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Farmers' Awareness and Adoption of Digital Agricultural Technologies for Sustainable Crop Production

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Abstract

The study was conducted at districts of Hisar and Fatehabad in the state of Haryana during the period 2022–23 to examine the farmers' awareness and willingness to adopt digital technologies in agriculture. Digitalization may be broadly classified into two domains: its direct impact on augmenting agricultural productivity and its indirect function in enabling farmers to make better-informed and higher-quality decisions. Thus, four villages, Rajli, Ghirai, Berseen, and Majra, were randomly selected for data collection. A total of 120 farmers were selected as respondents, and their socio-personal, socio-economic, and communicational characteristics were analyzed. The findings of the study revealed that the respondents exhibited a high level of awareness about digitalization in agriculture, with a significant percentage aware of various aspects of digital technologies. They were well-informed about the potential benefits, including enhanced productivity and sustainability. In terms of adoption, a substantial number of farmers had already integrated digital technologies into their farming practices. They used digital tools for various purposes, such as online data collection, automation of farm works, nutrient management, and soil health monitoring. Overall, the study highlighted the growing awareness and adoption of digital technologies among farmers in the selected regions. These technologies have the potential to revolutionize agricultural practices and improve productivity, sustainability, and the overall quality of produce. Digitalization in agriculture is poised to play a crucial role in shaping the future of farming.

Keywords: Digital agriculture, awareness, technology adoption, agricultural innovation

1. Introduction

The level of agricultural productivity exhibits significant variations across different regions of the globe. The existing disparity can be attributed to credit constraints, inadequate insurance markets, and deficient infrastructure and also suboptimal agricultural practises and inadequate management also contribute significantly to this issue. Farmers face challenges in adopting ICT for sustainable agriculture due to barriers like affordability, awareness, and complexity. Customized solutions can bridge the digital gap and enhance farming practices (Samadder et al., 2023). The adoption of digital technologies is crucial for achieving sustainability in agricultural systems and serves as a primary catalyst for enhancing productivity, achieving self-sufficiency, fostering competitiveness, and maximising profitability. (Kashina et al., 2022; Mohd et al., 2021). The implementation of digital technologies in farming tools and practises is an inevitable advancement in the field of agriculture (Walter et al., 2017; Klerkx et al., 2020). The current transformation is facilitated by advanced technologies such as remote sensing services, artificial intelligence (AI), immersive reality, the Internet of Things (IoT), and blockchain (BCT), all of which are integrated with mobile technologies (Sarkar et al., 2023). The advent of digital innovation has presented novel prospects for food enterprises within a digitally oriented agri-food system (Ganeshkumar and David, 2022). The utilisation of the internet's rapid expansion and its accompanying digital technologies, such as mobile phones, holds significant importance in facilitating farmers' access to necessary information and fostering revolutionary advancements in the agricultural sector (Anonymous, 2024). The success of farmers in agricultural pursuits is heavily contingent upon the availability and accessibility of precise, dependable, and focused information. The achievement of sustainable development in the agricultural sector is contingent upon the establishment of efficient communication channels for the widespread dissemination of agricultural technologies to

the ultimate beneficiaries (Khoshnodifar et al., 2016; Muriuki et al., 2016). In contrast to traditional extension approaches, the utilisation of ICT-based extension advisory methods offers the opportunity to effectively engage a larger number of farmers, typically in a prompt and cost-efficient manner. Consequently, these methods hold promise for expanding the involvement of small-scale farmers in overall agricultural production (Finger, 2023; Saravanan et al., 2015). Instead of consistently engaging in face-to-face interactions with farmers, extension agents employ a variety of communication methods such as phone calls, text messaging, videos, and internet platforms. This approach aims to minimise transaction costs and enhance the frequency of engagement between extension agents and farmers. ICT tools improve financial literacy and access to information for women (Sangeetha et al., 2016). Farmers' adoption of digital agricultural services is influenced by adoption intention and facility conditions, with performance expectation, social influence, and data quality playing crucial roles in shaping behavior (Wang and Dong, 2023). The implementation of digital advancements holds the potential to enhance decision-making processes in the field of agriculture and improve the efficacy of farm management techniques. However, it is imperative to ensure that farmers are provided with up-to-date information regarding the latest advancements in agricultural technologies and tools, which can be achieved through the implementation of specialised educational programmes (Al-Ammary and Ghanem, 2024). Farmers adopt digital technologies for sustainable crop production based on factors like age, education, access to credit, and perceived impact of crises, aiming for efficient and effective solutions (Akudugu et al., 2023). These advancements have the potential to significantly improve the practises and outcomes of agriculture and related activities, enhances farmers' knowledge and positively correlated with education, income, and innovation. (Madhushekar et al., 2024; Patel and Sayyed, 2014). The aim of this study is to examine the level of awareness among farmers regarding the digitalization of agricultural practises and their willingness to adopt digital technologies in the field.

