ISSN Online: 3006-4708
ISSN Print: 3006-4694

SOCIAL SCIENCE REVIEW ARCHIVES
https://policyjournalofms.com

Strengthening Livelihood Development of Small Scale Wheat Farmers: Comparative Effectiveness of Public and Private Extension in Supporting Crop Adaptation Strategies

Karim Ullah[1], Ikramul Haq[1]

[1,2] Department of Agricultural Extension Education and Communication, The University of Agriculture, Peshawar-Pakistan Email: karimullah977@gmail.com

DOI: https://doi.org/10.70670/sra.v3i4.1614

Abstract

Agricultural production systems are facing greater climate variability, resource constraints, and market uncertainty, which seriously threaten the livelihood of Small Scale Wheat Farmers. In this context, effective extension services are considered a key driver for promoting crop adaptation strategies, enhancing productivity, and improving income stability. However, empirical evidence remains limited regarding how Public and Private Extension differ in their contribution to adaptation and Livelihood outcomes. Using cross-sectional data collected from 270 selected wheat farmers registered with both Public and Private Extension department in district Charsadda and Dir Upper, the study constructed adaptation indices and Visits indices and applied correlation and multiple regression analysis to examine relationships among variables. This study therefore addresses the needs to understand the effectiveness of extension contact and adaptation strategies in improving wheat-based production systems of Small scale wheat farmers. The key issue investigated was whether extension interaction and provided adaptation strategies significantly influence Wheat productivity and income, as core components of livelihood. Results showed a very strong positive correlation between wheat production and income (.93), confirming that productivity gains directly support livelihood improvement. Adaptation indices were positively correlated with production (.539**) and income (.579**) under Public Extension, while in regression analysis, contact with Public Extension showed significant positive effects on production (10.21) and adaptation (13.514). In contrast, Private contact had a weaker influence on productivity (4.268) and non-significant correlation between visits and adaptation (.075), indicating variations in service effectiveness. The study concludes that structured and frequent extension interaction, particularly under Public Extension, plays a critical role in building adaptive capacity and improving the Livelihood of Small Scale wheat Farmers through productivity and income gains. Recommendations include strengthening the quality of advisory services, improving adaptation-focused training, and enhancing coordination between Public and Private Extension to maximize developmental impact on Small Scale Wheat Farmers Livelihood.

Key word: Public Extension, Private Extension, Visits, Adaptation Strategies, Wheat, Productivity, Income, Correlation, Regression

Introduction

Wheat (Triticum aestivum) provides about 20% of the world's calories and protein, making it a staple for billions, especially in temperate and developing regions (Voučko et al., 2025; Albahri et al., 2023). It is a major source of dietary fiber, vitamins B, and essential minerals, contributing to reduced risks of cardiovascular disease, diabetes, and some cancers (Poole et al., 2025. Wheat is the cornerstone of Pakistan's food security and agricultural economy, occupying the largest area of any crop and constituting the primary staple for the national diet. Based on 3-year average ending 2021-23, the total area allocated for wheat cultivation averaged 9,061.9 (22,392.8) thousand hectares, with district Punjab possessing 72.8 percent, Sindh securing 13.3 percent, KPK keeping 8.5 percent, and district Balochistan bearing 5.4 percent. The total production provided 27,282.7 thousand tonnes, distributed as follows: Punjab produced 75.9 percent, Sindh supplied 14.1 percent, Khyber Pakhtunkhwa (KPK) contributed 5.2 percent, and Balochistan produced 4.8 percent. (API, 2023-24). The crop accounts for 7.8 per cent of value added in agriculture and about 1.9 per cent to GDP of the country. Wheat crop average yield of [e.g., 3.1 tons/ha] remains significantly below the achievable potential, highlighting a persistent yield gap that translates into foregone income and import dependency (GoP, Pakistan Economic Survey, 2023-24).

Wheat production faces significant challenges from climate change, land degradation, water scarcity, and rising input costs (Grote et al., 2021; Bohra et al., 2024); Kettlewell; et al., 2023) Growing-season climate (means + extremes) explains roughly 20–49% of global yield anomalies for major crops like wheat; 18–43% of that explained variance is specifically due to climate extremes (Vogel et al., 2019). A, 1 °C, global warming reduces average wheat yields by about 6.0% with strong regional differences (Hu et al., 2024). Similarly, Heino et al., (2023) also reported that frequent hot–dry events during the growing season consistently depress yields of all major crops and their probability has risen sharply, up to six-fold for wheat in some regions.

Role of Adaptation Strategies for Wheat Crop

Wheat's adaptability allows it to be cultivated across diverse climates, ensuring a stable food supply even as global demand rises (Wolniak and Grebski (2025). Irrigation consistently reduces yield sensitivity to heat and precipitation extremes, stabilizing production (Kukal, and Irmak. 2018; Gao et al., 2025) by practicing optimized irrigation can boost yields 30–50% and buffer climate impacts where water is available and Adjusting sowing dates, crop choice, and management can reduce yield (Kaium et al., 2025; Habib et al., 2022) to avoids heat at seedling or grain-filling stages; can recover 6–7.5% of otherwise lost yield; widely adopted by farmers in Pakistan and Bangladesh (Pathania et al., 2025; Shoukat et al., 2024). Farm led changes increased wheat productivity and net income in Pakistan, (Abid et al., 2016) by Shelterbelts, stiff-stem varieties, better drainage, and watercourse maintenance significantly cut storm and hail damage to wheat (Elahi et al., 2021; Ehsan et al., 2022).

Evidence on Agricultural Extension and Crop Adaptation strategies

Agricultural extension services function as a core mechanism for knowledge transfer, skill development, practice adoption, and adaptation by mediating between research institutions and farming communities through non-formal education and advisory systems (Raji et al., (2024); Abhijeet et al., (2023) Ananda et al., (2024). As structured "bridges" or agricultural knowledge and information systems, they translate scientific advances and adaptation practices into locally relevant recommendations, using tools such as training sessions, farmer field schools, demonstrations, media, and information and communication technology (ICT-based) advisories (Rejesh et al., 2024, 2024) (Raji et al., (2024); Xu et al., (2023); Ferdousi et al., (2024) Ananda et al., (2024). Through repeated, participatory interactions, extension agents build farmers' human capital by enhancing technical and decision-making skills in areas such as soil and water management, pest control, climate-risk management, and organic or conservation agriculture (Osumba, et al., 2021); Priya et al., 2025; Rejesh et al., 2024, 2024); Kumar et al., (2023); Khan and Ray (2023). These skills underpin the adoption of improved practices and technologies, including drought-resistant varieties, efficient irrigation, and climate-smart agriculture packages that raise productivity and resilience (Osumba et al., 2021; Rejesh et al., 2024); Chourad et al., 2024; Ananda et al., (2024). By raising awareness of climate risks extension services also enable agricultural adaptation to stresses, strengthening farmers' capacity to adjust production systems and livelihoods over time (Antwi-Agyei and Stringer, 2021; Priya et al., 2025; Makamane et al., 2025; Mungai et al., 2024; Ferdousi et al., (2024); Heena et al., (2025).

