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EDITED BY
Gary Wingenbach,
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REVIEWED BY
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Visva-Bharati University, India
Shivendra Kashyap,
G. B. Pant University of Agriculture and Technology, India

*CORRESPONDENCE
Subhashree Sahu
✉ subhashree28191@gmail.com
Ph. Romen Sharma
✉ romen.agext@gmail.com
Satyapriya
✉ satya118ext@gmail.com

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Exploring popular information sources and determinants of farmers' access to agricultural extension services in the Indo-Gangetic plains

Subhashree Sahu[1]*, Sitaram Bishnoi[1], Ph. Romen Sharma[2]*, Satyapriya[1]*, Girijesh Singh Mahra[1], Rajarshi Roy Burman[3], Sukanya Barua[1], M. Misha Madhavan[1], V. Sangeetha[1], Sanjeev Kumar Sinha[1], Rahul Singh[1], Monika Wason[1], Pratibha Joshi[1] and Shailendra Sharma[1]

[1]ICAR-Indian Agricultural Research Institute, New Delhi, India, [2]ICAR-Indian Institute of Maize Research (IIMR), Ludhiana, India, [3]Krishi Anusandhan Bhawan, ICAR, New Delhi, India

A study was undertaken to analyse farmers' access to various agricultural extension service sources, their preferences and to delineate underlying determinants for their access. The study used NSSO 77th survey dataset of 14,782 households of IGP states (Bihar, Haryana, Punjab, Uttar Pradesh, West Bengal). Farmers' preferences varied, with private agencies—particularly input dealers—emerging as the top choice, followed by traditional mass media channels and the public extension system. Utility of Cooperative model, and farmer-based organizations have not yet been fully explored for information needs. The inputs (seeds, fertilizers, plant protection) were the most sought-after information. However, in an era of changing needs, farmers should strive to acquire additional information on aspects such as marketing, climate change, and post-harvest functions. The type of information sought by the farmers, influences their preferred sources of extension services. Irrespective of the source, the degree of access diminishes with the decreasing landholding. Among the five IGP states, Haryana emerged as the champion of information access for farmers, while Bihar lagged. Multivariate probit analysis reported that the likelihood of access to agricultural information sources was positively influenced by age, gender, education, size of operational landholding, irrigated area, and sale of produce at MSP. The study suggests making the extension services for small and socio-economically marginalized farmers more inclusive. Inclusiveness of extension services is essential for sustainability because it ensures that all farmers, regardless of their landholding, gender, age, caste, etc., have access to knowledge and resources they need to adopt improved agricultural practices and thus, secure prosperous livelihoods.

KEYWORDS

agricultural extension services, Indo-Gangetic plains, information needs, mass media, multivariate probit, public extension, private extension, progressive farmers

1 Introduction

In this modern age dominated by data and information, timely access to the right and up-to-date information can prove a major game-changer, even in the fields of agriculture. Right information has multi-faceted benefits for agriculture and can prove instrumental in substantially improving farm productivity, efficient farm management, reduced risk and uncertainty, diversification of the farming systems, being competitive and consequently, boosting the farmers' incomes (Van den Ban and Hawkins, 1998; Sharma, 2002; Adhiguru et al., 2009; Brhane et al., 2017; Krishna et al., 2019; Anang et al., 2020) and addressing the diverse needs of heterogenous farming community (Munshi, 2004; Negi et al., 2020). While a mere 40% of farm households in India benefit from access to agricultural information, a commendable three-fourths of those with access actively integrate it into their decision-making (Birthal et al., 2015). These contrasting figures underscore both the need for wider information access and the potential for positive impact once information barriers are overcome. Studies like Owens et al. (2003), Godtland et al. (2004), Davis et al. (2010), and Birthal et al. (2015) show a clear link between information access and increased farm income. Information's impact on farm income is not one-size-fits-all. While formal sources might work better for cash crops (Birthal et al., 2015), local networks could be crucial for subsistence farmers. We need context-specific information delivery strategies to unlock the full potential of knowledge.

There have been multiple players in the Indian agricultural scenario, who cater to the extension and information needs of the farmers, namely, the public extension agents including Government organizations, KVKs, ATMA, Agricultural departments, Agricultural universities; the private extension players like the input dealers; Voluntary organizations; cooperatives; farmer-based organizations; mass media and the modern ICT tools, etc. A better understanding of the patterns in which the farmers access these sources for retrieving the needed agricultural information and the underlying factors which closely influence this pattern, may help us in formulating the content or guide the policy-makers in devising contextually appropriate extension programs for their easy uptake by the farmers. This is of immense importance for revamping the sluggish public-sector extension system, which has been ailing due to irrelevant and obsolete content and large-scale information failure (lack of feedback and limited reach to farmers) (Swanson and Mathur, 2003; Joshi et al., 2005; Anderson and Feder, 2007; Sontakki et al., 2010; Babu et al., 2012, 2013; Kumar et al., 2012; Sulaiman, 2012). The findings from the 59th and 70th National Sample Survey Office (NSSO) surveys in India underscore the limited accessibility of extension services for farmers, especially among those who are socially and economically marginalized (Sajesh and Suresh, 2016; Krishna et al., 2019). An in-depth understanding of how the farmers absorb and adapt to the available information, will also guide us what are the future trends of information search and help us in predicting how different organizational designs will influence the nature of information generation, transmission, adoption, and assimilation (Stiglitz, 2000; Mittal et al., 2010; Ali and Kumar, 2011).

Indian farmers are a heterogenous group and the factors that influence the likelihood of accessing an information source are not common to farmers of diverse agro-ecological regions in a country. Therefore, understanding the specific socio-economic and psychological factors functional at an individual level, which affects their information-seeking behavior, access, and use is the first and foremost step toward better targeting of our extension programs and advisory services (Bernard et al., 2015). Despite the extensive and pluralistic nature of India's public extension systems (Raabe, 2008; Glendenning et al., 2010), there exists a huge information gap among the farmers, a tremendous disconnect between knowledge production and utilization by farmers. Bridging this gap requires actively listening to and understanding the needs of farmers, their clients. Understanding the relevance of the issue, the research study was designed to attempt to shed light on the prevalent information networks, farmers' perceptions and determinants of the information-seeking behavior of the farmers of Indo-Gangetic plains in India with respect to the various extension advisory sources.

