone surveys were repeated for each of the three videos. Appendix 7 disaggregates this table with each combination of video and data collection method

Results

Three key results emerged:

1. Extension workers varied in 'how much' they shared videos.
2. Extension workers varied in 'how' they shared videos.
3. Extension workers varied in 'why' they shared videos.

Linking back to our conceptual framework, the first two key results center on extension worker 'responses', while the third key result centers on extension worker 'dispositions', including how these were influenced by the video-sharing 'propositions' and 'extension workers' 'encounters' with them. In this way, the conceptual framework is used in reverse to observe and explain extension workers' uses and perceptions of the affordances posed by video-assisted extension (Fig. 2).

Key result #1: Extension workers varied in 'how much' they shared videos

The 294 participating extension workers collectively facilitated 1,368 views of the three videos. 60% of extension

workers did not open, let alone watch, any of the videos sent to them (Fig. 5). Conversely, less than 5% of extension workers facilitated 60% of the video views, with the most 'successful' extension worker facilitating 133 views of their unique link to the irrigation video. The total number of video views facilitated by each extension worker was interpreted as a proxy for the extent to which extension workers successfully shared these farming videos. This interpretation appeared valid considering more than 70% of the total video views (979 out of 1,368) were from unique 'Internet Protocol' (IP) addresses. Moreover, 24% of surveyed extension workers reported that they primarily shared videos by screening them on a personal smartphone, which would most likely have always had the same IP address.

The role of extension workers was the strongest predictor of the extent of their video sharing, of all the demographic characteristics listed in Table 3. CSISA field technicians were typically more engaged in sharing videos than JEEViKA agri-entrepreneurs (Fig. 6). CSISA field technicians facilitated an average of eight views per video, while JEEViKA agri-entrepreneurs facilitated an average of 0.6 views per video. These numbers illustrate that extension workers varied markedly in how much they shared farming videos, despite all extension workers receiving the same videos through the same WhatsApp messages.

We also observed variability in video-sharing outcomes across videos, not just across extension workers (Fig. 5). Extension workers collectively facilitated 579 views of the early planting video, 431 views of the irrigation management video, and 358 views of the weed management video. The variation in outcomes across different videos and different extension workers also appeared to interact. Indeed, the extension workers who were most successful in sharing one video were not always the most successful in sharing the other videos (Fig. 5).

Key result #2: Extension workers varied in 'how' they shared videos.

Extension workers creatively adapted the functions, methods, and recipients of video sharing to their contexts. Like 'key result #1', this result relates to the 'responses' component of the Glover et al. (2019) conceptual framework, where technology users engage in a "functional (re)configuration of the technological design to suit its new situation".