Wheat farmers in Pakistan and Bangladesh, access to extension and training regarding adaptation strategies for crops significantly increases the probability of adopting adaptation measures such as changing sowing dates, varieties, fertilizer use, and irrigation, with positive impacts on yields and income (Mahmood et al., 2020; Abid et al., 2016; Rana et al., 2023; Jatav et al., 2021). Climate-specific trainings on resilient wheat farming increase the likelihood of adaptation by about 31% and encourage multiple adaptation strategies (Mahmood et al., 2020) Similar patterns appear for wheat blast-affected farmers in Bangladesh, where extension access is a key determinant of shifts in varieties, crops, and intercultural practices (Rana et al., 2023) Systematic reviews of climate-smart agriculture confirm that extension is central for disseminating resilient varieties, conservation practices, and risk-mitigation strategies (Thottadi and Sing 2024); Ferdousi et al., (2024); (Rejesh et al., 2024).

Research Gap

Public and Private Extension

Extension department clearly promotes wheat farmers' adaptation, but comparative evidence on public versus private providers is sparse and mostly indirect. Regarding Capacity building & technical training public extension often more active in on-farm visits, demonstrations, and training; rated more effective for farmer capacity building (Kabir and Islam, 2023). In Ireland, mixed Public–Private and purely Private Extesnsion systems target different farmer types but show similar economic outcomes (Balaine et al., 2022). Regarding Service quality and responsiveness Public extension sometimes constrained by high agent–farmers ratio and limited resources, While Private extension Frequently rated higher for responsiveness, tailoring to needs, and continuous learning opportunities (Tham-Agyekum, et al., 2024).

Recent reviews on adaptation strategies for crops and extension underline that outcome-based evaluations dominate at single links (e.g., "extension → adoption" or Climate Smart Agriculture "CSA → yield"), while integrated, longitudinal studies covering the entire pathway—extension contact → adaptation decisions → productivity → multi-dimensional livelihood change—are scarce (Rejesh et al., 2024; Antwi-Agyei and Stringer, 2021; Mnukwa et al., 2025). There is also limited attention to heterogeneity by gender, wealth, and region along this chain (Ongachi, and Belinder, (2025).

Need of the Study

The studies document that both public and private extension can improve adaptation, productivity, or selected livelihood indicators, comparative, theory-driven research that explicitly traces and contrasts the full pathway from public versus private extension contact to adaptation, productivity, and livelihood improvement for small farmers is still largely missing (Ongachi, and Belinder 2025; Rajkhowa and Qaim, 2021; Mudzielwana et al., 2025; Mishra et al., 2024; Loki and Mdoda 2023). Therefore, it is crucial to conduct a research on small scale wheat farmers' livelihood and the role of Public and Private agricultural extension services in order to combat poverty, improve food security, foster economic growth, and guarantee sustainable farming methods. The farmers will not only gain benefits from this study, but it will also offer beneficial insights into the effectiveness of both the sectors (Public and Private Extension) in enhancing livelihood of small scale wheat farmers.

Objectives

1. To examine relationships among provided adaptation strategies of crops, Public and Private Extension agent visits to farmers, production, and income.

2. To assess the effect of Public and Private Extension agent visits and the provided crop adaptation strategies on Wheat Productivity.

Methodology

The present research was conducted in Khyber Pakhtunkhwa (KP) Pakistan to target the services provided by Public and Private Extension Services to Small Scale Wheat Farmers. Descriptive survey design dedicated to documenting farmer perceptions and profiles, Focus were remained on two Agro-Ecological Zones (AEZ): (1) High Dry Mountains (AEZ-AI) and (2) Plain Valley (AEZ-C). District Charsadda and Dir Upper were purposively selected from these two zones.

A list of respondents was obtained from Public and Private Extension services providers for the identification of potential respondents for this study. The sample size was determined on the basis of Guesses Variability i.e. 50% for maximum sample size as suggested by Kasely and Kumar (1989). The number of farmers (respondents) included in the present study was determined using formula for unknown population that is defined in Equation (1) (Shehzad, 2020).

n = Z^2 V 2 / D2 .... (1)

Where, **n** = Total size of the sample; **D** = Estimate acceptable margin (6%); **Z** = Error of the confidence level limit or normal variation (95%) and constant for this value is 1.96; **V** = 50%, this is because of the assumption that 50% of the farmers had taken the services both from private and Public extension sector. Similar, study also takes the assumption of 50% i.e Ullah and Nawab, (2019).

n = (1.96)2 x (50)2 / (6)2 = 267 almost 270

For the selection of respondents simple random sampling technique was used. From each selected district, 135 farmers was selected randomly from each district utilizing both department services, thus making a total Final Rounded to 270 sample size (135x2=270) respondents. Keeping in view the objectives of the study, well-structured interview schedule was prepared which was comprised of close ended and Five point Likert Scale. Data was analyzed on Statistical Package for Social Sciences Software (SPSS), Simple mean, frequencies, correlation, multiple linear regression and weighted score were calculated.

Adaptation Strategies of Crops Index (ASCI) Formula

$$\mathrm{ASCI} = \frac{\sum(\mathrm{S_i} \times \mathrm{A_i})}{\mathrm{N}}$$

Where:

- **ASCI** = Adaptation Strategies of crops Index
- **S_i** = Score of the i-th adaptation strategy provided by the both extension department
- **A_i** = Adoption status of the strategy (1 = adopted, 0 = not adopted)
- **N** = Total number of adaptation strategy indicators

This index was calculated **separately for Public Extension provided adaptation strategies of crops (PASCI) and Private Extension provided adaptation strategies of crops (PrASCI)**.

