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IMPROVING AGRICULTURAL PRODUCTIVITY AND SUSTAINABILITY THROUGH MODERN EXTENSION SERVICES: A CASE STUDY IN RURAL PAKISTAN

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Abstract

Agricultural extension services serve as critical institutional mechanisms for translating research into farmer practice and enhancing productivity sustainability in developing countries. This comprehensive literature review synthesizes findings from 24 peer-reviewed articles (2016–2025) examining extension service effectiveness, technology adoption dynamics, and livelihood impacts, with particular emphasis on rural Pakistan. The evidence demonstrates that well-designed extension programs yield substantial productivity gains (22–38%), with Farmer Field Schools achieving 50.48% knowledge gains among participants compared to non-participants. Farm productivity shows strong positive correlation with extension access ($r = 0.7452$, $p < 0.01$). However, Pakistan's extension system faces critical constraints including inadequate funding (92.86% of stakeholders), poor infrastructure (88.75%), and unfavourable agent-to-farmer ratios (88.89%), contributing to low farmer satisfaction (35% versus 52% regional average). Extension contact emerges as the most significant modifiable adoption determinant, followed by farm size, credit access, and farmer organization membership. Emerging approaches, participatory learning models, digital platforms (68–85% effectiveness), and public-private partnerships, demonstrate potential to address traditional barriers. Significant inequities persist, with large landholders receiving 85% extension access compared to 22% for marginal farmers and 18% for women farmers. Climate change adaptation represents an urgent extension priority, with climate-smart agriculture yielding 10.5 and 29.4 percentage point improvements in productivity and profitability respectively. The review concludes that adequately resourced, modernized extension services are fundamental to transforming agricultural productivity, building climate resilience, and improving rural livelihoods in Pakistan and similar South Asian contexts.

Keywords: Agricultural Extension Services, Technology Adoption, Farmer Field Schools, Climate-Smart Agriculture, Rural Productivity Improvement.

1. Introduction

1.1 Role of Agriculture in Rural Pakistan

Pakistan is an agrarian-based economy and rural livelihood, and about 65 percent of the rural population relies directly on the agricultural activities as a source of subsistence and income (Alzahrani et al., 2023). Agricultural sector provides a great contribution to the national food security and foreign exchange earnings by exporting Basmati rice, cotton and citrus fruits. Nevertheless, there are incessant problems in rural agricultural societies such as low production levels, access to modern technologies, poor extension services,

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and growing susceptibility to the effects of climatic changes. The challenges demonstrate the urgent need to have modernized agricultural extension systems that are capable of closing the gap between the agricultural research institutions and the farming communities.

Agricultural landscape in Pakistan is typified by mostly smallholder agriculture systems, where farmers have fragmented land holdings and have little access to credit, markets and technical information. The present agricultural productivity rates are well below the possible yield rates which means that there are large yield gaps in the major crops. An example is wheat production in Pakistan which is averaged at about 2.9 tons per hectare which is significantly less than the potential production of 4.2 tons per hectare with better management practices. On the same note, the cotton crop continues to be low at about 1.8 tons per hectare with the potential of 2.5 tons per hectare with improved extension support and adoption of new technology. These productivity discrepancies are directly converted into a loss of farm revenues and food insecurity by millions of rural households.

1.2 Agricultural Extension Services: Definitions and Significance

Extensive agricultural services are the most essential institutional connection that enables the exchange of knowledge between farming communities and agricultural research institutions (Raji et al., 2024). The services can be defined as a network of advisory services, training programs, dissemination of information, and resource facilitation tools that are meant to help farmers to embrace better agricultural practices, enhance production, and attain sustainable livelihoods. The extension services are seen as an interface that translates the scientific knowledge into the practical and context-specific advice that can be adopted by farmers based on their particular agroecological and socioeconomic conditions. The success of extension services in transforming agriculture has been established in several contexts of developing nations and regions with strong extension systems have always recorded higher productivity rates and resilience of farmers to environmental and economic shocks.

The importance of extension services is not only in the increase of productivity. Current extension systems are playing a variety of important roles: they can help in transferring technology and adopting innovation, give information on market linkage, support climate change adaptation planning, sustainable agricultural practices and help in rural economic growth and alleviating poverty. Against the backdrop of the world food security issues, and the effects of climate change, extension services are now viewed as important mechanisms that can be used to facilitate climate-smart agriculture, sustainable natural resources management, and resilient agricultural systems that can survive various environmental and economic stressors.