2 Materials and methods

The present study analyses data particular to the Indo-Gangetic plains, extracted from the dataset (of 2018–19) generated from the 77th round of the "Situation Assessment of Agricultural Households and Land and Holdings of Households in Rural India, 2019," conducted by the National Sample Survey Organization (NSSO), Government of India.

Indo-Gangetic plains (IGP) (Figure 1) in India is the major foodgrain-growing region, consisting of five major states (Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal) and considered as the "food bowl of India." It produces about 50% of the total foodgrains to feed 40% of the population of the country (Pal et al., 2009). The IGP represents eight agro-ecological regions and 14 agro-ecological subregions (Pal et al., 2009). Based on climatic, hydrologic, and physiographic variations, the IGP consists of four homogeneous divisions, namely Trans-Gangetic Plains (TGP), Upper Gangetic Plains (UGP), Middle Gangetic Plains (MGP) and Lower Gangetic Plains (LGP). The Indian part of IGP extends from 73° E longitude and 32° N latitude to 89° E longitude and 21° N latitude. These five states cover nearly 15.65% of the total geographical area of the country and are home to 37.4% of the population of the country. The Plains gradually slope from north-west toward the Bay of Bengal in the east and undergo a gradual transition in climate, physiography, natural vegetation and cropping systems. The rainfall ranges from less than 400 mm per year in the north-west to more than 1,800 mm per year in the lower Gangetic plains of Bengal. It has the highest cropping intensity and most of the agricultural land is irrigated.

We are currently working in our institute's project focused on the Indo-Gangetic Plains region. The IGP, especially the eastern part has been identified as a region where there is a lot of untapped potential to realize higher agricultural productivity. There are significant differences in these regions in terms of natural resource endowment, demography, and agricultural productivity. Despite vast fertile potential, the Indo-Gangetic plains grapple with stagnant agricultural productivity due to limited embrace of advanced farming technologies (Taneja et al., 2014). Today, the Indo-Gangetic states are facing with some of the most serious agro-ecological problems like declining productivity and falling ground water table, increasing soil salinity (Abrol et al., 2000) and agricultural pest problems due to excessive and improper use of resources. This region has also been demarcated as an area of high social

FIGURE 1
Indo-Gangetic plains (source: Springer Nature; https://images.app.goo.gl/VqJPkvEsRMMmN2PA9).

vulnerability (Chhetri and Chaudhary, 2011), which may become food insecure by the early 2030s due to the changing climate scenario (Swaminathan, 2010). We have extracted data specific to this region from the NSSO survey for this area to derive meaningful insights and implement targeted interventions tailored to the selected belt. Various past studies indicate that accessibility and availability of relevant, and timely information can lead to enhanced penetration of improved agricultural technologies and have profound impact on the agricultural productivity, and thus consequently, ensure livelihood security of the agricultural households. Our focus on this specific belt underscores our commitment to addressing region-specific challenges and contributing to the overall advancement of agricultural practices.

Agriculture is dominated by a large number of marginal farmers and smallholders with varying levels of knowledge, skills, capital, and resource bases. The information requirements of such a heterogenous community are diverse. A farmer's choice of information source is not one-size-fits-all. A multitude of factors, from social identity to farm practices, are believed to influence how farmers seek agricultural information. It is hypothesized that farmers' choices for information sources is differentiated by various explanatory attributes like the backgrounds of the farmers, age, gender, education, caste, size of operational landholding, irrigated area, *per capita* monthly expenditure, primary income source, access to institutionalized credit sources, choices like membership in FPOs, insurance of crops and sale of produce at MSP. Knowing what influences their choices will allow us extension professionals to tailor information delivery for maximum impact. Thus, the present study was an attempt to delve deeper into the intricate patterns of information-seeking behavior of the farmers and devise suitable mechanisms with various institutional stakeholders to address the existing information gap. In this study, the issues for investigation were therefore as follows:

1. What are the preferred information sources across the farmers of different land-holding categories?
2. What are the preferred information sources for the farmers across different states of Indo-Gangetic plains?
3. What are the preferred information sources for a particular category of information?
4. What are the factors differentiating the farmers with respect to their information-seeking behavior in terms of their socio-economic conditions, resource bases, social identity and farm practices?

The data consisted of 14,782 households, of which 14,046 cultivated crops and 10,539 owned livestock. The study aimed to find out the level of farmers' access, their preferences and the determinants of access to various agricultural extension service sources. The sources were broadly categorized into five groups: (a) Public Players (Government extension agents/ATMA, Krishi Vigyan Kendras, Agricultural universities/colleges, and veterinary departments); (b) Private Players (input dealers, private commercial agents, private processors, and ACABC); (c) Farmers' organizations (cooperatives/dairy cooperatives, and FPOs); (d) Mass media/ICT (Kisan Call Centre, print media, radio/TV/other electronic media, and smartphone apps); and (e) Progressive farmers.

The descriptive statistics including mean, frequencies, and percentages were used to analyze the trends and preferences of farmers' access to the extension service sources. Then, probit regression analysis was employed to analyse the determinants of the access by modeling "Access dummy" as 1 = access to any of the extension service sources and 0 = Otherwise. But, since there were multiplicity effects from various sources (not mutually exclusive) used by the farmers, Multivariate probit (MVP) regression analysis was performed. The MVP model is a generalization of the probit model

used to estimate several correlated binary outcomes jointly. It can jointly predict the likelihood of accessing two or more sources of extension services. The MVP estimation technique takes into account the correlation in error terms by simultaneously modeling the impact of a group of covariates on each of the agricultural extension sources. It involves estimating a series of binary probit models while permitting the error terms of these sources to correlate independently. Neglecting to address these interrelations may result in distorted estimates (Lin et al., 2005; Velandia et al., 2009; Dougherty, 2011; Kassie et al., 2013).

The general equation can be expressed as:

$$Y_{i\mathrm{k}} = (a_{i\mathrm{k}^*}\ x_{\mathrm{ik}}) + e_{i\mathrm{k}}.$$

where Y_{ik} is the dependent variable of access to different k extension service sources (public players, private players, farmers' organizations, mass media and progressive farmers), x_{ik} is the vector of variables hypothesized to determine the access to various sources enlisted, α_{ik} is the estimated parameter, and e_{ik} is the error term. The variables that are modeled to determine access to the extension service sources are age, gender, education, caste, landholding size, number of family members in working age group, *per capita* monthly expenditure, primary income source, access to irrigation, membership in FPOs, sale of produce at MSP, the experience of crop losses and insurance of the crops.