Visits Index Formula

Following a similar methodological approach, an Extension Visits index was also calculated. This was done by computing the simple average of the reported frequencies of visits from extension agents received by each farmer.

$$\mathrm{VI} = \frac{\sum \mathrm{V_i}}{\mathrm{N}}$$

Where:

- **VI** = Visits Index
- **V_i** = Visit/contact score of extension services
- **N** = Total number of contact indicators

- This index was calculated **separately for Public Extension Visits to Farmers (VPF) and Private Extension visits to Farmers (VPrF).**

Pearson correlation

The Pearson correlation coefficient measures the strength and direction of a linear relationship between two continuous variables. Mathematically:

$$r_{W.PW.I} = \frac{\sum(W.P_i - \bar{W.P})(W.I_i - \bar{W.I})}{\sqrt{\sum(W.P_i - \bar{W.P})^2 \sum(W.I_i - \bar{W.I})^2}} \quad r_{ASCIW.P} = \frac{\sum(ASCI_i - \bar{ASCI})(W.P_i - \bar{W.P})}{\sqrt{\sum(ASCI_i - \bar{ASCI})^2 \sum(W.P_i - \bar{W.P})^2}} \quad r_{ASCIVI} = \frac{\sum(ASCI_i - \bar{ASCI})(VI_i - \bar{VI})}{\sqrt{\sum(ASCI_i - \bar{ASCI})^2 \sum(VI_i - \bar{VI})^2}}$$

Where:

- **W.I** = Wheat Income
- **W.P** = Wheat Production
- **VI**= Visits Index: Public Extension Visits to Farmers (VPF) and Private Extension visits to Farmers (VPrF)
- **ASCI** = Adaptation strategies of Crops index: Public Extension adaptation strategies of crops (PASCI) and Private Extension adaptation strategies of crops (PrASCI).

Multiple Linear Regression Model

The impact of Public and Private Extension agents contact/visits with farmers and crop adaptation strategy promoted by Public and Private Extension and their adoption by farmers, on wheat productivity was calculated using multiple linear regression analysis while controlling for the socioeconomic characteristics of farmers. Mathematically the equation as given below

$$WP_i = \beta_0 + \beta_1 Edu_i + \beta_2 Area_i + \beta_3 Exp_i + \beta_4 Age_i + \beta_5 VI_i + \beta_6 ASCI_i + \varepsilon_i$$

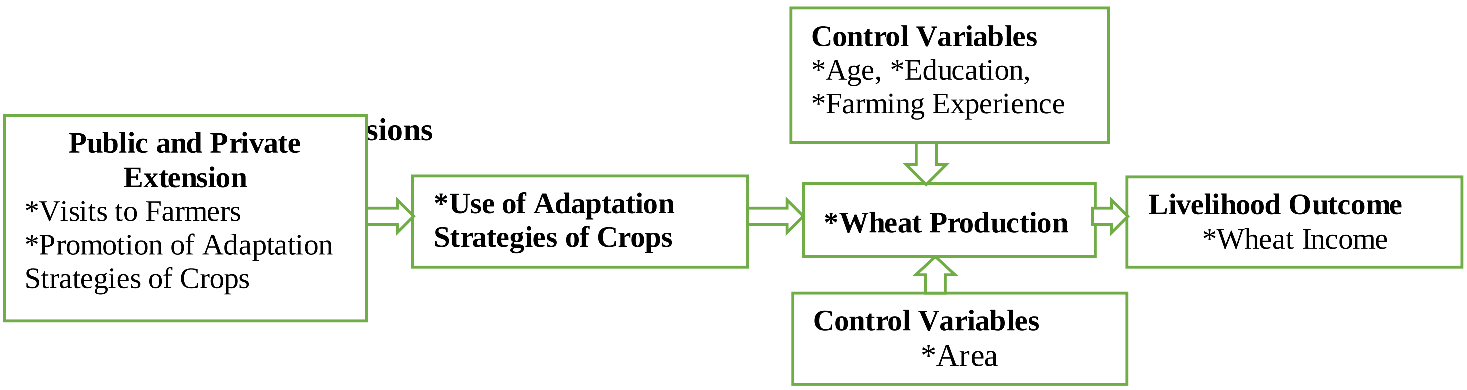
Definition of the Variables

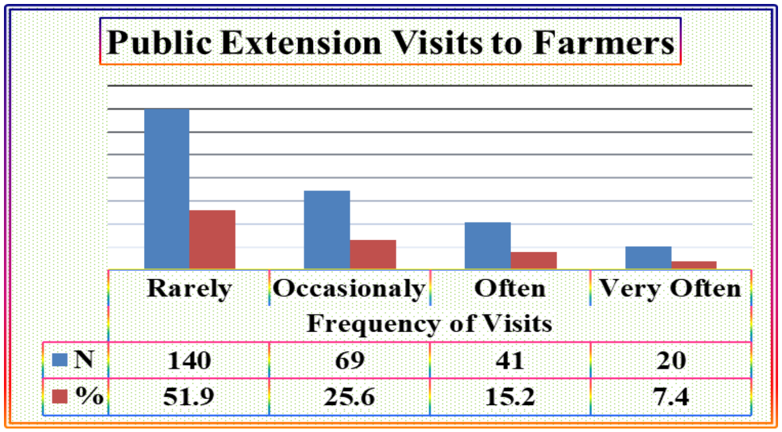
Symbol	Meaning
W.P	Wheat Production (kg) — **Dependent variable**
Edu	Years of schooling
Area	Wheat area (acre)
F.Exp	Farming experience (years)
Age	Age of farmer (years)
VI	**Visit Index:** Public Extension Visits to Farmers **(VPF)** and Private Extension visits to Farmers **(VPrF)**
ASCI	**Adoption strategies of Crops index:** Adaptation strategies of Crops index: Public Extension Promoted adaptation strategies of crops **(PASCI)** and Private Extension Promoted adaptation strategies of crops **(PrASCI).**
$\boldsymbol{\beta_0}$	**Intercept**
$\boldsymbol{\beta_1 \ldots \beta_6}$	**Estimated coefficients**
$\boldsymbol{\varepsilon_i}$	**Random error term**

Conceptual Frame work For the Study

The study is based on the assumption that extension services act as a capacity-building mechanism that improves adaptive behavior, which in turn enhances production and income, ultimately strengthening Livelihood of Small Scale Farmers.