2. Materials and Methods

The current experiment was carried out in the districts of Hisar and Fatehabad within the state of Haryana during the period 2022–23. Two villages, Rajli and Ghirai, from the Barwala block of the Hisar district, as well as two villages, Berseen and Majra, from the Fatehabad block of the Fatehabad district, were chosen randomly. In order to gather the necessary data, a random sampling was employed to choose 30 farmers from each of the selected villages. Consequently, a total of 120 farmers were selected as respondents for the present investigation. The study took into account various factors related to the farmers, including their socio-personal characteristics (such as age, education, caste, and land holding), socio-economic characteristics (such as irrigation methods, sources of irrigation, farming systems, crop rotation practises, and farm machinery), and communicational characteristics (such as extension contact and exposure to mass media). Additionally, the study considered the farmers' utilisation of Kisan Credit Card (KCC) and Soil Health Card (SHC), as well as their overall awareness and adoption of digitalization in agriculture for the purpose of sustainable crop production. The study assessed the level of awareness among farmers regarding the digitalization of agriculture for the purpose of achieving sustainable crop production using a 2-point continuum, with 'Aware' being assigned a value of '1' and 'Not aware' being assigned a value of '0'. In a similar vein, the study also assessed the participants' level of adoption, categorising it as either 'Adopted' (coded as '1') or 'Not adopted' (coded as '0'). Data was collected from the sampled respondents using an interview schedule that was deliberately designed and pretested prior to its administration. Meaningful inferences were drawn by employing appropriate statistical measures, such as the mean, frequency, percentage, and rank order.

3. Results and Discussion

3.1. Profile of selected respondents

3.1.1. Age distribution

The majority of respondents (66.67%) belonged to the middle age category, while a smaller proportion (21.67%) were classified as old age. The remaining respondents (18.33%) fell into the young age group, specifically those aged up to 35 years.

3.1.2. Educational attainment

Approximately 29.17% of the respondents possessed a pre-university/diploma level of education, while 21.67% had completed their graduation. Twenty percent (20.00%) of the individuals possessed a high school education, while 14.17% of them had attained education up to the post-graduate level. A small proportion of respondents (3.33%) possessed a middle school education, while an even smaller percentage (6.67%) had only completed primary schooling. The remaining 5.00% of respondents reported having no formal education, indicating a state of illiteracy.

3.1.3. Caste distribution

A majority of respondents (60.00%) belonged to the general caste, while the other backward class (OBC) accounted for 29.17% of the participants. A total of 10.83% of the respondents were identified as belonging to the scheduled caste (SC) category.

3.1.4. Land ownership

Regarding land ownership, a majority of the respondents (60.00%) were classified as small farmers, with land holdings ranging from 2.5 acres to 5.0 acres. The remaining farmers were categorized into three groups based on their land size: marginal farmers (up to 2.5 acres), medium farmers (5.00

to 10.00 acres), and large farmers (10.00 acres and above), accounting for 05.83%, 18.33%, and 15.84% of the total population, respectively.

3.1.5. Preferred information medium

All participants expressed their interest in mobile devices (100.00%) as the primary medium for accessing information related to the digitalization of agriculture and the welfare of farming communities. Mobile devices were ranked as the most preferred medium, followed by the internet (95.83%), newspapers (81.67%), television (66.67%), radio (54.17%), and farm magazines (50.00%).

3.1.6. Sources of information

The primary source of information for farmers was progressive farmers (100.00%), followed by Agricultural Development Officers (ADOs) (82.50%), Private agency extension officers (69.17%), Extension Scientists (63.33%) of the University/Krishi Vigyan Kendras in their district, subject matter Specialists (61.67%), and Sub-Divisional Agriculture Officers (48.33%) of the Department of Agriculture.