3 Results

3.1 Access of the farmers to different sources of agricultural extension services

From the analysis of the descriptive statistics (Table 1), it was observed that about 60% of agricultural households had accessed agricultural information from the various categories of sources of extension services. Over a third (35.78%) of farmers turned to private agencies for various needs, dominated by input dealers (33.98%) and the rest sparsely distributed among private processors, private commercial agents, NGOs and ACABCs. Input dealers' role as a comprehensive resource for information, advice, and readily available farm inputs, with credit options, offering a convenient single-window solution, positions themselves as the most accessed information sources. Interestingly, larger farms showed a stronger preference for private processors (12.78%), hinting at their potential involvement in value-adding and secondary processing. Progressive farmers emerged as the second most sought-after source for agricultural information, accounting for 32.88%. However, some studies and previous literature quotes them as the preferred information choices due to easy accessibility, socio-cultural homogeneity, credibility with the farmers (Rogers, 2003; Bhagat et al., 2004; Mittal and Mehar, 2013; Krishnan and Patnam, 2014). Adhiguru et al. (2009), Babu et al. (2012), Sharma (2014), and Awatade et al. (2018) reported that the first-hand experiences shared by fellow farmers and input dealers seemed more relevant and reliable to farmers than information from other channels, leading to higher adoption rates.

Smartphone apps and KCC have not caught on when it comes to agricultural information, despite the increasing social penetration and popularity. Traditional media still reigns supreme, with 11.5% of farmers relying on radio, TV, and print. The public extension system showed a poor state of affairs, contrary to the popular opinion with limited access to only 10% of the households. The public extension system in India is fraught with severe limitations like limited reach and manpower, lack of funds, poor monitoring and evaluation mechanism and inefficient organizational structures for providing quality information at appropriate times (Ferroni and Zhou, 2012; Babu et al., 2013; DFI, 2017). Maharashtra farmers show mixed feelings about public sector extension services, with an average satisfaction of 55.49 (range 25–100) (Awatade et al., 2019). The veterinary department was the most accessed among the public extension system, followed by ATMA with a meager 1%. However, Gulati et al. (2018), Nandi and Nedumaran (2019), Kale and Saravanan (2020), and Raabe (2008) concluded that the public extension system was the dominant information source for farmers; followed by private input dealers.

Despite of the success of the cooperative model and government emphasis on Farmer Producer Organizations (FPOs) (Sulaiman, 2012), a meager 2.24% of the households were served by farmer-based organizations for their agricultural information needs. This finding was reiterated by Alvi et al. (2021), where a small proportion of respondents identified group meetings as their primary source of information on agriculture in spite of being affiliated to Self Employed Women's Association (SEWA), Gujarat. However, studies report that while formal systems struggle with reach, grassroots knowledge sharing thrives. Two-thirds of farmers rely on these informal networks, like peer-to-peer advice and local markets, to stay informed about modern agricultural advancements. The role of social networks "as a means of information exchange" is amply recognized in the literature *viz.* Conley and Udry (2001), Miguel and Kremer (2003), Bandiera and Rasul (2006), Matuschke and Qaim (2009), Oster and Thornton (2012), Krishnan and Patnam (2014), and Songsermsawas et al. (2016). Further, we can observe that access to majority of the information sources by farmers goes upward along with the increase in the size of the land holdings, thus, hinting toward the bias or favoritism of our Extension system toward the large and resourceful farmers. The finding was confirmed with the earlier results of Adhiguru et al. (2009), Sajesh and Suresh (2016), and Ferroni and Zhou (2012).

The chi-square test results (Table 1) reveal a significant difference among farmers of different landholding categories in their access to the aforementioned sources of agricultural extension services, except to the NGOs.

3.2 Access of the farmers to different sources of agricultural extension services across IGP states

Farm households in IGP states have varying access to different sources of extension service, as shown in Table 2. Haryana emerged as the champion of information access for farmers, while Bihar faced significant barriers and lagged in access to sources of agricultural extension services. Public extension thrived in Haryana and Punjab, fueled by robust veterinary departments. While input dealers and progressive farmers were key information sources across most states, Punjab stood out with its higher reliance on traditional mass media like radio and TV. However, a worrying trend observed

TABLE 1 Percentage of farmers of various landholding categories accessing different sources of agricultural extension services.

	Marginal	Small	Semi-medium	Medium	Large	Pooled	x^2
Progressive farmers	31.86	36.72	41.71	41.51	42.89	32.88	94.60[a]
Input dealers	32.38	39.72	48.48	47.63	51.60	33.98	179.01[a]
Private processor	2.42	3.07	4.57	3.88	12.78	2.61	41.65[a]
Private commercial agents	1.33	2.59	3.70	3.89	1.73	1.59	29.52[a]
NGO	0.13	0.33	0.17	0.18	0.00	0.15	0.57
ACABC	0.10	0.06	0.82	0.00	2.76	0.13	44.34[a]
Private	34.03	42.25	50.79	52.17	54.99	35.78	218.37[a]
Veterinary department	6.96	11.87	22.43	28.19	46.26	8.41	198.44[a]
Gov extension agent/ ATMA	0.62	2.39	3.64	5.38	13.55	1.00	118.88[a]
KVK	0.56	1.09	3.12	6.60	9.28	0.81	221.92[a]
Agril university/college	0.05	0.39	0.72	6.58	7.72	0.21	242.22[a]
Public	7.92	14.65	26.53	35.08	64.57	9.78	354.58[a]
Radio/TV/other media	7.27	11.87	17.19	22.90	42.00	8.39	208.87[a]
Print media	3.49	6.63	11.94	10.16	15.99	4.25	144.84[a]
KCC	0.89	2.69	4.65	11.27	18.54	1.38	240.88[a]
Smart phone apps	0.49	1.69	4.89	4.86	6.35	0.85	214.09[a]
Mass media/ICT	9.73	18.06	25.42	28.74	46.76	11.50	334.69[a]
Cooperatives/dairy coop.	1.62	2.86	5.43	6.13	3.56	1.96	84.07[a]
FPOs	0.18	0.92	0.41	0.64	8.09	0.28	30.74[a]
Farmers organization	1.80	3.79	5.84	6.77	11.65	2.24	109.86[a]
Total	56.86	66.75	75.09	75.83	89.15	58.87	250.63[a]

#Marginal: <1 Ha; Small: 1–2 Ha; Semi-medium: 2–4 Ha; Medium: 4–10 Ha; Large: >10 Ha.
The figures in the table are in percentage of farmers of various landholding categories accessing different sources of agricultural extension services. x^2 indicates the chi-square value and ##.
[a]indicates $p < 0.01$ in chi-square test.

was—farmer-based organizations remained largely untapped as information resources across all states. The results of the chi-square test are provided at the last column of Table 2. The results indicate a significant variation in farmers' access to different sources of agricultural extension services across the five IGP states, except for access to services provided by NGOs.