Author's Own Conceptual Framework





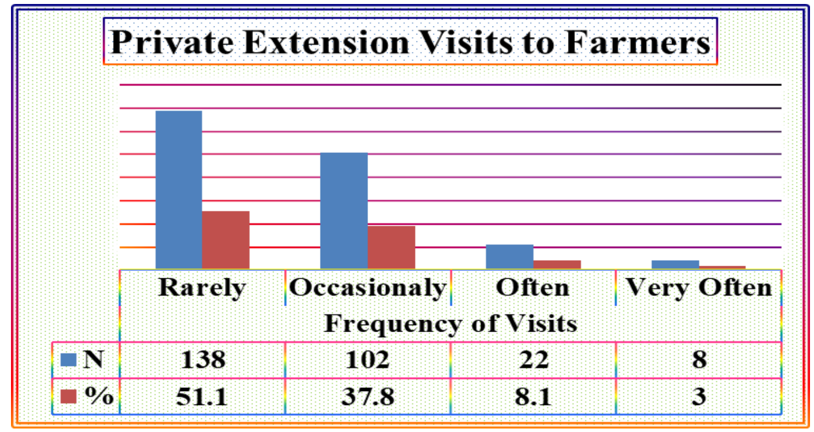


Figure 1 Sources: Data Survey, 2025: N=Number of Respondents   Figure 2 Sources: Data Survey, 2025: N=Number of Respondents

Table 1 Respondents regarding Adaption Strategies of Crops Provided by Public and Private Extension

Adapted Strategies of Crops	**Public Extension**							**Private Extension**							**Adopted**	
	1	**2**	**3**	**4**	**5**	**W.S**	**Rank**	**1**	**2**	**3**	**4**	**5**	**W.S**	**Rank**	**Yes**	**No**
Helped in scheduling management of Farm operation	23	32	34	28	153	1043	1	36	54	61	52	67	834	3	**182**	**88**
Helped in integration of Agroforestry	13	30	50	65	112	1030	2	47	50	39	61	73	826	4	**214**	**56**
Guided how to get Institutional/Governmental Support	41	63	52	62	75	905	3	59	36	70	52	45	715	9	**165**	**105**
Guided to recognize and integrate indigenous knowledge	41	40	52	62	75	859	4	59	44	70	52	45	731	8	**161**	**109**
Provided guidance on proper management of Fertilizer	45	39	37	78	71	856	5	44	47	73	42	64	801	6	**157**	**113**
Intercropping of different crops are taught	33	57	45	70	65	854	6	38	49	67	66	50	813	5	**167**	**103**
assisted in spacing and adjusting of plant locations and to cope with climate variability	40	39	60	63	68	850	7	13	32	33	61	131	1062	1	**177**	**93**

Motivated adoption of new crop varieties	46	40	48	57	79	847	8	45	77	42	72	34	738	7	**160**	**110**
Adoption of new technologies is encouraged	44	36	58	72	60	834	9	22	54	43	23	128	969	2	**151**	**119**

1. Strongly disagree 2. Disagree 3. Somewhat agree 4. Agree 5. Strongly agree W.S= weighted Score Sources: Data Survey, 2025

Figure 1, shows the frequency of visits from Public Extension and Private Extension across districts. In Public Extension majority of respondents reported “rarely” (once in a year) visits (140, 51.9%), followed by “occasionally” (69, 25.6%). This indicates limited regular contact from Public extension staff. In contrast in Figure 2, Private Extension services show stronger presence at the “occasionally” level (twice a year) (102, 37.8%), while rarely visits also remain high (138, 51.1%). However “often” and “Very Often”, categories remain low for both systems, with Public extension 41, 15.2% and 20, 7.4% and Private Extension 22, 8.1% and 8, 3%.

Table 1 provides a descriptive and ranking analysis of agreement with Crops adapted Strategies delivered by Public Extension and Private Extension, which formed the basis of the Public adaptation Index and Private adaptation Index. The data show that respondents generally reported high levels of agreement on scale 4–5 with public extension services compared to private. The top-ranked public strategy “helped in scheduling management of farm operation” received the highest Weighted Score (1043, Rank=1), with a large proportion of respondents selecting “Agree” and “Strongly agree.” This indicates that operational planning support from Public Extension is highly valued. In contrast the same strategy under Private Extension received a lower weighted score (834, Rank=3), showing comparatively weaker perceived effectiveness. Similarly “Integration of Agroforestry” was second ranked under public extension (1030, Rank =2), while Private Extension positioned it fourth (826, Rank=4). This suggests that public extension has a stronger role in promoting systems-based and climate-resilient practices, supported by sustainable agriculture studies. Interesting divergence appears in the strategy “assisted in spacing and adjusting plant locations” where Private Extension obtained the highest weighted score (1062, Rank=1), exceeding Public Extension (850, Rank=7). This indicates that Private Extension may be more focused on technical field-level adjustments. However key “institutional support services” show strong public difference. “Guidance on Institutional/Governmental Support” under Public Extension ranked 3rd (905), while Private Extension placed it at Rank=9 (715), showing private systems are less effective in linking farmer to government structures. The adoption outcome columns further strengthen this pattern. For most strategies adoption of these adaptation strategies of crops with “Yes” responses exceed “No” responses, indicating positive behavioral translation. For example, “Scheduling Management” shows 182 “Yes” response Vs 88 “No” response, while “Agroforestry” shows 214, “Yes” response Vs 56 “No” response. This confirms that publicly supported strategies are widely adopted by the farmers. Overall the higher weighted score and better Rank positions under Public Extension across most indicators demonstrate stronger service quality and perceived usefulness. Private extension shows strength in selected technical areas but lags in institutional and strategic support.