3.1.7. Farm machinery

The majority of farmers (70.00%) possessed a rotavator, which was ranked as the most common farm machinery. This was followed by the seed-cum fertiliser drill (54.17%), Zero till seed drill (37.50%), mould board plough (23.33%), puddler (18.33%), laser land leveler (13.33%), happy seeder (12.50%), Straw chopper (11.67%), and Super straw management system attached with combined harvester, shrub master & rotary slasher (4.17%).

3.1.8. Sources of irrigation

The majority of respondents had access to irrigation through a canal (100.00%), followed by the utilization of submersible pumps (54.17%), bore wells/tube wells (48.33%), and tanks (12.50%).

3.1.9. Farming practices

The participants exhibited a predominant preference for a farming system involving livestock (93.33%), with poly house vegetable production (18.33%) and organic farming (12.50%) ranking second and third, respectively. A small proportion of farmers engaged in various agricultural practices, including agroforestry (10.00%), floriculture (8.33%), mushroom cultivation (5.83%), beekeeping (05.00%), and poly house nursery (03.33%).

3.1.10. Crop rotation

A majority of the respondents implemented a crop rotation strategy, with the most commonly adopted rotation being cotton-wheat (62.50%), followed by rice-wheat (54.17%), pearl millet-mustard (5.21%), and sugarcane-wheat (1.88%) rotations.

3.1.11. Awareness of soil health cards

A significant majority of respondents possessed awareness of the duration (95.00%) for which the soil health card is valid, as well as the purpose of the soil health card (93.33%) as a tool for assessing soil health. A substantial proportion of respondents also possessed a soil health card (87.50%) and were aware of its role in promoting the prudent use of fertilizers (85.00%).

3.1.12. Kisan credit card

A significant proportion of participants possessed awareness of the kisan credit card (93.33%), with a majority reporting possession of such a card (91.67%). The respondents also had a substantial understanding of the renewal period for the kisan credit card (90.00%), as well as its role as a convenient and straightforward loan option (88.33%), devoid of any complications.

3.2. Awareness level of farmers about digitalization in agriculture

The data in Table 1 predicted the awareness level of farmers about digitalization in agriculture and revealed that the farmers were aware with 81.67% level of awareness about the statements like 'Are you aware about digitalization in agriculture?', 'Agricultural digitalization is the process of integrating advanced digital technology in agriculture', 'Digital soil health cards used to know the status of soil health, soil nutrients etc.' and 'Digitalization helps to mitigate the effects of climate change like environmental pollution etc.' which ranked I, followed by 'Digitalization in agriculture helps to reduce the input cost. (80.33%) ranked II 'Agricultural digitalization enables competition in digital markets of food systems' and 'Agricultural digitalization helps to get real time feedback (80.00%) ranked III; 'Digitalization in agriculture gives extra returns' and 'Agricultural digitalization safeguard farmers' data and privacy' (79.17%) ranked IV; 'Digitalization in agriculture is beneficial for sustainable crop production', 'Agricultural digitalization can use for diseases surveillance, pests, weeds, estimation of crop yield, crop damage, irrigation alert etc.', 'Digital agriculture, generally known as an evolution of precision agriculture to create a new paradigm in complete food systems cycle' and 'Agricultural digitalization updates pricing and trading' (78.33%) ranked V, 'Digitalization in agriculture doesn't needs extra resources', 'Digitalization in agriculture gives employment to youths throughout the year', 'Digital technology helps farmers to improve farm productivity and income', and thus the digitalization of agriculture has the potential to enhance the farm management process by providing farmers and farm advisors with intelligent and prompt insights, thereby resulting in improved farm efficiency (Lioutas et al., 2019), 'Digital ecosystems for agriculture practices play a significant role in long-term economic growth and structural transformation', 'Remote sensing and GIS forecast of weather, crop loss due to flood and rainfall, mapping of fields, crop output, soil temperature', 'Agricultural digitalization support digital entrepreneurship ecosystem' and 'Digitalization helps to improve farm management information system' (76.67%) ranked VI and it concluded

Table 1: Awareness level of farmers about digitalization in agriculture (n=120)