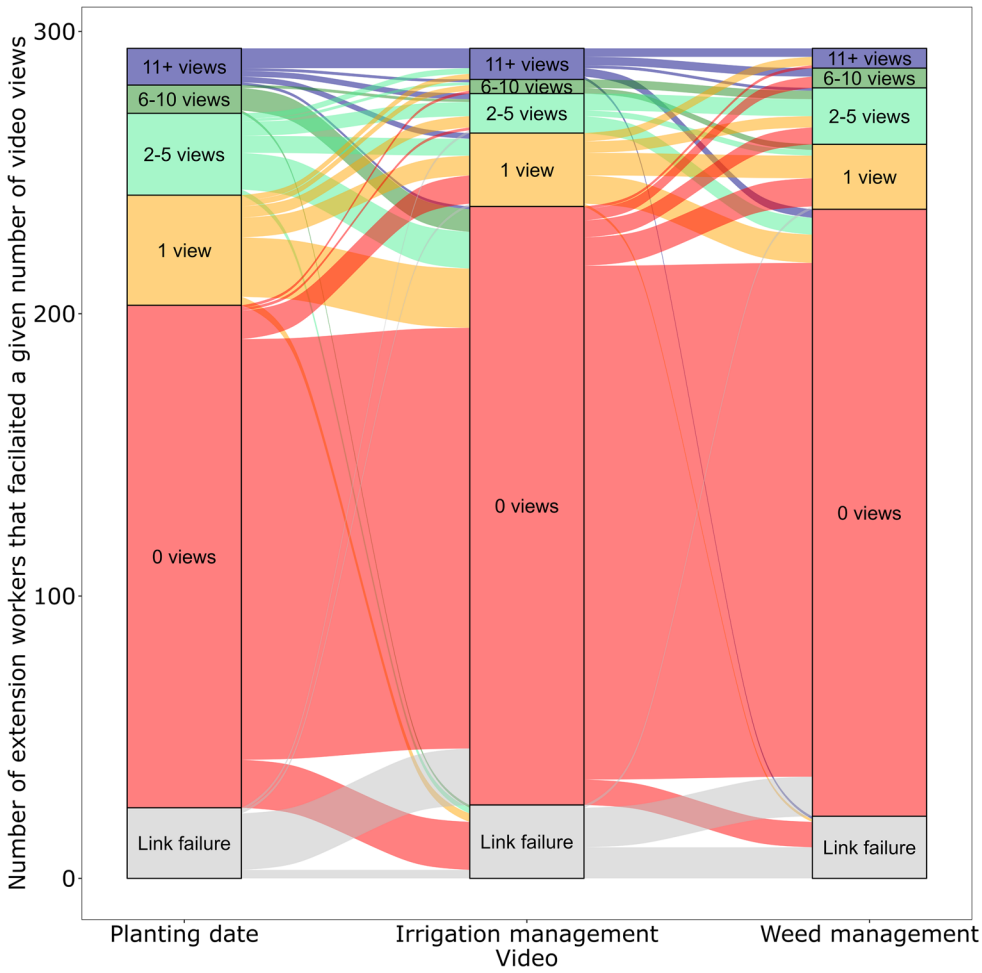

Fig. 5 Variation in video-sharing performance across extension workers ($n=294$), and across videos ($n=3$). 'Wistia' link tracking data enabled us to observe how many views each extension worker facilitated for each video because each extension worker received a unique link to each video. 'Link failure' refers to the small minority of cases where extension workers reported in phone surveys that their video link did not work on their smartphone