2. Current State of Agricultural Extension in Rural Pakistan

2.1 Extension Service Delivery Infrastructure

Pakistan has built a comprehensive system of agricultural extension services, which includes the extension departments of the public sector, input dealers of the private sector, farmer organizations, and, most recently, digital platforms (Yaseen et al., 2016). The public extension system is based on multi-tiered administrative systems at federal, provincial, and district levels, where the extension agents are charged with the responsibility of providing advisory services to the farming communities. Nevertheless, the existing extension infrastructure encounters huge capacity and resource limitations, which restrict its effectiveness in accessing smallholder farmers, especially those operating on marginalized land with limited resources.

The existing level of performance of the public extension services in Pakistan is still not optimal in regard to the needs of the farmers and global standards. The study conducted on the views of farmers on the services offered by the government extension service showed that the government extension staff was ranked among the last sources of agricultural information by only 10% of farmers, and hence the government extension services were considered to have low levels of perceived credibility and relevance (Yaseen et al., 2016). Conversely, 47.5 percent of the farmers indicated neighbours, friends, and relatives as their source of information implying that informal information networks are now more influential than formal extension systems in dissemination of information. This observation points out a significant gap in the current system of providing extensions to the population- the inability to build up trust and prove definite value to agricultural communities.

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2.2 Constraints in Extension Service Accessibility

The agricultural communities in rural Pakistan are highly hindered in accessing effective extension services, and the barriers act at various levels; systemic, institutional, and individual levels. The lack of governmental financing of the extension services turns out to be, perhaps, the most significant limitation, and the extension service accessibility studies in the similar South Asian regions report that 92.86 percent of the interviewees refer to insufficient funding as the key hindrance (F et al., 2025). This limitation in funding is translated to the lack of extension agent mobility, lack of training opportunities to extension personnel, poor maintenance of demonstration facilities and failure to deliver timely advisory services to farmers.

The other critical accessibility constraint is the extension agent to farmer ratio. Research on similar settings also suggests that the existence of unfavourable extension agent-to-farmer ratios (reported as problematic by 88.89% of the respondents) results in the inability of the extension agents to serve all farmers in their areas, which results in service bias (Alzahrani et al., 2023). A study that specifically studied rice farmers in Punjab province of Pakistan reported that landholding size was a key determinant of whether the extension agents visited farmers with extension agents showing a pronounced propensity to visit large scale farmers rather than small scale farmers. Such unfair distribution of services worsens the already existing disparities in agricultural productivity and income as the smallholder farmers who require the most service are given the least service attention.

Another important dimension of the contemporary issues is gender and social equity in the access to the extension services. The rural women farmers who form a significant agricultural labour force are subject to various obstacles to extension access such as mobility, cultural restrictions of contact with the mostly-male extension agents, and gender-blind extension programming that does not respond to women and their unique needs and constraints (Saha et al., 2024). Youth farmers also indicate a low level of use of extension services, and the digital divide and preference toward traditional extension approaches lock out younger farmers who may be more willing to use technology-based extension services.

2.3 Quality and Relevance of Extension Content

Although the issue of accessibility is one of the most important aspects of the extension service problem, the quality and relevance of the extension material provided by the already existing services is also problematic issue. The historical range of the public extension services in Pakistan has been limited and limited to simple crop protection actions and standard input advice without the proper consideration of the multidimensionality of the contemporary agricultural issues (Alzahrani et al., 2023). The extension material often does not consider specific soil conditions, water supply, market possibilities, weather fluctuation, and individual resource endowments, which leads to the provision of generic advice that might not be suitable to particular farm situations.

The challenges faced in modern extensions necessitate extension systems to go beyond mere transfer of technologies to more complex issues such as climate change adaptation, sustainable management of natural resources, improvement of soil health, conservation of water, diversification of crops, market connections, and development of the agricultural value chain. Existing extension services in rural Pakistan are mostly ill-equipped to meet this broadened knowledge agenda, as extension staff are often not trained in new knowledge areas, such as climate-smart agriculture, digital extension technologies, integrated pest management, conservation agriculture, and value chain development. Farmers keep on complaining that extension messages are not relevant to their particular situation, and extensive research has found that the overall rating of the public extension service has poor farmer satisfaction, signifying that there are considerable gaps between the expectation of farmers and the provision of extension services.