3.3 Diversity of access to information sources

Farmers gather information from multiple sources because no single source gives complete information. The analysis of the data collected (Table 3) shows that one-thirds of the marginal farmers access a single source of information and only 17.84% access the information from two sources. Small farmers tap into 24.36% of available technical advice sources, while large farms leverage 28.96%, while accessing two different sources. This pattern extends to accessing 3 or more sources. Farm size directly correlates with information diversification. In totality, a meager 2.36% of the farming households accessed more than three sources of information for agricultural information. This trend indicates that with a rise in landholding size, there is an increasing tendency to gather information from diversified sources. Greater access to information sources empowers farmers with knowledge and the ability to verify its accuracy through cross-checking and triangulation. While accessing multiple information sources can make farmers better informed, the downside is the potential for information overload and confusion. As Kapoor and Kumar (2021) point out, too much information can lead to information asymmetry and lead to indecisiveness. There has been significant variation in access of households to multiple sources of agricultural extension services based on landholding categories, as indicated by the results of the chi-square test available in Table 3.

3.4 Information wise preference of the sources of agricultural extension services

The farmers tend to rely on certain specific sources for a particular type of information. This study concludes that for crop cultivation (Table 4), the most sought-after information was improved seed (47.54%), fertilizer application (30.13%), and plant protection (17.92%), for which farmers mostly relied on progressive farmers, input dealers and radio/TV. Thus, the popular choices are the traditional media and the ones closer to their social identity like progressive farmers and input dealers of their locality. Very few households have sought information on farm machinery, harvesting and marketing advice. The study by Awatade et al. (2017) indicated

TABLE 2 Sources of agricultural extension services accessed by farmers across IGP states.

	Punjab	Haryana	UP	Bihar	West Bengal	Total	x^2
Progressive farmers	13.19	35.82	38.53	30.23	24.09	32.88	432.08[a]
Input dealers	22.52	41.19	37.38	22.82	37.13	33.98	370.09[a]
Private processor	3.65	4.44	3.32	1.48	1.13	2.61	56.09[a]
Private commercial agents	1.55	0.66	2.53	0.20	0.81	1.59	80.57[a]
NGO	0.19	0.01	0.16	0.21	0.11	0.15	2.23
ACABC	0.13	0.05	0.23	0.01	0.00	0.13	20.25[a]
Private	25.52	43.16	39.78	23.81	37.90	35.78	382.64[a]
Veterinary department	35.56	40.84	7.65	2.77	1.01	8.41	1.7e+03[a]
Govt extn agent/ATMA	2.30	1.84	0.32	1.61	1.64	1.00	29.13[a]
KVK	3.25	1.87	0.61	0.46	0.85	0.81	108.08[a]
Agril university/college	1.85	0.40	0.14	0.05	0.15	0.21	44.26[a]
Public	37.35	42.66	8.48	4.53	3.19	9.78	1.4e+03[a]
Radio/TV/other media	19.69	5.66	8.35	5.40	9.90	8.39	203.79[a]
Print media	5.54	5.36	4.96	1.79	4.31	4.25	112.86[a]
KCC	6.47	2.98	0.70	2.18	0.77	1.38	216.13[a]
Smart phone apps	7.15	1.59	0.56	0.55	0.35	0.85	344.59[a]
Mass media/ICT	22.62	12.59	11.86	8.27	11.13	11.50	178.50[a]
Cooperatives/dairy coop.	5.02	2.86	2.20	1.37	1.00	1.96	118.21[a]
FPOs	0.69	0.15	0.37	0.01	0.28	0.28	25.54[a]
Farmers organization	5.71	3.02	2.56	1.38	1.28	2.24	121.29[a]
Total	52.46	74.01	62.60	51.16	54.09	58.87	266.12[a]

The figures in the table are in percentage of farmers of different states accessing different sources of agricultural extension services. x^2 indicates the chi-square value and ##.[a]indicates $p < 0.01$ in chi-square test.

TABLE 3 Access of households to multiple sources of agricultural extension services based on landholding categories.

Operational land holding category	No. of sources assessed				x^2
	Single	Two	Three	Four & above	
Marginal	32.16	17.84	5.39	1.47	322.75[a]
Small	29.13	24.36	8.84	4.42	43.24[a]
Semi-medium	22.82	25.00	16.54	10.73	191.86[a]
Medium	17.60	27.09	15.23	15.91	104.34[a]
Large	5.25	28.96	25.23	29.71	46.02[a]
Total	31.25	18.91	6.34	2.36	

The figures in the table are in percentage of farmers accessing multiple sources of agricultural extension services. x^2 indicates the chi-square value and ##.[a]indicates $p < 0.01$ in chi-square test.

TABLE 4 Major categories of information sought and preferred information sources for crop cultivation.

Type of information	Preference ranking of sources ($N = 14,046$)					
	I	II	III	IV	Total seekers	Non-Seekers
Seed/variety	22.13 (Prog farm)	16.64 (Inp Deal)	2.59 (Rad, TV)	6.18 (Others)	47.54	52.46
Fertilizer	14.82 (Inp Deal)	9.62 (Prog farm)	2.36 (Rad, TV)	3.33 (Others)	30.13	69.87
Plant protection	8.17 (Inp Deal)	4.38 (Prog farm)	2.24 (Rad, TV)	3.13 (Others)	17.92	82.08
Farm machinery	0.58 (Prog farm)	0.26 (Rad, TV)	0.19 (Inp Deal)	0.45 (Others)	1.48	98.52
Harvest/market	0.79 (Rad, TV)	0.78 (Prog farm)	0.67 (Inp Deal)	1.18 (Others)	3.42	96.58
Others	0.77 (Prog farm)	0.61 (Rad, TV)	0.19 (Pvt. Proc)	0.58 (Others)	2.15	97.85

Figures in the table indicate the percentage of households that sought a given type of information from a particular source.
#Non-seekers refer to households who did not seek information of said type from any of the 16 sources stated in Table 1.

the major aspects on which farmers sought information were: soil, weather and climate, nutrient management, market prices and income generating activities; followed by livelihood diversification, agricultural marketing, agripreneurship, seeds, subsidies, plant protection material, weed management, pest and disease management and crop diversification. However, farmers opined of partial fulfillment of most of the information needs. Farmers did not feel the need of information on post-harvest management, unlike the marketing aspects, which indicated their ignorance or unwillingness on aspects of value addition, quality control, etc. The NSSO survey, unfortunately, overlooks crucial new and emerging areas like climate change adaptation, government scheme awareness, and risk mitigation strategies, all of which are critical information needs (Gandhi and Johnson, 2017) for modern farmers. In our opinion, this blind spot significantly limits the ability of the survey to capture a comprehensive picture of the information needs for today's farmers.