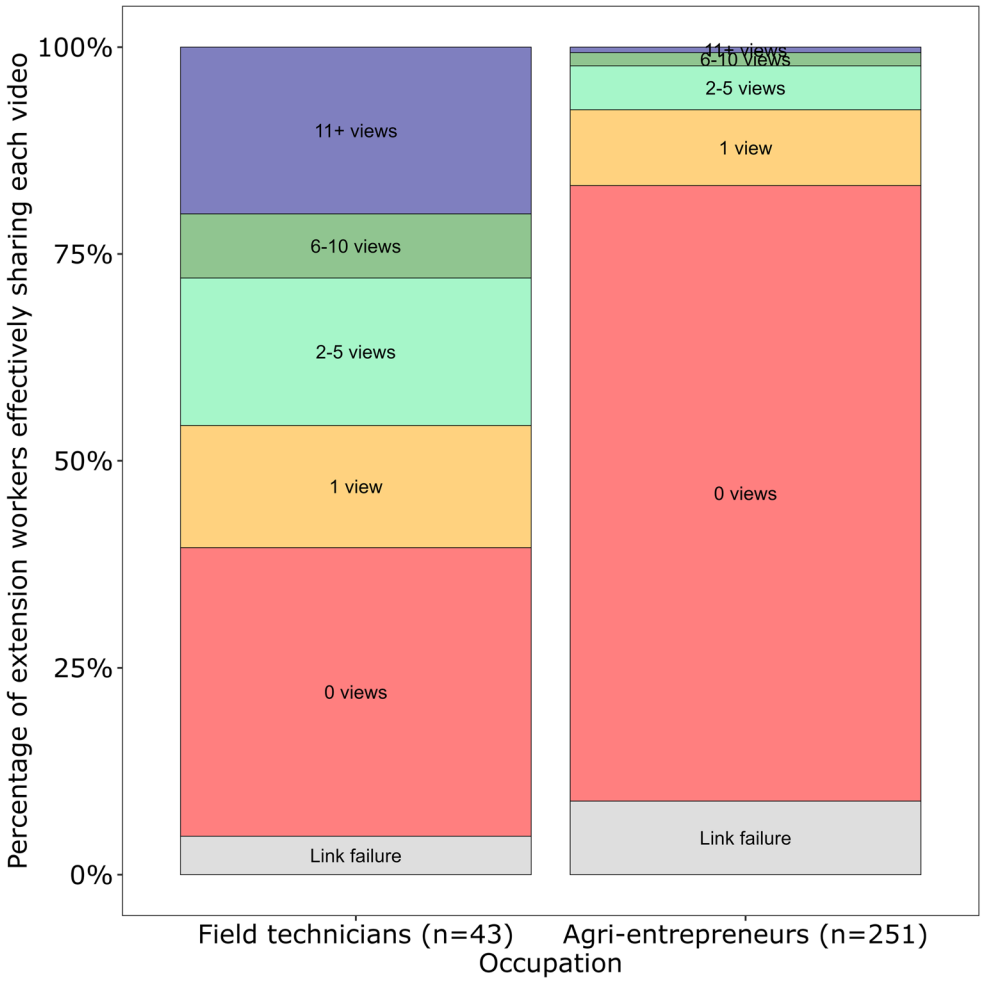

Fig. 6 Average sharing performance of each extension worker for each of the three videos, disaggregated by the organization participating extension workers worked for. The sample size refers to the number of participating extension workers from each organization. The number of views refers to the average views facilitated per extension worker per video – not views of all three videos aggregated

Adapting the functions of video sharing

The standardized WhatsApp message invited extension workers to share videos as a discrete extension activity. Some interviewed extension workers rejected this compartmentalized mode of engagement and instead used videos to complement, not just supplement, their other extension activities. For example, some extension workers reported using the link to provide reference material for their field demonstrations; "I show them the video first and then take them to the field". Other extension workers reported using videos to provide credibility to their advice shared in face-to-face conversations.

Conversely, other interviewed extension workers adapted the function of sharing videos to pursue priorities outside of extension. One interviewed CSISA extension worker reported sharing the video to recruit a farmer for an on-farm field trial designed for research, not extension:

> He was hesitant about it in the beginning. He had questions like will it work for him, what problems he would face as a small farmer. I showed the video to him to clear his doubts and hesitation so that he can relate to it as he is a small farmer and the video is all about small farmers. So, I showed the video to him as it is all about small farmer. He had interest already and the video helped remove his hesitation to take the method up.

Also, interviewed JEEViKA extension workers who shared the early wheat planting video often reported doing so to strengthen their relationships with farmers and thereby increase their input shop sales. For example:

> If I show them the video and share with them, they will acknowledge the fact that I have knowledge about the new technique and ultimately they will come and buy inputs like seeds and fertilizers from me.

Adapting the methods of video sharing

Extension workers also varied in the ways they shared the farming videos. According to the phone surveys, 70% of extension workers primarily relied on WhatsApp to share

Table 4 Synthesis of affordances and anti-affordances offered by videos to extension workers, according to semi-structured interviews

	Affordances	Anti-affordances
Performance expectancy	**Some extension workers were highly motivated to help farmers through extension** **Planting date video may support farmers through its**: - Brevity - Featured agronomist - Featured farmer - Specific and practical advice - Visualization of practices and benefits	**Some extension workers prioritized non-extension work** **Videos may not support extension because videos**: - Common in rural Bihar - Not always trusted - Not always taken seriously **Planting date video may not support extension because**: - Some farmers already know - Unactionable for some farmers - Video may misalign with extension worker values **Encounter with video-sharing proposition over WhatsApp may not support sharing videos because**: - Unclear instructions - Not motivating
Social influence	- Opportunity to build reputation and trust	- Opportunity to lose reputation and trust
Effort expectancy	- Quick and easy, especially over WhatsApp - Videos can save time explaining things verbally or one-to-one	- Minor hassle encouraging farmers to watch - Minor hassle responding to farmer questions - Addressing negative feedback - Showing videos on phone can be time-consuming - Showing videos on projector difficult given low projector availability, portability, and ease of use - Extension worker's phone number might be misused
Facilitating conditions	- Mobile network availability - Extension worker smartphone access	- Time unavailability given caregiving responsibilities, rice harvest, and preparations for religious festivals. - Limited relationships with farmers to share the video with - Mobile network unaffordability - Husband using the smartphone - Broken smartphone