Table 2 Description of Dependent and Independent Variable

Variables	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**
Socio economic characteristic				
Education	7.44	3.15	0	16
Age of the Farmers	35.96	7.22	19	59
Farming Experience (Years)	13.03	4.42	4	27
Wheat Crop				
Wheat Area (Acre)	0.61	0.18	0.19	1.06
Wheat Production Kg **(Dependent Variable)**	1124.95	354.24	288	1928
Wheat Income	68697.02	21198.38	24255	130928
Indices				

Visits of Public Extension to farmers Index (VPI)	1.79	0.96	1	4
Visits of Private Extension to farmers Index(VPrI)	1.63	0.76	1	4
Public Extension (Adaptation Index of Crops) (PASCI)	2.04	0.81	0	4
Private Extension (Adaptation Index of Crops) (PrASCI)	2.04	0.82	0	4

Sources: Data Survey, 2025

The descriptive results in table 2 show that Socio economic characteristics of respondents reflect a moderately educated and experienced farmer population. The mean year of education was 7.44 with Sd. = 3.15, ranging from 0 to 16, indicating varying levels of formal education. The mean Age was 35.96 years Sd = 7.22, showing that most farmer are within productive age group. Farming Experience averaged 13.03 years Sd. = 4.42 signaling strong practical background. Regarding wheat crop indicators, Wheat area in acre had a mean of 0.61 and Sd = 0.18, showing smallholder land holdings. Wheat Production in (Kg) (dependent variable) had a mean of 1124.95 with Sd = 354.24, ranging from 288 to 1928 kg, indicating considerable variation in output levels. Wheat income averaged 68697.02 and Sd. = 21198.38, reflecting economic importance of the crop. Extension contact indices show limited interaction. Visits of Public Extension to farmer Index had a mean of 1.79, Sd. = 0.96, while Private visits were slightly lower at 1.63, Sd. = 0.76. This suggests limited regular advisory contact. For adaptation indices Public Extension Adaptation Index and Private Extension Adaptation Index of crops both had mean 2.04, indicating moderate levels of agreement with provided strategies. However the range from 0 to 4 shows that not all farmer are equally benefiting.

Table 3 Correlation Analysis among Public Extension Variables

	W.P (KG)	W.I (Rs)	VPF	PASCI
W.P (KG)	1			
W.I (Rs)	0.93**	1		
VPF	0.47**	0.499**	1	
PASCI	0.539**	0.579**	0.348**	1
** Correlation is significant at the 0.01 level (2-tailed).				
PASCI= Public Extension adaptation Strategies of Crops Index				
PVF= Public Extension Visits to Farmers; **W.P**= Wheat Production ; **W.I**= Wheat Income				
Weak Correlation= Light Colour **Strong Correlation**= Dark Colour				

Sources: Data Survey, 2025

Table 4 Correlation Analysis among Private Extension Variables

	W.P (KG)	W.I (Rs)	VPrF	PrASCI
W.P (KG)	1			
W.I (Rs)	0.93**	1		
VPrF	0.142*	0.125*	1	
PrASCI	0.403**	0.407**	0.075*	1
** Correlation is significant at the 0.01 level (2-tailed).				
* Correlation is significant at the 0.05 level (2-tailed).				
PrASCI= Private Extension adaptation Strategies of Crops Index				

PrVFI= Private Extension Visits to Farmers; **W.P**= Wheat Production ; **W.I**= Wheat Income
Weak Correlation= Light Colour **Strong Correlation**= Dark Colour

Sources: Data Survey, 2025

The correlation results provide important evidence on the relationships among Wheat Production, Wheat income, Adaptation strategies of crops provided by Public Extension and Private Extension, and Visits of Public and Private Extension to farmers, when examined separately for Public Extension (Table 3) and Private Extension (Table 4). These results allow a comparative understanding of how public and private extension systems influence adoption and economic outcomes. In Table 3, Wheat Production shows a very strong positive relationship with Wheat income reported at .930**, indicating that increases in wheat production directly translate into higher wheat income. The strength of this relationship in Table 3, show that public extension-supported production growth is economically meaningful. Further, in Table 4, Adaptation strategies provided by Private Extension is moderately to strongly positively correlated with Wheat Production .403** and Wheat income .407. These values fall within the 0.30–0.49 range, showing that adoption of publicly provided adaptation strategies of crops significantly contributes to better production and income, although it does not alone explain all variation. This pattern supports the innovation adoption paradigm discussed by Pansera (2013). Moreover, Visits of Public extension to farmers in Table 3 shows a moderate to strong positive correlation with Wheat Production .47**, Wheat income .499**, and Adaptation strategies of crops provided by Public Extension .348**. These relationships indicate that frequent public extension visits not only encourage adoption but also translate into meaningful production and income gains. This finding aligns with previous extension impact studies (Cawley et al., 2018) where regular field contact was found to be critical for effective adoption. In contrast, Table 4, provides a divergent pattern. Wheat Production again shows a very strong positive relationship with Wheat income .930**, confirming that the production income link is consistent across both extension systems. However, the role of private extension visits and adoption indices displays weaker patterns. In Table 4 Most notably, Visit of Private extension to farmers exhibits only a weak positive relationship with Wheat Production .142* and Wheat income .125*, and a non-significant relationship with Adaptation strategies of crops provided by Private Extension .075. This indicates that frequency of private visits alone does not strongly influence adoption or economic outcomes, standing in contrast to the stronger patterns observed for public extension visits in Table 3.

Table 5: The Effect of Public Extension Contact with Farmers and the Public Extension Adaptation Strategies of Crops Index on the Productivity of Wheat Crop

Variables	Multiple Linear Regression Model			
	Unstandardized Coefficients		t-value	Sig
	B	Std. Error		
(Constant)	-28.87	19.567	-1.475	0.141
Education	5.734	1.385	4.139	0.000
Wheat Area	1817.621	28.628	63.49	0.000
Farming Experience	2.41	1.212	1.988	0.048
Age of the Farmer	-1.853	0.65	-2.852	0.005
Visits of public extension to farmers	10.21	4.81	2.123	0.035
Public adaptation Index	13.514	5.224	2.587	0.01
Dependent Variable: Wheat Production (Kg): **Control Variable:** Education, Farming Experience, Age, Wheat area **Main Predictor:** Public Extension Visits to Farmers, Public Adoption Index **R. Square**= .985 **F. Statistics**=1467.422 **Highly Significant*****(000)				

Sources: Data Survey, 2025

Table 6: The Effect of Private Extension Contact with Farmers and the Private Extension Adaptation Strategies of Crops Index on the Productivity of Wheat Crop

Variables	Multiple Linear Regression Model			
	Unstandardized Coefficients		t-value	Sig
	B	Std. Error		
(Constant)	-35.24	20.584	-1.712	0.088
Education	6.32	1.39	4.548	0.000
Wheat Area (Acre)	1839.255	28.13	65.384	0.000
Farming Experience	3.154	1.205	2.617	0.009
Age of the Farmer	-1.901	0.656	-2.896	0.004
Visits of Private extension to farmers	9.677	5.058	1.913	0.057
Private Extension adaptation index	4.268	5.056	0.844	0.399
Dependent Variable: Wheat Production (Kg): **Control Variable:** Education, Farming Experience, Age, wheat area **Main Predictor:** Private Extension Visits to Farmers, Private Extension Adoption Index **R. Square**= .985 **F. Statistics**=1422.634 **Highly Significant*****(000)				