3.5 Determinants of access to sources of agricultural extension services

In order to analyse the determinants of access to the various sources of extension services, the probit regression was conducted (Table 5). The probit regression was used to model access dummy (1 = access to any of the 16 sources, 0 otherwise). But, as the farmers relied on a number of sources, which were not mutually exclusive; Multivariate probit (MVP) regression was used to jointly predict access to two or more information sources of technical advice by an agricultural household. The significant Wald Chi-square test statistics [$chi^2(20) = 124.98$; $p = 0.000$] indicate that the model with independent variables shows a significant improvement as compared to the null model. We found from the analysis that the probability of access to agricultural information sources was positively influenced by the age, gender, education level of the household head, size of operational landholding, irrigated area, and households that sold crop produce at MSP.

Age significantly influenced access to information from public sources and mass media. This may be because of positive association of age and usage of the traditional sources of information. This finding was in line with the studies of Danso-Abbeam et al. (2018) and Tiwari et al. (2008). Farmers with higher education are more likely to access farmers' organizations and mass media. The exposure to different types of mass media and the new approaches of collectivization is only possible through education, which is clearly evident in our results. They recognize the value of accessing information through organized channels. Paltasingh and Goyari (2018) highlighted that the farmers with higher education were more likely to adopt modern agricultural technologies and participate in farmers' organizations. Also, education enhances technological literacy and thus higher education enables the farmers to navigate and leverage the digital tools and platforms more effectively (Parmar et al., 2019). However, Maake and Antwi (2022) contradicted stating that farmers with higher education were more likely to perceive public extension services as effective and utilize them more frequently in South Africa.

Landholding had a positive influence on access to public and private information sources. The possible reason could be that the small and marginal farmers practice subsistence type of agriculture and thus, do not refer to diverse sources of information like mass media, and farmer organizations. Larger landowners in India were more likely to adopt agricultural innovations and thus willing to invest on getting credible information, thus using a mix of public and private extension sources. Results of Rehman et al. (2013) also revealed that education and size of land holding had highly significant positive relationship with access to agricultural information while age and farming experience had non-significant relationship. Moreover, Indian Extension system is guilty of focusing on the larger farmers, so as to project significant impact in the shortest time possible and better-off households (DFI, 2017).

Female-headed households are less likely to access public and private information sources than male-headed households. Women's limited access can be attributed to the socio-cultural norms prevalent in the study region. Cultural norms play a pivotal role in influencing the roles assigned to men and women within a community. Deeply ingrained cultural beliefs set the tone for traditional gender roles, expectations, and stereotypes, which can create barriers for women, limiting their access or creating inequal distribution of resources, including credit, land, and human capital, which further exacerbates gender disparities (Sulaiman and Reddy, 2014). This in turn leads to low participation of women in decision-making processes, both at the household and community levels. This lack of involvement can lead to a low information-seeking behavior. Limited mobility, low social exposure and low participation in public spaces or interactions with formal institutions can hinder their access to information from government offices, community centers, or private dealers (Vark, 2013; Venkatasubramanian et al., 2014; World Bank Group, FAO, IFAD, 2015; Beevi et al., 2018). Time constraints may also restrict their ability to actively seek out information from public or private sources. Lower education levels and low digital literacy can restrict access to online information sources like government websites, news portals, and educational resources. The persistence of women's lack of access to extension services was also confirmed by Mooko (2005), Alvi et al. (2021), MoAFW (2019), CARE (2020), and UN Women (2017a,b,c). This can be corrected only through gender-sensitive policy research and technology dissemination (Paudyal et al., 2019).

Households with a higher number of members within the working age group (15–65 years old) exhibited a greater likelihood of accessing public sources and farmer organizations. This may be due to the fact that the larger labor force present in the household will motivate them to go for collectivization and learn ways to diversify their production system. This increased manpower may create a greater interest in accessing resources and information provided by farmer organizations to enhance agricultural productivity. The working-age population is more likely to establish and maintain social networks, both within the community and through farmer organizations. Households with crop cultivation as their primary source of income are more likely to access progressive farmers because replicating the successful experiences would increase their probability of earning profits. However, the households where primary income was from animal husbandry were more reliant on the public extension system. This may be because animal husbandry can be more complex and need species-specific knowledge and tailored advice. Also, finding private consultants with specialization in animal husbandry, especially in remote areas, might be less feasible compared to readily available crop consultants. They can be expensive too. The findings suggest that the households with higher *per capita* monthly consumer expenditure are more likely to access public extension system, farmer organizations and mass media,

TABLE 5 Determinants of access to sources of agricultural extension services.