the farming videos, 24% primarily relied on showing the video on their phones, 5% primarily relied on discussing the video content with farmers, and 1% primarily relied on Facebook posting. One interviewed extension worker even reported using a portable speaker, in conjunction with showing the video on his phone, to make the wheat planting video accessible to a larger group of women farmers. Interviewed extension workers' explanations for why they chose these media for sharing videos are analyzed in detail in Coggins et al. (2025a).

Adapting the recipients of shared videos

Extension workers also filtered the people they shared the video with. In some cases, this adaptation was desirable from the perspective of their extension program managers. Some extension workers selectively shared the planting date video with farmers who could benefit most from the videos, such as farmers who were geographically remote, had vacant fields required to plant wheat early, or would on-share the recommended farming practice. However, in other cases, this filtering excluded marginalized social groups and was thus undesirable from the perspective of extension program managers. For example, some extension workers only shared videos with farmers with smartphones (generally wealthier farmers), farmers who visited input shops (generally male farmers), and farmers with whom extension workers were personally connected.

Key result #3: Extension workers varied in 'why' they shared videos.

Interviewed extension workers reported diverse reasons for their varied engagement with video sharing (Table 4). These reported reasons are organized using the conceptual framework visualized in Fig. 2.

Performance expectancy: 'will sharing the video help?'

Some interviewed extension workers saw value in the videos to help them help farmers. Some extension workers valued the wheat planting video for its brevity, practical specificity regarding sowing dates, and explanation of benefits that resonate with farmers. Other extension workers valued the video for including perspectives from an agronomist with "scientific knowledge", while other extension workers valued the videos for also including perspectives of farmers that are "relatable" and "will not tolerate losses". Other interviewed extension workers saw value in the videos for their "visual impact" in demonstrating novel farming practices and their benefits:

> There is a difference between saying and explaining orally and showing. If [farmers] see the video, they get motivated. When they see the video, they can see the practical difference and difference between the thickness of the grain yielded by the application of new technique and the grain produced from older methods. (Male agri-entrepreneur)

In contrast, other interviewed extension workers were uninterested in sharing the farming videos because they perceived videos as generally unhelpful for supporting farmers. Some extension workers observed that videos are now very common in rural Bihar and farmers rarely trust them or take them seriously. For example, an older male agri-entrepreneur perceived:

> [Farmers] will watch it as a movie but will not implement it practically. Later, they will forget about it and not take it that seriously, unless, they see the practical application. So, the video is not that effective.

Other extension workers were uninterested in sharing the farming videos because they had concerns about the specific videos shared with them. For example, some extension workers thought the planting date video was irrelevant to farmers already aware of the benefits of planting wheat early, or farmers who could not plant wheat earlier, given unharvested rice crops, machinery inaccessibility, fertilizer unavailability, seed unaffordability, or limited capacity or interest to take risks with novel farming practices. Also, interviewed extension workers occasionally disagreed with the advice conveyed in specific videos. For example, an interviewed JEEViKA agri-entrepreneur was enthusiastic about promoting organic agriculture and so unsurprisingly facilitated zero views on the weed management video, even though he facilitated seven views on the early wheat sowing video.

Other extension workers saw limited value in the specific videos because of their encounters with them over WhatsApp messages. Some extension workers explained a preference for being introduced to the video-sharing task through in-person meetings:

> If the agri-entrepreneurs would be briefed and informed in the meeting, they would gain confidence, realize the importance of the videos and understand the convenient ways to explain it to the farmers and how it would be helpful for the farmers.