Sl. No.	Statements	Level of awareness				Rank order
		Aware	%	Not aware	%	
1.	Are you aware about digitalization in agriculture?	98	81.67	22	18.33	I
2.	Agricultural digitalization is the process of integrating advanced digital technology in agriculture	98	81.67	22	18.33	
3.	Digital soil health cards used to know the status of soil health, soil nutrients etc	98	81.67	22	18.33	
4.	Digitalization helps to mitigate the effects of climate change like environmental pollution etc	98	81.67	22	18.33	
5.	Digitalization in agriculture helps to reduce the input cost	97	80.83	23	19.17	II
6.	Agricultural digitalization enable competition in digital markets of food systems	96	80.00	24	20.00	III
7.	Agricultural digitalization helps to get real time feedback	96	80.00	24	20.00	
8.	Digitalization in agriculture gives extra returns	95	79.17	35	29.17	IV
9.	Agricultural digitalization safeguard farmers' data and privacy	95	79.17	25	20.83	
10.	Digitalization in agriculture is beneficial for sustainable crop production	94	78.33	26	21.67	V
11.	Agricultural digitalization can use for diseases surveillance, pests, weeds, estimation of crop yield, and crop damage, irrigation alert etc	94	78.33	26	21.67	
12.	Digital agriculture, generally known as an evolution of precision agriculture to create a new paradigm in complete food systems cycle	94	78.33	26	21.67	
13.	Agricultural digitalization updates pricing and trading	94	78.33	26	21.67	
14.	Digitalization in agriculture doesn't needs extra resources	92	76.67	28	23.33	VI
15.	Digitalization in agriculture gives employment to youths throughout the year	92	76.67	28	23.33	
16.	Digital technology helps farmers to improve farm productivity and income	92	76.67	28	23.33	
17.	Digital ecosystems for agriculture practices play a significant role in long-term economic growth and structural transformation	92	76.67	28	23.33	
18.	Remote sensing & GIS forecast of weather, crop loss due to flood and rainfall, mapping of fields, crop output, soil temperature	92	76.67	28	23.33	
19.	Agricultural digitalization support digital entrepreneurship ecosystem	92	76.67	28	23.33	
20.	Digitalization helps to improve farm management information system	92	76.67	28	23.33	
21.	Digitalization applications help to use proper data in decision-making, leads to low-input agriculture	88	73.33	32	26.67	VII
22.	Digital technology helps in reducing water consumption and the use of agrochemicals	88	73.33	32	26.67	
23.	Digital technologies are transforming agricultural value chains and modernizing operations	86	71.67	34	28.33	VIII
24.	Digitalization helps to overcome restriction of natural resources	86	71.67	34	28.33	
25.	The basic goals of sustainable agriculture are environmental health, economic profitability, and social and economic equity	78	65.00	42	35.00	IX
26.	Are you aware about smart phone application for remote monitoring & controlling of farm operations	78	65.00	42	35.00	
27.	Digital transformations strengthen access to foundational data and promote data sharing	65	54.17	55	45.83	X

that these technologies assist farmers in identifying and addressing issues, establishing cause-effect relationships, and ultimately making more informed planning decisions (Newton et al., 2020); 'Digitalization applications help to use proper data in decision-making and thus it is cleared that Big data and Artificial Intelligence (AI) applications have been shown to improve the decision-making abilities of farmers, as supported by references (Wolfert et al., 2017), leads to low-input agriculture' and 'Digital technology helps in reducing water consumption and the use of agrochemicals' (73.33%) ranked VII; 'Digital technologies are transforming agricultural value chains and modernizing operations' and 'Digitalization helps to overcome restriction of natural resources' (71.67%) ranked VIII; 'The basic goals of sustainable agriculture are environmental health, economic profitability, and social and economic equity' and 'Are you aware about smart phone application for remote monitoring and controlling of farm operations' (65.00%) ranked IX and 'Digital transformations strengthen access to foundational data and promote data sharing' (54.17%) ranked X from ascending to descending percentage order of their awareness level about digitization in agriculture. The survey revealed that the respondents had an awareness level of 75.93%, showing that the farmers were well-informed about the possible advantages, such as increased productivity and sustainability by the digitalization in agriculture.