Explanatory variables	Probit model		Multivariate probit model				
	Access to AES	Marginal effect	Public	Private	Mass media	Farmers organization	Progressive farmers
Log (age)	0.09[c] (0.09)	0.04[c] (0.03)	0.12[b] (0.12)	0.23 (0.11)	0.14[b] (0.11)	0.37 (0.17)	0.18 (0.12)
Gender of the HH	0.09[b] (0.08)	0.04[b] (0.03)	0.05[b] (0.14)	0.04[c] (0.11)	0.18 (0.13)	−0.05 (0.18)	0.02 (0.1)
Education of the HH	0.02[c] (0.01)	0.01[c] (0.00)	0.02 (0.01)	0.01 (0.01)	0.02[a] (0.01)	0.02[a] (0.01)	0.01 (0.01)
Number of household members in the working age group (15–65 age)	0.01 (0.01)	0.00 (0.00)	0.05[a] (0.02)	0.00 (0.02)	0.02 (0.02)	0.05[a] (0.03)	0.00 (0.02)
Log (household *per capita* monthly consumer expenditure)	0.12 (0.09)	0.05 (0.04)	0.77[a] (0.11)	−0.11[c] (0.1)	0.33[b] (0.11)	0.58[c] (0.13)	−0.03 (0.1)
HH with crop cultivation as a primary income source	0.03 (0.06)	0.01 (0.02)	−0.07 (0.09)	−0.11 (0.07)	0.10 (0.08)	0.31 (0.13)	0.08[c] (0.04)
HH with animal husbandry as a primary income source	−0.10 (0.14)	−0.04 (0.06)	0.23[a] (0.17)	−0.38 (0.17)	−0.54 (0.18)	0.82 (0.3)	−0.33 (0.17)
Scheduled tribe (ST)	−0.00 (0.15)	−0.00 (0.06)	−0.18 (0.38)	−0.15[b] (0.2)	−0.39[c] (0.23)	−4.55 (0.28)	0.18 (0.24)
Scheduled caste (SC)	−0.12 (0.08)	−0.05 (0.03)	−0.11 (0.10)	−0.38[a] (0.10)	−0.23 (0.12)	0.20 (0.16)	−0.01 (0.10)
Other backward class (OBC)	−0.02 (0.07)	−0.01 (0.03)	0.02 (0.10)	−0.24[a] (0.09)	−0.13 (0.10)	0.07 (0.14)	0.11 (0.09)
Base: General caste							
Landholding categories							
Marginal landholding HH (<1 Ha)	−0.79[a] (0.36)	−0.27[a] (0.10)	−1.28[a] (0.29)	−0.25[a] (0.4)	−0.78 (0.35)	−0.09 (0.34)	−0.25 (0.35)
Small landholding HH (1–2 Ha)	−0.66[a] (0.36)	−0.26[a] (0.13)	−1.12[a] (0.28)	−0.08[a] (0.41)	−0.6 (0.33)	−0.01 (0.34)	−0.18 (0.34)
Semi-medium landholding HH (2–4 Ha)	−0.48[b] (0.36)	−0.19[b] (0.14)	−0.87[a] (0.27)	−0.06[b] (0.39)	−0.49 (0.34)	−0.05 (0.35)	−0.07 (0.33)
Medium landholding HH (4–10 Ha)	−0.49 (0.38)	−0.19 (0.15)	−0.87[a] (0.3)	−0.09[b] (0.43)	−0.41 (0.31)	−0.09 (0.38)	−0.05 (0.34)
Base: Large Landholding HH (>10 Ha)							
Proportion of irrigated area	0.35[a] (0.10)	0.14[a] (0.04)	−0.58[a] (0.12)	0.58[a] (0.14)	0.15 (0.15)	0.30 (0.21)	0.57[a] (0.14)
Access to credit from formal sources	−0.14 (0.06)	−0.05 (0.02)	−0.07 (0.09)	−0.21[b] (0.07)	−0.14 (0.07)	−0.07 (0.12)	0.06 (0.08)
Membership in farmers' organization	0.12 (0.12)	0.04 (0.04)	0.53 (0.21)	−0.15 (0.14)	−0.02 (0.13)	0.81 (0.31)	0.15 (0.17)
Sold crop produce at minimum support price (MSP)	0.00[c] (0.13)	0.00[c] (0.05)	0.04[a] (0.12)	0.16 (0.13)	0.05[a] (0.12)	0.27 (0.16)	0.00 (0.13)
HH experienced crop losses	0.11 (0.08)	0.04 (0.03)	0.04 (0.09)	0.20[b] (0.08)	0.09 (0.08)	0.01 (0.13)	0.18 (0.08)
Crop insured	0.17 (0.09)	0.06 (0.04)	0.36 (0.13)	0.14 (0.13)	0.11 (0.13)	−0.21 (0.14)	0.10 (0.12)
Constant	−0.66 (0.88)		−5.72 (0.98)	−0.53 (1.04)	−2.66 (1)	−8.5 (1.14)	−1.43 (1)
Wald chi^2 (25)/(125)	124.98		3650.96				
Prob > chi^2	0.0000		0.0000				
Log-likelihood	−2294550.3		−4888579.9				
N	14,782						

#a, b, and c indicates $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

but were less likely to access private sources, probably because of the high costs involved for the private advice.

The study found that households belonging to ST, SC and OBC castes were less likely to report private extension system as their major source of information, as compared to the general castes. Krishna et al. (2019) reported, the likelihood that a farmer from one of the marginalized castes would contact an extension agent was 26–63% lower compared to one from non-marginalized caste. Similar Alvi et al. (2021) also found caste identity as one of the mediating factors determining access to extension sources, apart from crop type, and geographic location. This may be due to low awareness about various sources due to low education levels (Thorat, 2009; Desai and Dubey, 2012) and low social exposure (Krishna et al., 2019, Gupta I. et al., 2020; Gupta S. et al., 2020). Also, studies by Ito (2009), Anderson (2011), Desai and Dubey (2012), Kumar (2013), Krishna et al. (2019), Gupta I. et al. (2020), Gupta S. et al. (2020), and Anderson et al. (2006) indicate the limited or differential access to productive resources and social barriers as the hindering factors for the lower castes to access information. The dependence on traditional practices and subsistence agriculture in these communities, as observed by Rao (2017), can limit

their engagement with commercial farming knowledge. This challenge is compounded by the inherent bias of the extension personnel toward large and wealthy farmers, further restricting their access to relevant information and support (Munshi, 2004; Kondylis et al., 2017; Nakano et al., 2018). Lower castes are generally located in remote areas which limits their access to formal sources of information and extension (Moloo et al., 2018). The present study found that the marginalized castes relied majorly on farmer-to-farmer exchange of information and the public extension system; where there was no significant difference in these social groups as compared to the general castes. However, some studies like Birthal et al. (2015) and Rao (2017) suggest unequal access to public extension services for farmers from marginalized castes. Lower caste households in India struggle to access formal information sources related to agriculture, according to Birthal et al. (2015), compelling them to depend more on informal channels for crucial knowledge (Negi et al., 2020), potentially perpetuating existing inequalities. The non-uniformity of access to information across households belonging to different castes was also accompanied with the varying degrees of usefulness of the information obtained (Rao, 2017; Krishna et al., 2019).