Different again, some JEEViKA agri-entrepreneurs were uninterested in sharing the farming videos because they prioritized non-extension work. One female agri-entrepreneur perceived that some agri-entrepreneurs in her district were like "train coaches that are attached to the main engine, they are just going with the flow without passion and motivation". In contrast, other interviewed agri-entrepreneurs prioritized non-extension work because they were highly engaged in their other agricultural responsibilities, particularly trading agricultural inputs (see the material and methods for the multi-faceted job description of JEEViKA agri-entrepreneurs). It is important to note that interviewed JEEViKA agri-entrepreneurs commonly appeared intrinsically motivated to support farmers, not just to fulfil professional responsibilities, but because they cared about their communities:

> I like helping the farmers and when farmers in my area, village, family and locality do well I feel very happy and like it.

Social influence: 'what will people think of me if I share the farming video?'

Some extension workers were drawn to the reputational opportunities of circulating farming videos. One extension worker hoped that once farmers "succeed with the [recommended farming] practice they will say that the video I shared helped them". Another agri-entrepreneur thought circulating farming videos could build their reputation, even if the videos do not influence farming practices:

> It depends on them whether they follow or not. However, one thing gets engraved in their mind that I am giving a disseminating information on new techniques and technology in the field of farming and I am trying to help them and whatever information I am giving is for their benefit and betterment.

Conversely, other extension workers were cautious of the reputational risks of circulating farming videos that could be unhelpful or disagreeable to farmers. One female agri-entrepreneur explained, "it takes time to build an image but your image can be destroyed in seconds". Correspondingly, another agri-entrepreneur was particularly wary of the risk of negative public feedback:

> I firmly believe that people have the right to dislike anything they choose. However, one should avoid discouraging others and propagating unfavorable viewpoints. One's reputation is tarnished. If people do not like what I advocate they can politely express their opinion and say no. But after calling me for briefing and then criticizing me behind my back and spreading negative words about the subject… It only

> demotivates, hurts and derails the purpose which is meant for farmers' betterment.

Effort expectancy: 'will sharing the video be difficult?'

Most interviewed extension workers perceived sharing videos as relatively easy and time-efficient, particularly if sharing videos over WhatsApp. For the planting date video, some CSISA field technicians reported hassles "encouraging [farmers] to watch the video", taking "calls from people seeking more information", sharing their phone number with people that might "misuse" it, or responding to the "handful of people, perhaps 1–10%, that gave negative comments and created a nuisance". However, extension workers generally reported these hassles as minor and, in some cases, saved time as the video meant they "didn't have to explain everything".

Facilitating conditions: 'can I share the farming video?'

Interviewed extension workers commonly reported having insufficient time to watch and share farming videos. Some extension workers encountered the wheat planting video at a time of day when they were engaged in caregiving or household responsibilities. One female agri-entrepreneur recommended, "for women, the right time to share the video is between 5 pm and 8 pm". Other extension workers encountered the video at an inconvenient time of year, as some were busy preparing for the multi-day Chatth Puja festival; "cleaning the house and decorating it, buying puja stuff". Other extension workers were busy with responsibilities surrounding the harvest of monsoon rice crops.

A minority of extension workers reported other reasons for being unable to share the farming videos, even if they wanted to. Some extension workers reported that they did not watch or share the videos due to compatibility issues with material objects, such as video links not working on low-quality smartphones, broken smartphones, or mobile network unavailability (in one reported case). Other reported constraints were related to socio-economic constraints of extension workers, such as mobile network unaffordability, their husband holding their smartphones, or the extension workers lacking relationships with farmers to be able to share videos with them:

> I am already working here. But in other Panchayats there are new recruits so their relationship with the farmers are not yet established… So, videos were not shared much in those Panchayats. (Male agri-entrepreneur)

Discussion

In the present study, 294 extension workers were asked to share three wheat agronomy videos with farmers in their communities in India's eastern state of Bihar. Despite the standardization of the intervention, extension workers varied widely in 'how much' (key result #1), 'how' (key result #2), and 'why' (key result #3) they shared the videos with farmers. In other words, extension workers heterogeneously *appropriated* video-assisted extension rather than homogenously *deploying* video-assisted extension.

In numerous cases, the observed appropriations of video-assisted extension by extension workers appeared desirable from the perspective of extension service managers. For example, extension workers used videos to complement, not just supplement, their existing face-to-face extension activities (see key result #2). However, not all appropriations of video-assisted extension by extension workers appeared desirable from the perspective of extension program managers. For example, some extension workers' video-sharing practices excluded women and less wealthy farmers.