3.3. Adoption level of farmer about digitalization in agriculture

The data in Table 2 predicted the adoption level of farmers about digitalization in agriculture and resulted that the farmers adopted agriculture digitalization about the statements like 'Digitalization in agriculture helps to online data of crops on Meri Fasal Mera Bayora portal (89.17%) level of adoption which ranked I followed by 'Agricultural digitalization helps for survey of field crops online' (88.33%) ranked II; 'Agricultural digitalization helps for automation of farm works like harvesting, spraying, seeding, weeding, thinning, sorting and packing' (86.67%) ranked III and it is revealed that respondents gained information to develop the agriculture in different agricultural activities, like viz., pre-harvest and post-harvest agricultural activities (Kumari et al., 2022; Pradhan et al., 2018); 'Agricultural digitalization helps to improve nutrient management' (85.83%) ranked IV; 'Agricultural digitalization helps to reduce the soil degradation' and 'Agricultural digitalization helps to observe soil moisture condition' (85.00%) ranked V and it confirmed that soil sensors play a significant role in providing valuable guidance for making informed decisions regarding irrigation and fertilization (Johnson et al., 2020); 'Digitalization in agriculture helps to online data of crops for any flagship schemes of Haryana Government in the State' (81.67%) ranked VI; 'Agricultural digitalization helps in selection of crops (*Kharif* and *Rabi*)', 'Agricultural digitalization gives the idea of fertilizers usage pattern' and 'Agricultural digitalization helps for crop grown suited to soil type' (80.00%) ranked VII; 'Agricultural digitalization helps in timely application of inputs in crops' (79.17%) ranked VIII; 'Agricultural digitalization helps in timely management of inputs', 'Agricultural digitalization helps to increase farm income by applying recommended fertilizers dosage at appropriate time' and above the mentioned statements supported that the utilisation of digital tools enables farmers to optimise their time allocation (Das et al., 2019) and reduce the level of exertion required for various farm management activities (Sreeram et al., 2017), thereby enhancing their working conditions, and 'Equipments of spraying and aerial photography of field i.e. drones in agriculture', 'Digitalization helps to tracking of crops from sowing to sale out the produce' (78.33%) ranked IX; 'Agricultural digitalization helps to plan the irrigation schedule' and 'Agricultural digitalization helps in biological image detection & recognition of field crops' (77.50%) ranked X and thus analytical sensing devices, had been found to be effective in facilitating the detection of crop diseases (Yang, 2020); 'Agricultural digitalization helps in adoption of crop rotation', 'Agricultural digitalization helps to detect/track the farm equipments operations' and 'Monitoring equipments for climate sensing and monitoring' (76.67%) ranked XI and it was confirmed that the utilization of data gathered from sensor nodes, unmanned aerial vehicles, and satellites enhances farmers' capacity to manage weather variations (Goel et al., 2021), as proper understanding of these information led to their effective use in field condition (Buruah et al., 2023); 'Mobile phone apps helps for farm management' (75.83%) ranked XII, thus it found evidence that mobiles were being used in ways which contribute to productivity enhancement (Shanthy et al., 2022); 'Agricultural digitalization helps in future cropping pattern' (75.00%) ranked XIII and last one i.e., 'Agricultural digitalization helps to improve the quality of produce' with adoption level of 73.33% which ranked XIV and respectively from ascending to descending percentage of farmers' about their adoption level regarding digitization in agriculture. The adoption rate was determined to be 80.15%.

3.4. Constraints encountered by the farmers in agricultural digitalization

The following constraints were encountered by the farmers in agricultural digitalization which were categorized on the basis of degree of seriousness of constraints as viewed by the percentage of farmers as under:

The data presented in Table 3 revealed that the most serious constraints were 'Lack of funding and technical support to farmers in adoption of digitations technologies' (81.67%); 'Lack of standardization of information sharing for smallholders' (80.83%) and 'digitalization requires higher computer efficiency' (80.00%) which were ranked 1st, 2nd, and 3rd, respectively. The others constraints like' digitalization in agriculture maximize detachment from nature' (60.00%), and 'digitalization in agriculture is not

Table 2: Adoption level of farmer about digitalization in agriculture (n=120)