Sources: Data Survey, 2025

The comparative analysis of Table 5 and Table 6 reveals clear divergence in the effectiveness of Public and Private Extension systems on wheat productivity. Both models demonstrate excellent goodness of fit, table 5 (R^2 = .985, F = 1467.422, P = .000), table 6 (R^2 = .985, F = 1422.634, P= .000) indicating that the selected control and main predictor variables explain almost all variation in Wheat Production. In both models control variables show consistent behavior. Education and Wheat area exhibit strong positive and statistically significant effects, indicating that education and land scale remain foundational drivers of agricultural productivity. Similarly Age of the Farmer produces a negative and significant effect in both contexts, signaling that increasing age may reduce innovation adoption and operational efficiency, aligning with prior findings in extension research (Rogers, 2003). However the primary difference between the two models emerges when examining extension-related variables. In table 5 Visits of public extension to farmer show a significant positive effect (B = 10.21, t = 2.123), while Public adoption Index exhibits a strong and significant relationship with productivity (B = 13.514, t = 2.587). This indicates that Public Extension not only increases contact but also effectively translates adaptation strategies into tangible yield gains. In contrast table 6 reveals weaker private extension impacts. Although visits of private extension to farmer demonstrates a positive coefficient (BB = 9.677), its statistical significance is marginal (P = .057). More critically Private adoption Index failed to show statistical significance (B = 4.268, P = .399), signaling that private adaptation strategies do not consistently contribute to productivity improvements. This contrast strongly suggests that public extension systems are more effective in bridging the gap between knowledge delivery and practical adoption. The institutional structure, training mandate, and reach of public extension may explain its superior performance, asserted by Anderson and Feder (2007). In contrast Private extension may be more commercially oriented, which can limit its capacity to provide context-specific and inclusive adaptation solutions.

Conclusions

The study population consists of small scale farmers, moderately educated and experienced farmer, with moderate production levels but low extension contact and moderate adaptation levels. Public

Extension provides more comprehensive and highly ranked adaptation strategies, which are also widely adopted by respondents. Private Extension services appear more narrow and technical with limited strategic impact. Public Extension exhibits stronger and more consistent relationships between extension visits, adoption index, production, and income, compared to Private Extension. The findings indicate that adoption indices play a critical mediating role, with public adaptation strategies demonstrating greater effectiveness than private adoption mechanisms. In summary the results clearly indicate that Public extension services and their associated adaptation strategies play a more effective and statistically significant role in increasing wheat productivity compared to Private extension. While both systems provide contact, only Public adaptation indices show consistent and strong impacts on output.

Recommendations

Extension authorities should increase field visit frequency and strengthen local presence to improve adoption, quality of adaptation strategies for crops and productivity outcomes. Policy-makers should strengthen the capacity of Private Extension in areas of institutional linkages and holistic crop management. Collaborative platforms between Public Extension and Private Extension can combine technical strength with strategic guidance. Future programs should prioritize farmer training on integrated and climate-smart agriculture. Policy makers should integrate adoption indices as key performance indicators for both extension systems, to ensure that visits translate into meaningful outcomes. Furthermore it is recommended that policy-makers should strengthen public extension systems, particularly by enhancing farmer access to context-specific adaptation strategies. Additional training and resources should be provided to private extension agents to improve the quality and effectiveness of their advisory services.

Literature Cited:

Abhijeet, Kanta Kumar Sahu, Raj Bardhan, Nikita Singh Chouhan, Devanshu Dixit, Somdutt Tripathi, Anjali Pandey, and Rizwan Ahmed. (2023). "A Comprehensive Review on Role of Agricultural Extension Services in the Sustainable Development of Global Agriculture". International Journal of Environment and Climate Change 13 (10):3514-25. https://doi.org/10.9734/ijecc/2023/v13i103021.

Abid, M., Schneider, U. A., & Scheffran, J. (2016). Adaptation to climate change and its impacts on food productivity and crop income: Perspectives of farmers in rural Pakistan. Journal of Rural Studies, 47, 254-266.

Albahri, G., Alyamani, A., Badran, A., Hijazi, A., Nasser, M., Maresca, M., and Baydoun, E. (2023). Enhancing Essential Grains Yield for Sustainable Food Security and Bio-Safe Agriculture through Latest Innovative Approaches. Agronomy. https://doi.org/10.3390/agronomy13071709.

Ananda, K R, Ankit Pal, Anamika Sharma, Ramesh Chand Bunkar, Sulekha, Mohammed Umar Ali, and Lalit Upadhyay. 2024. "A Review on Scaling Up Successful Agricultural Extension Techniques for Global Benefit". Journal of Experimental Agriculture International 46 (7):844-60. https://doi.org/10.9734/jeai/2024/v46i72638.

Anderson, J. R., & Feder, G. (2007). Agricultural extension. Handbook of agricultural economics, 3, 2343-2378.

Antwi-Agyei, P., & Stringer, L. (2021). Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. Climate Risk Management. https://doi.org/10.1016/j.crm.2021.100304.

API. 2023-2024. Agriculture Policy Institute, Ministry of National Food Security and Research Government of Pakistan Islamabad. Retrieved on 25.1.2025. Pp.3.

Balaine, L., Buckley, C., & Dillon, E. (2022). Mixed public-private and private extension systems: A comparative analysis using farm-level data from Ireland. Land Use Policy. https://doi.org/10.1016/j.landusepol.2022.106086.

Billah, M., Rahman, M., Mahimairaja, S., Lal, A., & Naidu, R. Role of Agriculture Extension and Rural Advisory Services in Strengthening Climate-Smart Agricultural System: A Systematic Review. Journal of Sustainable Agriculture and Environment. 2025 https://doi.org/10.1002/sae2.70076.

Bohra, A., Choudhary, M., Bennett, D., Joshi, R., Mir, R., & Varshney, R. (2024). Drought-tolerant wheat for enhancing global food security.. Functional & integrative genomics, 24 6, 212 . https://doi.org/10.1007/s10142-024-01488-8.

Cawley, A., O'Donoghue, C., Heanue, K., Hilliard, R., & Sheehan, M. (2018). The impact of extension services on farm-level income: an instrumental variable approach to combat endogeneity concerns. Applied Economic Perspectives and Policy, 40(4), 585-612.