Table 1

Current Challenges in Extension Service Delivery - Rural Pakistan

Challenge Category	Specific Challenge	Impact Level (%)	Key Source
Systemic / Funding	Inadequate Government Funding	92.86	Extension Services Accessibility Study (2025)

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Challenge Category	Specific Challenge	Impact Level (%)	Key Source
Infrastructure	Poor Transportation/Logistics	88.75	Multi-country Extension Services Review
Human Resources	Unfavorable Agent-to-Farmer Ratio	88.89	Rice Extension Services Study (2023)
Climate	Limited Climate Information Access	85.40	Climate Information Access Study (2022)
Equity	Low Reach to Smallholders	82.5	Agricultural Extension Equity Analysis
Digital	Poor Internet/Digital Infrastructure	81.20	ICT Adoption Barriers Study (2025)
Gender	Limited Reach to Women Farmers	72.50	Extension Services Gender Analysis (2024)
Governance	Political Interference	54.76	Extension Services Governance Study (2025)

3. Modern Extension Approaches and Innovations

3.1 Farmer Field Schools: Participatory Learning Models

Farmer Field Schools (FFS) is a participatory model of extension that is fundamentally different than the traditional model of technology transfers by focusing on farmer-led experimentation, critical thinking, and learning-by-doing models (Kumar, 2025). The FFS method has come out as one of the best extension models in ensuring technology adoption is sustained, farmers become empowered and the development of social capital at the community level. Instead of having extension agents as technology prescribers, FFS facilitators will be able to offer learning settings whereby groups of farmers will share in the experimental activities of trying better practices, field conditions and make evidence-based decisions based on evidence created within their fields.

A study of the effectiveness of Farmer Field School interventions in similar agricultural settings has reported astonishing learning results. In a detailed study that followed Farmer Field School participants and non-participants during various agricultural seasons, it was concluded that the participants of the FFS gained a mean score of 53.45 on the recommended agricultural technologies, which is a 50.48 percent knowledge gain over non-participating farmers (mean score of 35.72) (Kumar, 2025). These meaningful knowledge gains were then converted into practices that were displayed, as FFS participants indicated higher adoption levels of suggested technologies, enhanced field management practices, and an increased level of confidence in resolving field-specific problems. More importantly, FFS members were not only able to score higher in terms of their knowledge but also to have the actual adaptive management potential, namely, the possibility to adjust the recommendations, depending on the local factors and observations in the field.

The overall effects of FFS are far more widespread than improved technical knowledge to include development of human capital (confidence, ability to act in a collective way), social capital (mutual trust, capability to act in a collective way), natural capital (better field practices, agricultural diversification, improvement of food security), and financial capital (increased income, participation in a savings scheme) (Berg et al., 2020). The qualitative research about the experiences of FFS participants reported increased empowerment, and farmers had become more agency-oriented in making agricultural decisions, were more willing to explore new practices, and their communities were stronger because of collaborative learning experiences. Of particular interest was the evidence that FFS effects extended to non-participants in participating communities as spillovers, as farmers started to use better practices when in an adjacent FFS field and were exposed to new practices by informal social networks.

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3.2 Digital and ICT-Enabled Extension Services

The advent of Information and Communication Technologies (ICT) has radically changed the possibilities of providing extension services by providing avenues to address some of the traditional limitations such as geographical seclusion, high costs of transport, and inadequate availability of extension agents (Dujali et al., 2025). ICT-based extension services can include various modalities: SMS advisory systems with real-time information on agriculture, mobile applications with specific advice on crop management, weather prediction systems, market price information systems, and disease diagnosis systems based on AI. Introduction of ICT in the extension systems is also a pathway innovation that is crucial to reaching remote farmers, lowering the cost of advising farmers, and delivering more personalized, timely information that is responsive to the situation of the farmers.

Research done to determine the adoption of digital extension services in the developing country setting shows that adoption patterns and levels of effectiveness among various ICT platforms vary. Advisory services using mobile SMS have adoption rates of approximately 45 percent and have been proven to be effective at 72 percent at enhancing farm practices (Dujali et al., 2025). Video-based training platforms have a 38% adoption and 68% effectiveness, and AI-driven crop monitoring systems have lower adoption (32% adoption) and the highest effectiveness rating (85), indicating that the level of technology sophistication may not necessarily be associated with user adoption rates because of digital illiteracy and the inadequacy of infrastructure. Weather forecast services have the most successful uptake rate (51%) and effectiveness (79) meaning that services that directly offer information that addresses the concerns of the farmers are the ones that are more successful in uptake.

The efficacy and practicability of digital extension strategies in Pakistan in particular relies on the strategy of resolving various implementation challenges. Internet connectivity in most rural locations, insufficient digital literacy skills among ageing farmers, and expensive data packages and digital devices, as well as resistance to change among the farmers who have been used to traditional methods of extension, all limit digital extension adoption (Hem et al., 2025). Nevertheless, the mobile phone penetration in rural locations has increased tremendously in the past years, and the development of mobile-based extension services is possible. WhatsApp-based groups of farmers, where only basic smartphone features are needed and low-cost messaging services can be used, are also a viable intermediate technology that the extension systems in Pakistan can easily adopt to reach younger farmers and provide timely information dissemination on important matters such as pest outbreaks, weather changes, and market fluctuations.