Sl. No.	Aspects	Level of Adoption				Rank order
		Adopted	%	Not Adopted	%	
1.	Digitalization in agriculture helps to online data of crops on Meri Fasal Mera Bayora portal	107	89.17	13	10.83	I
2.	Agricultural digitalization helps for survey of field crops online	106	88.33	14	11.67	II
3.	Agricultural digitalization helps for automation of farm works like harvesting, spraying, seeding, weeding, thinning, sorting and packing	104	86.67	16	13.33	III
4.	Agricultural digitalization helps to improve nutrient management	103	85.83	17	14.17	IV
5.	Agricultural digitalization helps to reduce the soil degradation	102	85.00	18	15.00	V
6.	Agricultural digitalization helps to observe soil moisture condition	102	85.00	18	15.00	
7.	Digitalization in agriculture helps to online data of crops for any flagship schemes of Haryana Government in the State	98	81.67	22	18.33	VI
8.	Agricultural digitalization helps in selection of crops (*Kharif* and *Rabi*)	96	80.00	24	20.00	VII
9.	Agricultural digitalization gives the idea of fertilizers usage pattern	96	80.00	24	20.00	
11.	Agricultural digitalization helps for crop grown suited to soil type	96	80.00	24	20.00	
12.	Agricultural digitalization helps in timely application of inputs in crops	95	79.17	25	20.83	VIII
13.	Agricultural digitalization helps in timely management of inputs	94	78.33	26	21.67	IX
14.	Agricultural digitalization helps to increase farm income by applying recommended fertilizers dosage at appropriate time	94	78.33	26	21.67	
15.	Equipments of spraying and aerial photography of field i.e., drones in agriculture	94	78.33	26	21.67	
16.	Digitalization helps to tracking of crops from sowing to sale out the produce.	94	78.33	26	21.67	
17.	Agricultural digitalization helps to plan the irrigation schedule	93	77.50	27	22.50	X
18.	Agricultural digitalization helps in biological image detection and recognition of field crops	93	77.50	27	22.50	
19.	Agricultural digitalization helps in adoption of crop rotation	92	76.67	28	23.33	XI
20.	Agricultural digitalization helps to detect/track the farm equipments operations	92	76.67	28	23.33	
21.	Monitoring equipments for climate sensing and monitoring	92	76.67	28	23.33	
22.	Mobile phone apps help for farm management	91	75.83	29	24.17	XII
23.	Agricultural digitalization helps in future cropping pattern	90	75.00	30	25.00	XIII
24.	Agricultural digitalization helps to improve the quality of produce	88	73.33	32	26.67	XIV
Overall Adoption level (%)			80.15%			

socially acceptable among farmers' (60.00%) ranked 4th; 'agricultural digitalization is complex in nature' , 'due to lack of practical knowledge the farmers can't handle the machine properly which may cause environmental damage', 'digitalization in agriculture requires high cost of technology, modernization cost, maintenance cost and lack of funding etc.', 'digitalization in agriculture change/keep away the stakeholders and production models', 'digitalization requires organizational support for better adoption' (56.67%) which ranked 5th; 'digitalization in agriculture provides wide scope for users to hide their identities', 'digitalization in agriculture requires a great deal of capital which is the main reason for discarded of latest technology at farmer level (55.00%) ranked 6th; 'digitalization in agriculture is remarkably easy to copy and reproduce the original things' (54.17%) ranked 7th; 'Digitalization in agriculture is easy to accidently delete or loss the information', 'digitalization in agriculture has poor usability in field at micro level', 'digitalization in agriculture requires repetitive labour (seasonal, technology based labour, skilled workforce, decentralization of work structure

Table 3: Constraints encountered by the farmers in agricultural digitalization (n=120)