An interesting observation recorded was that the households with irrigated lands were significantly accessing information from private sources and progressive farmers, as they are highly profit-oriented and need to adopt the most suitable and effective measures to boost crop productivity. Access to the public extension system experienced a notable decrease as the land area under irrigation declined significantly. Additionally, access to credit was negatively correlated with access to private extension systems. Surprisingly, membership in farmer organizations had no significant relationship with access to different sources of information, a finding which was contradicted by Manda et al. (2020). Equally astonishing was the revelation that households who insured their crops had no significant association with information access. The probability of seeking information from the public sector and mass media increased for households that sold their produce at Minimum Support Price (MSP). This is because households selling at MSP are likely to be more attuned to market dynamics, seeking information on pricing trends, government policies, and market conditions to make informed decisions about their produce. Mass media serves as a valuable source of market intelligence. Public extension system will inform about any changes or updates in policies that may impact their income and overall agricultural practices. Households experiencing crop loss were found to access the private sources of agricultural extension services, as they expect precise and specialized and tailored solutions from the private players to minimize or prevent crop losses. Farmers access private extension services with the hope that they may be offered more prompt and responsive assistance compared to public services, so as to enable implementation of quick, effective and timely interventions.

4 Discussion

Our study reported that the private agencies were the most popular information source among farmers, accessed by 35.78% of them. A study by Mukherjee and Maity (2015) indicates that private extension service providers can meet the information needs of farmers by supplying quick, timely, efficient and appropriate services. Agri-input dealers are the most trusted information source for the farmers in the rural domain (Ferroni and Zhou, 2012); as they not only provide information but also new variety/technology, other agricultural inputs and conduct demonstrations in farmers' fields (Kumar et al., 2020). Progressive farmers also served as preferred sources for agricultural information. This could be attributed to their easy accessibility (Mittal and Mehar, 2013), high credibility and socio-cultural compatibility, and potential for efficient and cost-effective information dissemination (Lukuyu et al., 2012). Bachhav (2012) and Mittal and Mehar (2013) argued that fellow farmers are the first preferred sources of information for the farmers followed by the print media and public extension personnel. Instead of favoring large and well-equipped farmers, the extension services should be redirected to prioritize farmers who truly reflect the local farming conditions. Oluwasusi (2014) found that the extension service needs of farmers were met by progressive farmers followed by input dealers, radio broadcasts and by public extension services.

For the most demanded information in agriculture like inputs (seeds, fertilizers, plant protection chemicals), the popular choices were traditional media, progressive farmers and input dealers. The findings of Meitei and Devi (2009), Babu et al. (2012), Bachhav (2012), Ghimire et al. (2012), Mittal and Mehar (2013), and Saravanan (2007) were in line with the study findings. There should be inclusion of multiple aspects which are of emerging importance in agriculture like climate change, post-harvest management, value chain systems management, market mobilization and quality control. Gulati et al. (2018) also highlighted Krishi Darshan as one among the major sources of agricultural information for the farmers. However, the information provided from multiple sources like private players, progressive farmers and mass media need to be triangulated and validated from Government agencies to establish their credibility before dissemination to the farming community. Prior to formulating any information set, it is essential to consider the varied needs and heterogeneous socio-economic and agro-ecological conditions of the farming population, especially the regional variations. Also, the information inclusiveness should be taken into consideration by giving special care to delivering information to small and marginal farmers, women and marginalized groups.

Inspite of many studies reporting the public players being the major providers of extension services in developing nations (Reardon et al., 2011; Kassem, 2014; Maoba, 2016; Berhane et al., 2018), the present study revealed that the public extension system served only 10% of the households for their information needs. The poor access can be attributed to unsustainable public costs, shortage of human resources, staff over-burdened with other routine works (Birner and Anderson, 2007), the tendency to neglect the women farmers (Raabe, 2008), a top-down and supply-driven approach, lack of farming system approach (Singh et al., 2012), bias toward the large farmers (Brhane et al., 2017), over-reliance on traditional means of public outreach, lack of information specificity with respect to quality, time and location (Sulaiman and Hall, 2002; Sajesh and Suresh, 2016; Vincent and Saravanan, 2020). The key is to establish partnerships among public, private, and non-governmental organizations to meticulously shape information and achieve a synergistic convergence of social welfare, speed, and efficiency. Also, we need to tap the potential of modern ICT tools for wider information dissemination and coverage.

Babu et al. (2013) reported that the preference toward the agricultural information source was primarily determined by

proximity, assured quality, sole option, and timely availability. The findings of poor access to FPOs and Cooperatives were reiterated in the studies conducted by Nagar et al. (2021), Babu et al. (2012), and Ferroni and Zhou (2012). There is a need to promote the role of FPOs and other similar farmer groups or collectives in catering to the information needs of farmers. We observed that multiplicity of information sources accesses increased with increasing landholding size. The findings are in line with Babu et al. (2012) and Shiri et al. (2014). Mittal and Mehar (2013) also concluded that small and marginal farmers use a single information source, especially the farmer-to-farmer interaction; 33% of the farmers use any combination of three sources and 22% of the farmers use all four categories of information. Nagar et al. (2021) concluded that with increasing education and land size, households tend to diversify their information sources.

The present study inferred that access to agricultural information sources is significantly determined by age, gender, education, landholding, irrigated area and sale of produce at MSP. Studies by Babu et al. (2012), Maake and Antwi (2022), and Mittal and Mehar (2013) indicate that age, education level, and farm size significantly influence the farmer's access to advisory services from public extension. Age and education have been reported to be positively significant for access, however age does not contribute to the adoption (Tchaogang et al., 2019; Nagar et al., 2021). However, a negative effect of age was studied by Jenkins et al. (2011), citing that increasing age makes them averse to search for new information and making changes in the cropping system. Study findings of Abraham (2008), Jensen (2010), and Mittal et al. (2010) highlighted that education, landholding size and the *per capita* income have a significant effect on access to information sources. Our findings were contradicted by Nagar et al. (2021) who reported that household size had no effect on access to information services. But it was congruent with our findings of male headed households accessing more information as compared to their female counterparts and increased information collection by households selling at MSP and with assured means of irrigation. Babu et al. (2012) studied that membership in FPOs significantly determine information access, which was not confirmed through our study. The study by Joshi et al. (2015) reported that when the principal source of income is "Livestock" as compared to "Crop cultivation," the likelihood of farmers accessing agricultural information goes down by 61% for livestock. Our findings were reiterated by Anderson (2011) and Nagar et al. (2021) who reported that as compared to SCs and STs, the OBCs and General categories have an advantage of access to extension service providers, attributed to their strong social networking and favorable socio-economic-cultural position in the society.