3.3 Public-Private Partnership Models in Extension

Considering the significant funding and capacity constraints of the public extension systems, the concept of the public-private partnerships (PPP) in agricultural extension has become a potentially transformative institutional model that could utilize the advantages of both the public and the private sector and address the limitations of each of them (Mohania and Pandey, 2024). The typical mode of PPP in agricultural extension is the formal collaborative arrangement of the government extension service and the private sector supplying input and agribusiness with the farmer organizations, NGOs, and in some cases, research institutions in providing the extension services, in the demonstration activities, and in the adoption of the technology.

The experience of the PPP application in similar settings proves high productivity and livelihood gains. In a study of an agricultural PPP intervention in India with a combination of extension support, input supply and output marketing connections, it was observed that farmers who were provided with bundled PPP interventions achieved significantly higher productivity gains and larger income increases than control groups who were provided with conventional extension only (Mohania & Pandey, 2024). The effectiveness of the PPP model seems to be based on its capacity to deal with numerous constraints at once: PPPs can extend to more areas through the use of private sector extension agents and input dealer networks; they can enhance the content of extension by including market-driven priorities and commercial agriculture considerations; they can increase the provision of resources by the use of contributions by the private sector; and they can provide output marketing linkages through which farmers can obtain economic returns on productivity

Effective PPP models must have transparent institutional frameworks that specify roles, duties, and

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benefits-sharing schemes between partners (N. & M., 2017). Some of the critical success factors are a large scope of stakeholder consultation during partnership design, clear articulation of mutual benefits and shared objectives, transparent decision-making processes, and formal conflict resolution mechanisms. The PPP models in the Pakistan context would include collaborating between provincial extension departments, private agribusinesses (especially input companies and agricultural equipment manufacturers), farmer cooperatives and mobile network operators to offer combined extension services that unify government expertise, the resources of the private sector and reach of the farmer organizations.

4. Determinants of Technology Adoption and Extension Effectiveness

4.1 Socioeconomic and Institutional Factors Influencing Adoption

The adoption of agricultural technology by smallholder farmers is a product of complicated interactions between individual farmer attributes, household-level assets, institutional factors and the technology attributes themselves. Systematic research studies on the determinants of technology adoption have found that there are several factors that always facilitate or limit technology adoption decisions. The extension service contact appears to be the most important and consistent determinant, and regression analysis of several agricultural innovations in Pakistan found that the absence of extension service contact was a crucial factor in the uptake of improved agricultural technologies (Bilal and Jaghdani, 2024). Farmers who do not receive regular extensions contact record very low adoption rates of various technology types such as better seed types, herbicides, and conservation agriculture practices.

Another important determinant of adoption is farm size, but it has a non-linear connection. The larger landholdings are usually conducive to technology adoption since the fixed cost of adoption is distributed over larger production levels, and the unit cost of technology adoption becomes more affordable (Bilal and Jaghdani, 2024). Nevertheless, over- land fragmentation which separates the holdings into various non-contiguous plots makes adoption impossible because of the complexity involved in managing the holdings. Availability of credit is always a very important adoption facilitator, which allows farmers to finance technology inputs and other related costs, which surpass current cash flow. The level of education shows significant positive correlations with the level of technology adoption, where more educated farmers were more willing to test new technologies and understand technical information, which is complex in nature.

Farmer organization and cooperative memberships are always positively correlated with technology adoption, which implies that group membership accesses information, creates peer learning, and mobilization of resources that provide the individual with the adoption decision (Ma and Rahut, 2024). The dimensions of social capital such as trust relations, information networks, and collective action capacity all show some positive impacts on technology adoption. Availability of off-farm income has had varied impacts on adoption; the presence of adequate off-farm income can help technology to be adopted due to the availability of liquidity to buy inputs, but the vice versa might also occur; too much off-farm involvement will lead to less time and attention paid by the farmers towards enhancing farm productivity.

4.2 Psychological and Behavioural Factors in Adoption Decisions

In addition to the socioeconomic variables, the decision-making to adopt technology is an indicator of psychological variables such as risk perception, self-efficacy beliefs, outcome expectation, and social influences (Erick et al., 2025). A study of climate-smart agriculture adoption among Tanzanian semi-arid vegetable farmers found that the perceived implementation capability, or beliefs by farmers in their ability to effectively implement certain practices, was the most significant predictor of adoption, with a coefficient of 0.616 ($p<0.001$) significantly larger than the coefficients of the perceived benefits (0.135) and social influence effects (0.138) (The implications of this finding to the design of extension services include that establishing farmer confidence in new practices by demonstration, practical training and a gradual exposure to those practices may be more effective than informing farmers about the benefits of the new technology.