Sl. No.	Constraints encountered	Degree of seriousness about constraints faced				Rank order
		Serious (1)	%	Not Serious (0)	%	
1.	Lack of funding and technical support to farmers in adoption of digitations technologies	98	81.67	22	18.33	I
2.	Lack of standardization of information sharing for smallholders	97	80.83	23	19.17	II
3.	Digitalization requires higher computer efficiency	96	80.00	24	20.00	III
4.	Digitalization in agriculture maximise detachment from nature	72	60.00	48	40.00	IV
5.	Digitalization in agriculture is not socially acceptable among farmers	72	60.00	48	40.00	
6.	Agricultural digitalization is complex in nature	68	56.67	52	43.33	V
7.	Due to lack of practical knowledge, the farmers can't handle the machine properly which may cause environmental damage	68	56.67	52	43.33	
8.	Digitalization in agriculture requires high cost (cost of technology, modernization cost, maintenance cost, lack of funding etc.)	68	56.67	52	43.33	
9.	Digitalization in agriculture change/keep away the stakeholders and production models	68	56.67	52	43.33	
10.	Digitalization requires organisational support for better adoption	68	56.67	52	43.33	
11.	Digitalization in agriculture provides wide scope for users to hide their identities	66	55.00	54	45.00	VI
12.	Digitalization in agriculture requires a great deal of capital which is the main reason for discarded of latest technology at farmer level	66	55.00	54	45.00	
13.	Digitalization in agriculture is remarkably easy to copy and reproduce the original things	65	54.17	55	45.83	VII
14.	Digitalization in agriculture is easy to accidently delete or loss the information	64	53.33	56	46.67	VIII
15.	Digitalization in agriculture has poor usability in field at micro level	64	53.33	56	46.67	
16.	Digitalization in agriculture requires repetitive labour (seasonal, technology-based labour, skilled workforce, decentralisation of work structure etc.)	64	53.33	56	46.67	
17.	Digitalization in agriculture requires frequent change of regulations and legal restrictions on technology	64	53.33	56	46.67	
18.	Digitalization in agriculture require some specific job, this can be a huge headache	63	52.50	57	47.50	IX
19.	There is an increasing tendency for farmer to socialize and communicate via digital devices	62	51.67	58	48.33	X
20.	Lack of real life connects to other people	62	51.67	58	48.33	
21.	Digitalization in agriculture has inadequate grant schemes criteria	62	51.67	58	48.33	
22.	Limitation of market access for established improved technologies	62	51.67	58	48.33	
23.	Digitalization in agriculture increased dependency on global markets	57	47.50	63	52.50	XI
24.	Digital devices may be discarded when no longer useful	56	46.67	64	53.33	XII
25.	Fear of digital media manipulation in agricultural digitalization	46	38.33	74	61.67	XIII
26.	There is job insecurity in agricultural digitalization	45	37.50	75	62.50	XIV
27.	There may be diversifying losses due to digitalization in agriculture	44	36.67	76	63.33	XV

Table 3: Continue...

Sl. No.	Constraints encountered	Degree of seriousness about constraints faced				Rank order
		Serious (1)	%	Not Serious (0)	%	
28.	There is difficulty of privacy in digitalization in agriculture	42	35.00	78	65.00	XVI
29.	Agricultural digitalization requires better coordination between various technologies	40	33.33	80	66.67	XVII
30.	There is low internet connectivity	38	31.67	82	68.33	XVIII
31.	Difficult to maintain agricultural digitalization	32	26.67	88	73.33	XIX
32.	Agricultural digitalization requires well qualified staffs	28	23.33	92	76.67	XX
33.	Requirement of high technology and machines in Agricultural digitalization	28	23.33	92	76.67	
34.	Agricultural digitalization is more expensive	28	23.33	92	76.67	
35.	Agricultural digitalization requires sufficient fund	26	21.67	94	78.33	XXI

etc.'; 'digitalization in agriculture requires frequent change of regulations and legal restrictions on technology' (53.33%) ranked 8th; 'digitalization in agriculture require some specific job, this can be a huge headache' (52.50%) ranked 9th; 'there is an increasing tendency for farmer to socialize and communicate via digital devices', 'lack of real–life connects to other people', 'digitalization in agriculture has inadequate grant schemes criteria', 'limitation of market access for established improved technologies' (51.67%) which ranked 10th. There are some other constraints revealed in table 12 like 'digitalization in agriculture increased dependency on global markets' (47.50%), 'digital devices may be discarded when no longer useful' (46.67%), 'fear of digital media manipulation in agricultural digitalization' (38.33%), 'there is job in-security in agricultural digitalization' (37.50%), 'there may be diversifying losses due to digitalization in agriculture' (36.67%), 'there is difficulty of privacy in digitalization in agriculture (35.00%), 'agricultural digitalization requires better coordination between various technologies' (33.33%), 'there is low internet connectivity' (31.67%) and 'difficult to maintain agricultural digitalization' (26.67%), which ranked 11th, 12th, 13th, 14th, 15th, 16th, 17th, 18th and 19th, respectively according to their problems. The least seriousness constraints which ranked in the last such as 'agricultural digitalization requires well qualified staffs', 'requirement of high technology and machines in Agricultural digitalization', 'agricultural digitalization is more expensive and 'agricultural digitalization require sufficient fund' viewed 23.33% and 21.67% farmers which ranked 20th and 21st, respectively.