The observed appropriations of video-assisted extension by extension workers advance empirical literature regarding the use and impacts of digital extension tools (DETs). As critiqued in the conceptual framework section, most empirical literature has examined the uses and impacts of DETs through a lens of 'adoption', which misleadingly assumes that extension workers and farmers passively receive and deploy DETs as fixed packages (Glover 2022; Glover et al. 2016, 2019). Nevertheless, a handful of empirical studies have observed that farmers and extension workers have not just received DETs but commonly *created* their own DETs using generic digital platforms, like phone calls (Butt 2015), WhatsApp (Coggins et al. 2025a), Facebook (Lee and Suzuki 2020), and YouTube (Fig. 1). As defined in the introduction, Faxon (2023) conceptualized this creation of informal DETs from generic digital platforms as 'appropriated agritech'. Going further, other studies have observed that farmers have actively appropriated *formal* DETs, i.e., adapted agriculture-specific digital platforms created by formalized extension actors (Coggins et al. 2022; Gandhi et al. 2007; Patel et al. 2010). For example, some farmers in Gujarat appropriated a digital farming knowledge-sharing platform to advertise off-farm businesses, stay awake while irrigating, and share poetry and jokes. However, to our knowledge, this is the first study observing that extension workers, not just farmers, have appropriated formal DETs. In other words, this is the first study observing the appropriation of formal DETs by intermediaries tasked with disseminating these technologies. Such an observation is consequential because the impacts of farming technologies

depend on who they are shared with and how they are shared (Glover 2022).

For theory, the observed appropriations of video-assisted extension by extension workers imply that Faxon's (2023) 'appropriated agritech' concept does not go far enough in conceptualizing appropriations of digital agriculture (Faxon 2023). The Faxon (2023) 'appropriated agritech' concept helpfully highlights how users commonly appropriate generic digital platforms as agritech. However, the term and its definition limit appropriation to generic digital platforms. This implication is limiting considering that formal digital agriculture platforms have also been appropriated by farmers (Patel et al. 2010; Gandhi et al. 2007) and extension workers (as observed in this study). Given this, our findings endorse the Coggins et al. (2022) conceptualization of digital extension tools (DETs) and Roeven et al. (2024) conceptualization of 'digital agriculture' (both defined in the introduction). Like Faxon (2023), these conceptualizations capture user-led creation of informal digital agritech from generic platforms. Unlike Faxon (2023), these conceptualizations also capture user-led adaptation of specialized digital agriculture platforms. In turn, these conceptualizations create additional room for relational theories of technology use, like affordance theory and domestication theory, and thereby a fuller understanding of the uses and impacts of digital agriculture (Richards et al. 2024; Carolan 2020).

For evaluators of video-assisted extension, the observed variability of video-assisted extension practices cautions against globalizing interpretations of video-assisted extension practices and their outcomes. As discussed in the introduction, IDinsight (2023) reviewed the five randomized controlled trials in Table 1 and generalized that "the available evidence suggests that the VMA approach is cost-effective" ('VMA' referring to video-assisted extension; IDinsight 2023). Such globalising assessments are misleading considering the variability of video-sharing practices and outcomes observed within and across video-assisted extension interventions (Table 1; Figs. 5 and 6; Baul et al. 2024). Randomized controlled trials have helpfully demonstrated that sharing farming videos *can* cost-effectively engage farmers *if* the propositions resonate with the values and capabilities of extension workers and farmers in a given context. The practically important question then becomes what video-sharing propositions resonate with relevant actors in a given context? Evaluators of video-assisted extension could address this question by quantifying the *distribution* of its outcomes, not just its *average* outcomes (Table 1; Beach et al. 2025). Moreover, evaluators could use qualitative process evaluations that reveal unintended uses, rejections, and outcomes of DETs (Faxon 2023; Munthali et al. 2018; Patel et al. 2010). Such observations can help extension service managers support *desirable* adaptations of video sharing, like complementing other extension activities (see 'key result #2'), or helping estranged family members reconnect (Gandhi et al. 2007). Correspondingly, such observations can also help extension managers mitigate *undesirable* adaptations of video-assisted extension, like excluding women and less wealthy farmers. The process evaluation in this study was enabled by its novel combination of the comprehensiveness of the Glover et al. (2019) framework with the concreteness of the Venkatesh et al. (2003) UTAUT framework (Fig. 2).