Chourad, R., Jamadar, R., Naik, V., Joshi, A., & Deshmanya, J. (2024). Innovative extension approaches for climate-smart agriculture: Building farmer resilience to environmental change. International Journal of Agriculture Extension and Social Development. https://doi.org/10.33545/26180723.2024.v7.i7sd.1142.

Ehsan, N., Hoogenboom, G., Qamar, M., Wilkerson, C., Wajid, S., & Aziz, F. (2022). Climate change risk perception and adaptation to climate smart agriculture are required to increase wheat production for food security. Italian Journal of Agronomy. https://doi.org/10.4081/ija.2022.2129.

Elahi, E., Khalid, Z., Tauni, M., Zhang, H., & Xing, L. (2021). Extreme weather events risk to crop-production and the adaptation of innovative management strategies to mitigate the risk: A retrospective survey of rural Punjab, Pakistan. Technovation, 102255. https://doi.org/10.1016/j.technovation.2021.102255.

Feder, G., & Savastano, S. (2017). Modern agricultural technology adoption in sub-Saharan Africa: A four-country analysis. In Agriculture and rural development in a globalizing world (pp. 11-25). Routledge.

Ferdousi, R., Islam, M., & Rashid, M. (2024). Role of Extension Service for Climate Change Adaptation in Agriculture: A Systematic Review for Developing Countries. Journal of the Bangladesh Agricultural University. https://doi.org/10.3329/jbau.v22i4.78863.

Gao, R., Cai, H., & Xu, X. (2025). Climate Variability and Agricultural Inputs: Effects on Grain Production and Yield Stability in China (1991–2020). Food and Energy Security. https://doi.org/10.1002/fes3.70096.

GoP. Pakistan Economic Survey, 2024. Islamabad: Ministry of Finance. 2024. Available online: http://www.finance.gov.pk/ survey_1415.html (accessed on 2 December 2024).

Grote, U., Faße, A., Nguyen, T., & Erenstein, O. (2021). Food Security and the Dynamics of Wheat and Maize Value Chains in Africa and Asia. , 4. https://doi.org/10.3389/fsufs. 2020.617009.

Habib-Ur-Rahman, M., Ahmad, A., Raza, A., Hasnain, M., Alharby, H., Alzahrani, Y., Bamagoos, A., Hakeem, K., Ahmad, S., Nasim, W., Ali, S., Mansour, F., & Sabagh, E. (2022). Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. Frontiers in Plant Science, 13. https://doi.org/10.3389/fpls. 2022.925548.

Heena, Prashant Dedha, Brahma Reddy, Raj Kumar, and Ajay Kumar. 2025. "The Economics of Climate Smart Agriculture: Role of Extension Education in Adaptation Strategies". Journal of Scientific Research and Reports 31 (7):660-67. https://doi.org/10.9734/jsrr/ 2025/v31i73285.

Heino, M., Kinnunen, P., Anderson, W., Ray, D. K., Puma, M. J., Varis, O., & Kummu, M. (2023). Increased probability of hot and dry weather extremes during the growing season threatens global crop yields. Scientific reports, 13(1), 3583.

Hu, T., Zhang, X., Khanal, S., Wilson, R., Leng, G., Toman, E. M., & Zhao, K. (2024). Climate change impacts on crop yields: A review of empirical findings, statistical crop models, and machine learning methods. Environmental Modelling & Software, 179, 106119.

Jatav, S., & Nayak, S. (2021). Determinants in the Adoption of Climate Change Adaptation Strategies: Evidence from Wheat Farmers in Bundelkhand Region, India. JOURNAL OF EXTENSION EDUCATION. https://doi.org/10.26725/jee.2021.3.33.6647-6658.

Kabir, M., & Islam, M. Effectiveness of Public and Private Extension Services in Building Capacity of the Farmers: A Case of Bangladesh. Sarhad Journal of Agriculture. 2023 https://doi.org/10.17582/journal.sja/2023/39.1.101.110.

Kaium, M., Ahmed, M., Habib-Ur-Rahman, M., Islam, M., Ratry, Y., Helal, M., Siddquy, M., Haque, M., Raza, A., Mansour, F., Alotaibi, M., Sabagh, A., & Roetter, R. (2025). Modeling impacts of climate-induced yield variability and adaptations on wheat and maize in a sub-tropical monsoon climate - using fuzzy logic. Scientific Reports, 15. https://doi.org/10.1038/s41598-025-09820-3.

Kasely, D. J. and K. Kumar. 1989. The collection, analysis and use of monitoring and evaluation data. The World Bank, IFAD, FAO, London: John Hopkins Univ. Press.

Khan, N., & Ray, R. (2023). Key Role of Extension Agents in the transfer and adoption of Agricultural Technologies: A Review. Data Plus. https://doi.org/10.62887/dataplus. 001.01.0007.

Kukal, M., & Irmak, S. (2018). Climate-Driven Crop Yield and Yield Variability and Climate Change Impacts on the U.S. Great Plains Agricultural Production. Scientific Reports, 8. https://doi.org/10.1038/s41598-018-21848-2.

Kumar, N., Mazhar, D., & Kumar, A. (2023). The role of agricultural extension in disseminating the technology of organic farming among greenhouse farmer's in India. International Journal of Agriculture Extension and Social Development. https://doi.org/ 10.33545/26180723.2023.v6.i2a.190.

Loki, O., & Mdoda, L. (2023). Assessing the contribution and impact of access to extension services toward sustainable livelihoods and self-reliance in Eastern Cape Province, South Africa. African Journal of Food, Agriculture, Nutrition and Development. https://doi.org/10.18697/ajfand.119.22990.

Mahmood, N., Arshad, M., Kaechele, H., Shahzad, M., Ullah, A., & Mueller, K. (2020). Fatalism, Climate Resiliency Training and Farmers' Adaptation Responses: Implications for Sustainable Rainfed-Wheat Production in Pakistan. Sustainability. https://doi.org/10.3390/su12041650.

Makamane, A., Loki, O., Swanepoel, J., Zenda, M., & Van Niekerk, J. (2025). Farmers' perceptions on the capacity of extension practitioners on climate change in the Eastern Cape Province of South Africa. Frontiers in Climate. https://doi.org/10.3389/fclim.2025.1534254.