The study examined the demographic, educational, and agricultural characteristics of 120 participants. Most were middle-aged, with diverse educational backgrounds. The majority belonged to the general caste and were small farmers with 2.5 to 5.0 acres of land. Mobile devices (Das and Jha, 2022; Lahiri et al., 2017) were the preferred medium for accessing agricultural information, with progressive farmers (Yadav et al., 2016) being the primary information source. Common farm machinery included the rotavator and seed-cum-fertiliser drill. Canal irrigation was predominant, and livestock farming was popular among respondents. Crop rotation, especially cotton-wheat (Singh et al*.,* 2022) and rice-wheat, was common. There was high awareness and possession of soil health cards and the kisan credit card. These findings underscore the need for targeted interventions to support sustainable agriculture and rural development.

The data presented in Table 1 showed that farmers have a strong awareness of digitization in agriculture. The study revealed that farmers were well-informed about incorporating sophisticated digital technologies in agriculture, utilising digital soil health cards for soil assessment, and the significance of digitalization in addressing climate change impacts. The results align with prior studies (Lioutas et al., 2019) emphasising the capacity of digitalization to optimise farm management through intelligent analysis and increased operational efficiency. The results indicated that farmers recognised the advantages of agricultural digitization, such as decreased input costs, participation in digital markets, and immediate feedback. This was consistent with the idea that digitalization might enhance production and sustainability in agriculture (Shanmuka et al., 2022). Farmers acknowledged the importance of digital technologies like Big Data and Artificial Intelligence (AI) in enhancing decision-making and minimising resource usage (Raman et al., 2024). Farmers' significant knowledge of digitization in agriculture was promising, indicating their willingness to embrace new technologies for the improvement of their farming methods. These findings emphasised the need to educate farmers about the benefits of digitalization in agriculture and offered them the support needed to incorporate these technologies into their farming practices.

Table 2 clearly demonstrated that farmers had significantly embraced digitization in agriculture. Farmers had adopted

digital solutions for purposes including online data gathering, automating farm tasks, managing nutrients, and monitoring soil health, as indicated by the data. This acceptance was vital as it showed that farmers were open to integrating new technologies to improve their farming methods. Farmers' enthusiasm for utilising digital tools in agricultural management was shown in the significant adoption rates of online data gathering on government portals and conducting field crop surveys online. Thus, revealed that implementation of digitalization of agriculture had the potential to yield significant increases in productivity (Sparrow and Howard, 2021), resulting in reduced labour expenses (Adegbola et al., 2019), and enhanced agricultural product quality (Bogue, 2020), Farmers were eager to invest in sophisticated agricultural practices, as shown by their adoption of technologies such as soil sensors and drones for monitoring soil moisture and aerial photography. Although widely adopted, there was a necessity for increased understanding and training on the efficient utilisation of these technologies. Many farmers might lack a complete understanding of the potential advantages of digitalization in agriculture or how to effectively utilise these instruments. Emphasising the necessity of offering training and support to farmers (Wodajo and Ponnusamy, 2016) to fully utilise the advantages of digitalization. The findings indicated a favourable inclination towards the implementation of digitalization in agriculture by farmers. Continuing to increase awareness and offer training could maximise the advantages of digitalization and enhance agricultural productivity.

The results from Table 3 highlighted significant hurdles to adopting digitalization in agriculture. Key constraints included the lack of funding and technical support, along with challenges related to standardization and computer efficiency. Other concerns included the perception of detachment from nature and social unacceptability. Addressing these challenges would require comprehensive policies, awareness campaigns, and support mechanisms. Additionally, issues such as privacy, security, and job insecurity underscored the need for robust data protection measures and employment strategies. Overall, overcoming these constraints would require collaborative efforts involving governments, policymakers, agricultural organizations, and technology providers.

4. Conclusion

The study revealed varying levels of farmer awareness about digitalization in agriculture, showing that low awareness did not hinder adoption if the technology met the user needs. Supporting young farmers, enhancing education, and training were crucial for adoption.

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