5 Conclusion

The study reveals significant disparities in the accessibility of agricultural extension services for agricultural information among farmers with varying landholding sizes. This underscores the pressing need for the development of targeted policy measures aimed at fostering inclusivity. These measures are essential to ensure that extension services become more accessible across the farming community, especially targeting the women, small and marginal farmers and those belonging to the marginalized sections of society, ultimately guaranteeing equitable benefits for all. The information should be so designed to cater to the diverse needs of the heterogenous farming community. The input dealers have emerged as the most preferred information sources, thus they need to be trained to provide authentic and relevant information to the farmer clientele. The promotion of farmer-to-farmer cross-learning can be enhanced by actively encouraging and acknowledging the accomplishments of successful farmers within the region. This can be achieved through the implementation of regular exposure visits, providing a valuable platform for knowledge exchange and recognition of best practices. The use of social networking in agriculture goes beyond mere communication; it builds communities, fosters knowledge exchange, and empowers farmers with the information they need for sustainable and successful agricultural practices. As technology continues to evolve, leveraging social networks will remain a dynamic tool for transforming how agricultural information is shared and utilized within farming communities. The increasingly popular farmer-based organizations merit effective promotion to fully realize the advantages offered by economies of scale. The government should play a pivotal role in validating and promoting agricultural content within mobile apps, ensuring its reliability and user-friendliness for the intended target group. Additionally, there is a pressing need to converge traditional mass media with cutting-edge Information and Communication Technology (ICT) tools to create a more comprehensive and effective information dissemination platform.

The extension services provided needs to be tailored to the specific needs and socio-economic conditions of all farmers; taking into account their different farming systems, livelihood strategies, and cultural contexts. The public extension system needs to be strengthened to deliver timely and need-based information in smart ways. The study identified the factors like age, gender, education, size of landholding, irrigated area, and households that sold crop produce at MSP as the underlying factors determining access to sources of extension services. Thus, these factors can serve as the foundational basis for designing better and well-informed policy decisions to further improve access to extension and advisory services in future. The study recommends robust government support for reinforcing the education system and enhancing the capacity of small and marginal farmers, as well as those from marginalized communities and women. This approach aims to uplift their economic conditions and guarantee fair access to resources. In essence, fostering inclusive extension services emerges as a crucial factor in advancing sustainable agriculture and environmental well-being.

The implications of the above study hold significance for farmers, agricultural universities, and state agricultural departments. For farmers, the findings provide insights into potential challenges and variations in accessing agricultural extension services, allowing them to better understand and navigate available resources. Agricultural universities can utilize this information to tailor their outreach programs, ensuring they address the specific needs of diverse farmer groups. State agricultural departments can benefit by refining their support strategies based on the identified patterns, ultimately contributing to more effective and targeted agricultural extension services. Overall, the study offers actionable insights that can inform policy decisions, resource allocation, and support mechanisms for the benefit of the agricultural community. As future research endeavors, we are also looking ahead to undertake a comparative analysis of factors influencing access and usage pattern of agricultural extension services across various regions of India; especially highlighting the

socio-cultural, geopolitical, agro-climatic factors, etc. Through this exercise, we aim to identify nuanced challenges and opportunities that can deliver more targeted and effective agricultural extension services. In addition, the analysis of the impact to explore the effectiveness of the accessed information on farmers' practices or livelihoods; is a planned aspect for future research studies.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: The data was extracted from the dataset generated from the 77th round of the "Situation Assessment of Agricultural Households and Land and Holdings of Households in Rural India, 2019," conducted by the National Sample Survey Organization (NSSO), Government of India.

Author contributions

SSa: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. SBi: Writing – review & editing, Methodology, Data curation. PS: Writing – original draft, Software, Methodology, Data curation. Satyapriya: Writing – review & editing, Project administration. GM: Writing – review & editing. RB: Writing – review & editing, Project administration. SBa: Writing – review & editing, Formal analysis. MM: Writing – review & editing, Formal analysis. VS: Writing – review & editing, Investigation. SSi: Writing – review & editing, Validation. RS: Writing – review & editing, Visualization, Validation. MW: Writing – review & editing, Validation. PJ: Writing – review & editing, Validation. SSh: Writing – review & editing, Visualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

Description of the explanatory variables used in the regression model.

Explanatory variables	Description of the variables
Age	Age of the household (HH) head in years
Gender	Gender of the household head, 1 = male, 0 otherwise
Education of the HH	Education level of the household head
Household members in the working age group	Number of family members between 15–65 age group
Household *per capita* monthly consumer expenditure	Household *per capita* monthly consumer expenditure
HH with crop cultivation as a primary income source	Dummy = 1 if the household's primary income source is a crop, 0 otherwise
HH with animal husbandry as a primary income source	Dummy = 1 if the household's primary income source is livestock, 0 otherwise
Scheduled tribe (ST)	Dummy = 1 if household belongs to ST, 0 otherwise
Scheduled caste (SC)	Dummy = 1 if the household belongs to SC, 0 otherwise
Other backward class (OBC)	Dummy = 1 if household belongs to OBC, 0 otherwise
General caste	Dummy = 1 if household belongs to general caste, 0 otherwise
Marginal landholding HH (<1 Ha)	Dummy = 1 if the size of operational holding is less than or equal to 1.00 ha, 0 otherwise
Small landholding HH (1–2 Ha)	Dummy = 1 if the size of operational holding is more than 1.00 but less than or equal to 2.00 ha, and 0 otherwise
Semi-medium landholding HH (2–4 Ha)	Dummy = 1 if the size of operational holding is more than 2.00 but less than or equal to 4.00 ha, 0 otherwise
Medium landholding HH (4–10 Ha)	Dummy = 1 if the size of operational holding is more than 4.00 but less than or equal to 10.00 ha,0 otherwise
Large landholding HH (>10 Ha)	Dummy = 1 if the size of the operational holding more than 10.00 ha, 0 otherwise
Proportion of Irrigated area	The proportion of irrigated area to the total cultivated land
Access to credit from formal sources	Dummy = 1 if the household had access to the formal credit system, 0 otherwise
Member of farmers' organization	Dummy = 1 if the household is a member of a farmer's organization, 0 otherwise
Sold crop produce at minimum support price (MSP)	Dummy = 1 if the household Sell agricultural produce at Minimum Support Price (MSP), 0 otherwise
HH experienced crop losses	Dummy = 1 if the household had experienced any crop loss, 0 otherwise
Crop insured	Dummy = 1 if the household has an insured crop, 0 otherwise