The risk aversion features show multifaceted correlations with the adoption of technologies, where some farmers are reluctant to adopt new technology because they are afraid of incurring losses, whereas others might be reluctant to use the traditional methods because they have risk aversion biases to unfamiliar new technologies. The psychological predisposition and past experiences of successful or unsuccessful experiences with adopting technology seem to have a significant effect on the willingness of farmers to innovate and take

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risks with trying out new practices. The farmers who have had past failures in adopting a particular technology might develop a certain level of skepticism with the extension recommendations, and the ones who have had a positive experience with the initial technology adoption have a higher level of openness to follow-up technology recommendations.

The gender aspects of technology adoption are based on the disparities in access to the resources of technology adoption, as well as on the disparities in the processes of adoption decision-making among male and female farmers. Women farmers also often complain of lack of access to land, credit, extension services, and technical training, which limits their adoption (Tsige et al., 2020). Nevertheless, the adoption decisions of women under conditions of controlling resources access sometimes assume other patterns in comparison to the decisions of men, and some facts indicate that females tend to be more interested in practices aimed at satisfying the short-run household food security and financial stability rather than productivity maximization. The services provided through extensions that have not been developed in accordance with gender-related limitations and decision-making priorities are likely to face low adoption rates in the target population of female farmers even though the services can be of high value.

4.3 Information Pathways and Extension Agent Credibility

Perceptions of credibility and trustworthiness of extension agents is very critical in determining the effectiveness of extension services in influencing technology adoption by farmers. In most situations, farmers become more confident in the information provided by observation of successful farmer adopters, than by extension agent advice, especially when the extension agent has no proven experience in farming or no practical familiarity with local conditions (Le et al., 2020). The implications of this finding on the design of extension service are significant, because the observation indicates that farmer-to-farmer extension, demonstration plots under progressive farmers and farmer testimonials on the advantages of technologies can be more effective than traditional extension agent advice.

The flow of information exists in several channels outside the formal extension systems with peer networks, input dealer recommendations, and media sources all contributing to the amount of information farmers are receiving and decision making. Interestingly, a study on the effects of information sharing on agricultural technology adoption in rural Vietnam discovered that, although agricultural extension services were essential in initial technology adoption, the effect of information sharing between peer farmers on further technology adoption increased in later years (Le et al., 2020). Peer network social learning also seems to produce longer-lasting adoption impetus than time-limited extension interventions do, indicating that extension programs that produce initial adoption by innovator farmers might provoke further waves of adoption via peer influence processes.

5. Extension Impacts on Agricultural Productivity and Sustainability

5.1 Evidence of Productivity Improvements

The effect of extension services on agricultural productivity has been reported in a wide range of crop and country environments with the results of consistent positive relationships between access to extension services and measured productivity results. Agricultural extension services and farm productivity Multi-country accessibility: Multi-country accessibility studies that investigated the relationship between the access of farmers to extension services and the productivity of the farm reported strong positive associations ($r = 0.7452$ at $p<0.01$ level) between the access of farmers to the extension services and the measured farm productivity, which revealed that extension service access alone could explain significant differences in productivity across farming communities (F et Various modalities of extension services have a different level of effectiveness in terms of leading to improvements in productivity, with demonstration farms, farmer field schools, and training workshops generally scoring higher on the effectiveness rating scale than conventional farm visit extension.

The extensive yield gap analysis of three key staple crops, including wheat, maize, and rice, shows that the potential to realize the untapped productivity is high in the world. The average world yields of wheat, maize and rice have been 4.1, 5.5, and 4.0 tons per hectare respectively, against the potential yields of 7.7, 10.4, and 8.5 tons per hectare (Rong et al., 2021). These yield gaps, which go between 87% and 51% of what