Mishra, P., Padhy, C., Mishra, N., Chakraborty, S., & Sai, M. (2024). Role and approaches of agricultural extension in climate resilient agriculture. International Journal of Agriculture Extension and Social Development. https://doi.org/10.33545/26180723.2024.v7.i5e.629.

Mnukwa, M., Mdoda, L., & Mudhara, M. (2025). Assessing the adoption and impact of climate-smart agricultural practices on smallholder maize farmers' livelihoods in Sub-Saharan Africa: a systematic review. Frontiers in Sustainable Food Systems. https://doi.org/10.3389/fsufs.2025.1543805.

Mudzielwana, R., Phophi, M., & Mafongoya, P. (2025). Assessing the Impact of Privatizing Public Agricultural Extension Services on Smallholder Farmers' Performance: A Case Study of Thulamela and Collins Chabane Municipalities, South Africa. Journal of Agribusiness and Rural Development, 75, 125 - 135. https://doi.org/10.17306/j.jard. 2025.00004r1.

Mungai, L., Messina, J., Zulu, L., Chikowo, R., & Snapp, S. (2024). The role of agricultural extension services in promoting agricultural sustainability: a Central Malawi case study. Cogent Food & Agriculture, 10. https://doi.org/10.1080/23311932.2024.2423249.

Ongachi, W., & Belinder, I. (2025). Agricultural extension as a pathway to livelihood diversification and sustainable development in rural communities: a systematic review. BMC Agriculture, 1. https://doi.org/10.1186/s44399-025-00005-x.

Osumba, J., Recha, J., & Oroma, G. (2021). Transforming Agricultural Extension Service Delivery through Innovative Bottom–Up Climate-Resilient Agribusiness Farmer Field Schools. Sustainability, 13, 3938. https://doi.org/10.3390/su13073938.

Pansera, M. (2013). Frugality, grassroots and inclusiveness: New challenges for mainstream innovation theories. African Journal of Science, Technology, Innovation and Development, 5(6), 469-478.

Pashaeypoor, S., Ashktorab, T., Rassouli, M., & Alavi-Majd, H. (2016). Predicting the adoption of evidence-based practice using "Rogers diffusion of innovation model". Contemporary nurse, 52(1), 85-94.

Pathania, R., Sharma, S., Prasad, R., & Rana, R. (2025). Modelling Adaptation Strategies to Mitigate Climate Change Impact in Wheat under Mid-Hill Regions of Himachal Pradesh. Journal of Mountain Research. https://doi.org/10.51220/jmr.v20-i1.50.

Poole, N., Donovan, J., & Erenstein, O. (2020). Agri-nutrition research: Revisiting the contribution of maize and wheat to human nutrition and health. Food policy, 101976 . https://doi.org/10.1016/j.foodpol.2020.101976.

Priya, N., Khatri, A., Kumar, A., Samota, S., Vishwakarma, S., Sukdeve, E., Tripathi, S., & Pathak, A. (2025). The Important Role of Extension Services in Strengthening the Capacity of Farmers' Resilience to Climate Change in India. Journal of Experimental Agriculture International. https://doi.org/10.9734/jeai/2025/v47i33329.

Rajesh, C. M., Jadhav, A., Manohar, K. N., Bhat, P. P., Rahul Prasad, R., Anil, K., & Pavan, V. (2024). A review on adaptive strategies for climate resilience in agricultural extension services in India. Archives of Current Research International, 24(6), 140-150.

Rajesh, C. M., Jadhav, A., Manohar, K. N., Bhat, P. P., Rahul Prasad, R., Anil, K., & Pavan, V. (2024). A review on adaptive strategies for climate resilience in agricultural extension services in India. Archives of Current Research International, 24(6), 140-150.

Raji, E., Ijomah, T., & Eyieyien, O. (2024). Improving agricultural practices and productivity through extension services and innovative training programs. International Journal of Applied Research in Social Sciences. https://doi.org/10.51594/ijarss.v6i7.1267.

Rajkhowa, P., & Qaim, M. (2021). Personalized digital extension services and agricultural performance: Evidence from smallholder farmers in India. PLoS ONE, 16. https://doi.org/10.1371/journal.pone.0259319.

Rana, M., Anik, A., Islam, M., & Jahan, M. (2023). Sustainable wheat production strategies in blast-affected areas of Bangladesh. Outlook on Agriculture, 53, 60 – 71. https://doi.org/10.1177/00307270231210589.

Shehzad. M. 2020. Analysis of Farmers' Perception Regarding Public And Private Agriculture Extension Services In Central Plain Valley Of Khyber Pakhtunkhwa, Pakistan. Thesis. Retrieved on July, 2024.

Shoukat, M. R., Wang, J., Habib-ur-Rahman, M., Hui, X., Hoogenboom, G., & Yan, H. (2024). Adaptation strategies for winter wheat production at farmer fields under a changing climate: Employing crop and multiple global climate models. Agricultural Systems, 220, 104066.

Tham-Agyekum, E., Abourden, G., Bakang, J., & Juantoa, B. (2024). Cocoa farmers' perspective on the quality of public and private agricultural extension delivery in Southern Ghana. Heliyon, 10. https://doi.org/10.1016/j.heliyon.2024.e30797.

Thottadi, B., & Singh, S. (2024). Climate-smart agriculture (CSA) adaptation, adaptation determinants and extension services synergies: a systematic review. Mitigation and Adaptation Strategies for Global Change, 29. https://doi.org/10.1007/s11027-024-10113-9.

Vogel, E., Donat, M., Alexander, L., Meinshausen, M., Ray, D., Karoly, D., Meinshausen, N., & Frieler, K. (2019). The effects of climate extremes on global agricultural yields. Environmental Research Letters, 14. https://doi.org/10.1088/1748-9326/ab154b.

Wakweya, R. (2023). Challenges and prospects of adopting climate-smart agricultural practices and technologies: Implications for food security. Journal of Agriculture and Food Research. https://doi.org/10.1016/j.jafr.2023.100698.

Wolniak, R., & Grebski, W. W. (2025). Sustainable Trends and Determinants of Wheat Cultivation in Poland (2004–2023): A Spatiotemporal Analysis of Productivity, Resilience, and Climate Adaptation. Sustainability, 17(5), 2225.

Xu, Z., Adeyemi, A., Catalan, E., , S., Kogut, A., & Guzman, C. (2023). A scoping review on technology applications in agricultural extension. PLOS ONE, 18. https://doi.org/10.1371/journal.pone.0292877.