For funders and managers of video-assisted extension services, the observed variability of video-assisted extension practices highlights the importance of engaging extension actors with goals and incentives aligned with supporting farmers. This implication can be seen in the variability of extension actors' goals and behaviours within the researched context. For example, field technicians generally shared videos more widely than agri-entrepreneurs (Fig. 6). Agri-entrepreneurs commonly did not see value in watching let alone sharing videos (Fig. 6), and the few that engaged in video sharing generally reported doing so to increase their input sales (see 'key result #2'). Neither case is ideal for extension managers as the first case involves no video sharing, and the second case excludes farmers who do not visit farming input shops, typically women and less wealthy farmers in this context. This example illustrates that depending on input retailers to play effective extension roles is fraught, as observed in other contexts (Nettle et al. 2018). More deeply, this example illustrates that outcomes from farming videos hinge on the goals of those sharing these videos. A practical implication for video-assisted extension practitioners is the importance of identifying and appropriately incentivising farmer-aligned video sharers (Klerkx 2020), such as the large subset of extension workers in this study who were highly motivated to support farmers in their community (Table 4).

For future research, we suggest analysing the goals and behaviors of algorithms that intermediate agricultural innovation systems. Like most other evaluations of video-assisted extension (Table 1), the present study only examined the video-sharing behaviors of human extension workers, specifically field technicians and agri-entrepreneurs. This means the existing literature neglects algorithmic extension actors like YouTube, Facebook, and farming chatbots underpinned by large language models (Carolan 2020). These algorithmic extension actors are increasingly influential in distributing farming advisory videos in Bihar and other rural contexts (Coggins et al. 2022; Singh et al. 2024). Such algorithmic extension actors are generally inaccessible to farmers without smartphones and mobile network access, typically women and less wealthy farmers in Bihar (Coggins et al. 2022). Moreover, it cannot be expected that the goals of algorithms in agriculture, like

YouTube, always align with the goals of farmers, let alone the goals of farm labourers, farmed animals, ecosystems, and food consumers affected by farmers' practices (Tzachor et al. 2022; Carolan 2020). These algorithmic extension actors appear set to become even more influential following recent investments in powerful 'large language models' built for agricultural extension, such as 'Farmer.Chat' and 'KissanAI' (Tzachor et al. 2022, 2023; Singh et al. 2024). Such algorithmic extension actors, therefore, require increased research attention.

Conclusions

The core empirical contribution of our study was an observation that extension workers did not homogenously deploy video-assisted extension but heterogeneously appropriated video-assisted extension. For theory, this finding implies that Faxon's conceptualisation of 'appropriated agritech' is limiting by only considering the appropriation of generic digital platforms (like Facebook) and thereby missing the appropriation of specialized digital agriculture platforms (like farming advisory videos). For evaluators of video-assisted extension, our core finding invites evaluators to proactively analyze the diversity of practices and outcomes rather than the predominant approach of generalizing average effects. For funders and managers of video-assisted extension services, our core finding highlights the need to attend to the goals of those who share farming videos, rather than just the farming videos themselves. A key limitation of our study was that its methods neglected algorithmic actors in video-assisted extension, like YouTube, Facebook, and AI-enabled chatbots. Further research should examine the behaviors and goals of these algorithmic extension actors, which are becoming increasingly influential in agricultural innovation systems in Bihar and globally.

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Declarations

Author biographies The lead author facilitated this research as a PhD student at the Australian National University. His interdisciplinary thesis draws on science and technology studies and systems agronomy to argue that the concept of 'adoption' misleads efforts to develop socially beneficial digital tools in agriculture. The authoring team featured multidisciplinary expertise in science and technology studies, gender studies, systems agronomy, and rural sociology.

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