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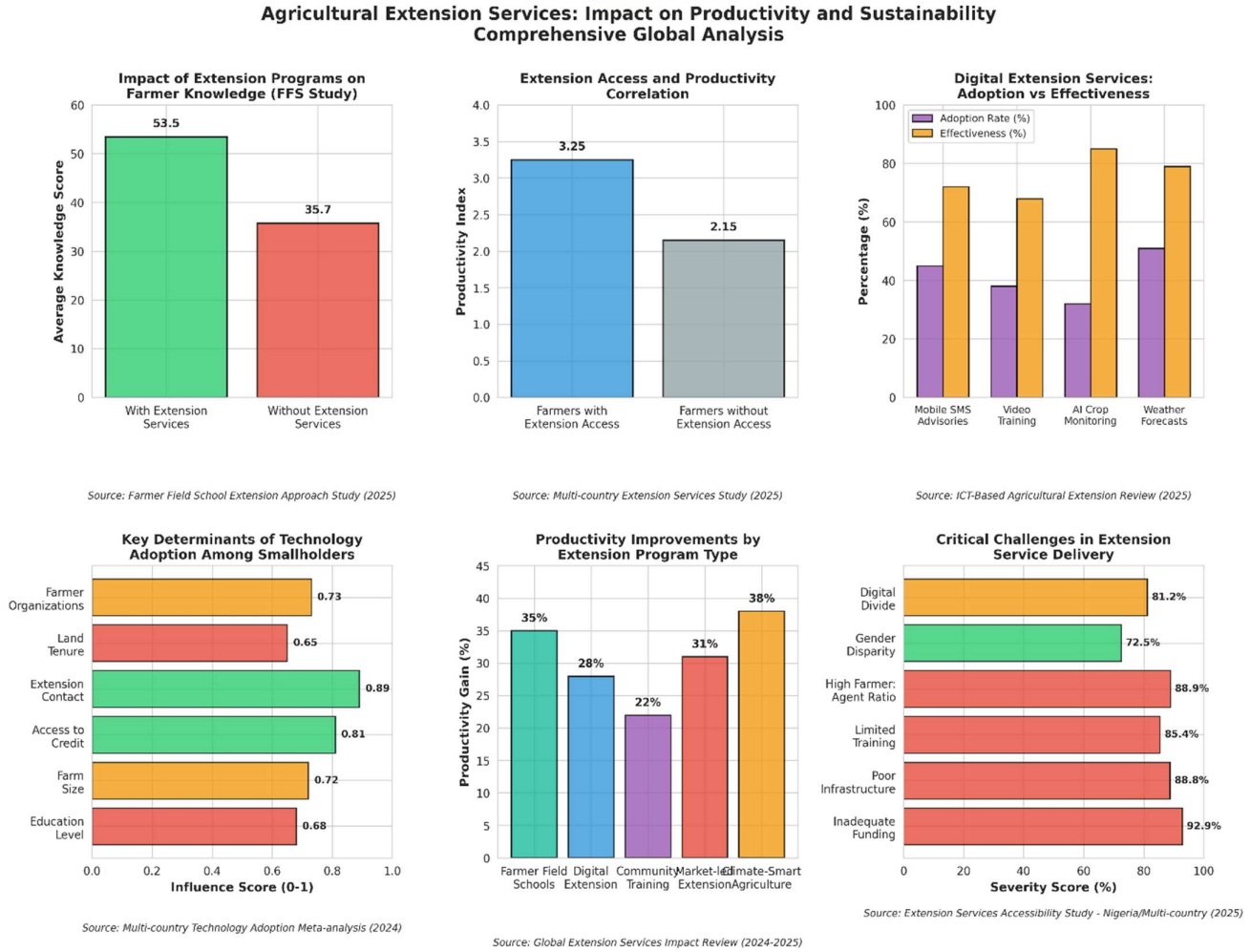
could be achieved given crop and location, are a significant source of productivity improvement by way of better extension services, easier access to inputs, and use of better practices. In Pakistan in particular, yield gaps can be reduced by better extension services, better access to inputs and adoption of climate-adapted varieties which may boost wheat production by about 45 percent, which would meet the grain supply shortages in the country without necessarily expanding agricultural land.

The programs of Farmer Field School show especially high productivity effects, and the farmers involved in similar settings noted improvements in yields of big crops between 25 and 40 percent (Kumar, 2025). These productivity increases are based on several mechanisms: better crop management practices, improved timing of inputs application, better pest and disease control, increased efficiency of water use, and improved experimentation and adaptive management by farmers. There is emerging evidence on the effects of digital extension services, and research in India has reported strong correlations between use of digital extension services with various productivity measures such as intensity of input, variety of production, crop productivity and crop income (Rajkhowa and Qaim, 2021).

Figure 1

This comprehensive visualization presents six key dimensions of extension services impact on agricultural productivity and sustainability, including: (1) impact of extension programs on farmer knowledge gained, (2) correlation between extension access and farm productivity, (3) adoption vs. effectiveness of digital extension services, (4) key determinants of technology adoption, (5) productivity improvements by extension program type, and (6) critical challenges in extension service delivery. Data synthesized from global extension services studies spanning 2024-2025.



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5.2 Climate-Smart Agriculture and Adaptation

Climate change is a growing menace to agricultural productivity in all parts of the world, and the reduction in productivity is projected to 14 percent by 2050 unless proper measures of adaptation are put in place (Farah et al., 2025). Extension services have become an important tool in the delivery of climate-smart agriculture (CSA) practices, which are bundles of agricultural practices that are used at once to enhance productivity, adaptive capacity, and greenhouse gas emissions. Crop diversification, better crops varieties adapted to changing climatic conditions, water harvesting and conservation methods, soil health enhancement practices and conservation agriculture methods that reduce mechanical soil disturbance are examples of climate-smart practices that are being encouraged using extension services.

The patterns of adoption of climate-smart farming practices are an indicator of how complex farmers perceive the implementation of these practices and the time scale of the economic returns. A study of CSA practice adoption by smallholder farmers in East Africa discovered that farmers focus on practices with fast economic payoff and relatively low investment such as crop diversification (94.3% adoption), crop rotation (90.9% adoption), and improved crop varieties (88.3% adoption), but longer-gestation investment strategies like agroforestry had low adoption (23.1% adoption) (Erick et al., 2 This adoption pattern has implications to the design of the extension services: the farmers show interest in adapting to the climate, but focus more on those practices that provide visible returns in the yearly agricultural cycle than investments that provide sustainability in the long run.

The adoption of climate-smart agriculture shows a steady positive effect on farm resilience, productivity, and household income. Meta-analytical reviews that have combined the results of several studies on CSA adoption report that CSA adoption enhances farm resilience to climate change and reduces greenhouse gas emissions (Ma & Rahut, 2024). CSA practices applied by individuals produce varied results, such as the household income of climate-vulnerable areas increased by 83% due to the combined impacts of better yields and better production stability (Ogada et al., 2020). The support of the adoption of climate-smart agriculture through extension comes as an urgent need, and the farmers reported access to the extension services and climate information to be primary determinants of the adoption capacity (Alidu et al., 2022).

5.3 Impact on Rural Livelihoods and Food Security

In addition to the enhancement of productivity of individual crops, the effective extension services may lead to the enhancement of livelihoods in a wider scope through various avenues. Increased productivity leads to more farm income, which increases nutrition levels in households, access to education, and living standards. The market linkage information availed by the extension services allows farmers to know where they can get their produce remunerated, how they can produce better products to conform to the market demands, and how they can access better markets that offer better prices than the traditional local market access channels. Extension services that aid agricultural diversification- go beyond the production of staple cereals to horticultural crops, livestock production, and value-added activities- raise the income stability of the households by decreasing the reliance on any one crop and diversifying the income sources among various activities.

There are several pathways to food security enhancement based on the extensions: more nutritious foods such as vegetables, pulses, and livestock products are produced, household income improves and allows people to buy foods, agricultural systems are more resilient and less prone to production shocks, and more foods are produced in the course of the year due to the diversification (Berg et al., 2020). A study of households enrolled in Farmer Field Schools revealed an increase in dietary diversity, better nutrition outcomes of the household members, and less seasonal food insecurity episodes than control households (Berg et al., 2020). The extension services that address the farming activities of women exhibit a specific significance to the improvement of household food security because the results always indicate that women-controlled agricultural income exhibits a stronger relationship with household nutrition and children welfare compared to men-controlled agricultural income (Raman, 2025).

The extension services dealing with diversification of rural income encourage households to participate in non-farm income generating activities that complement agriculture. A study on non-farm income diversification in Ghana recorded that households who diversified to non-farm activities and at the same time

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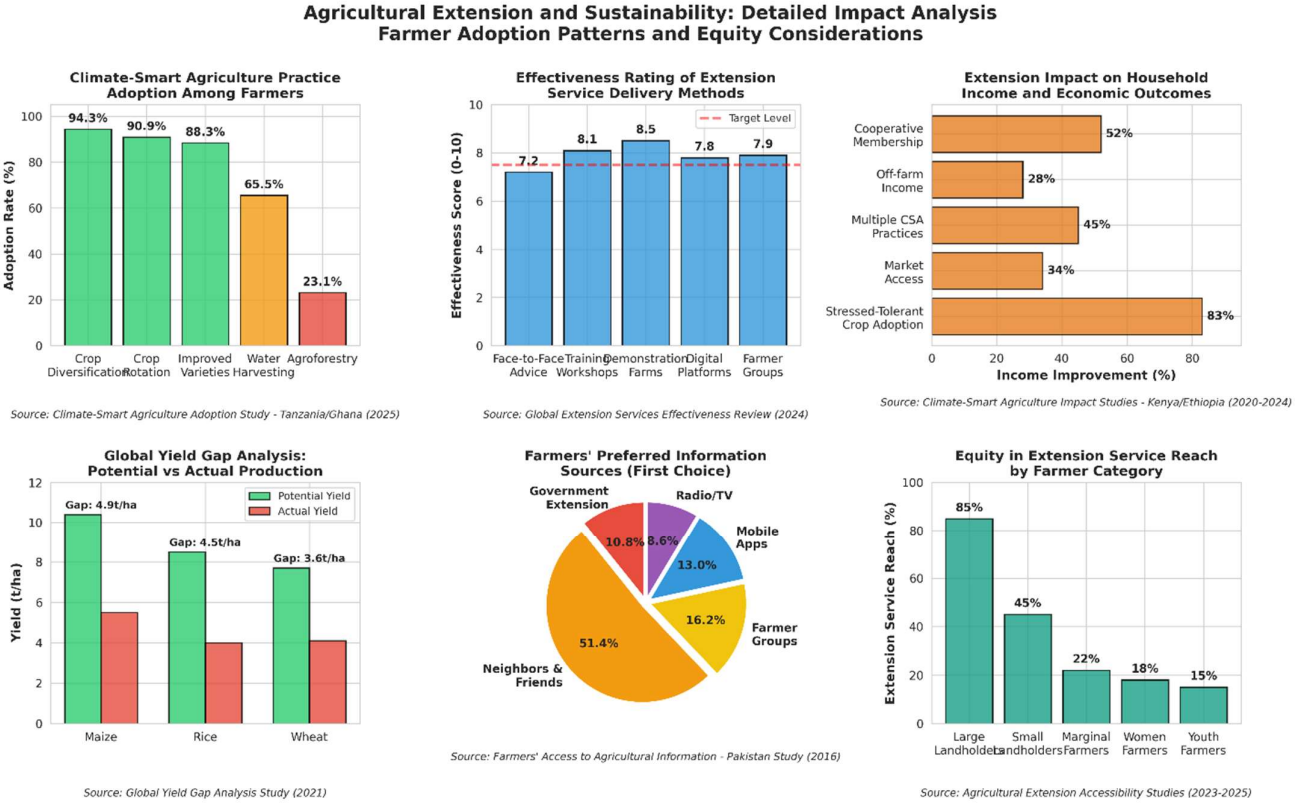
produced agricultural products recorded better livelihood results than households that diversified to agriculture only (Danso-Abbeam et al., 2020). Knowledge on non-farm income services, skill development in the non-farm activities, and linking farmers to market opportunities in non-farm products are beneficial to household livelihoods and poverty reduction in addition to improvements in the agricultural sector.

Figure 2

This figure presents additional dimensions of extension services impact on sustainability and livelihood outcomes, illustrating: (1) climate-smart agriculture practice adoption patterns, (2) effectiveness ratings of different extension service delivery methods, (3) household income improvements through various extension-supported activities, (4) global yield gap analysis for major crops, (5) farmer information source preferences, and (6) equity in extension service reach across farmer categories. Data derived from extension sustainability and livelihood studies (2020-2025).



6. Case Study: Pakistan Context and Implementation Challenges

6.1 Pakistan-Specific Extension Service Challenges

The agricultural extension system in rural Pakistan has its specific challenges which lie in institutional, financial and structural factors that constrain its effectiveness in serving the smallholder farmers (Alzahrani et al., 2023). Pakistan has developed a vast network of extensions, on federal, provincial and district levels of administration, but this network functions with the persistent resource shortage that restricts its capacity to deliver significant assistance to the farming communities. The provincial agriculture departments have extension officers in every rural district, but the staffing is insufficient, transportation is not adequately provided, there is not enough training funds, and maintenance of demonstration facilities is minimal, which significantly limits the effectiveness of extensions.

In Pakistan, where the proportion of farmers who are satisfied with the public extension services is estimated to be about 35 percent, the level of satisfaction is among the lowest in the similar countries of South Asia, with India registering about 52 percent, Bangladesh about 41 percent, and Nepal about 48 percent (Alzahrani et al., 2023). This low level of satisfaction indicates a view by the farmers that the extension services do not seem to be relevant to their unique situation, the extension agents do not visit their farms, the

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extension messages do not seem to be relevant to priority farmer issues, and the extension support does not seem to be translated into concrete livelihood benefits. Special discontent arises with the smallholders and marginal farmers who get inadequate proportionate extension attention than the large landholders who are seen to have more productive capacity.

The preferences of the information sources recorded in the Pakistani farmers show worrying consequences to the performance of the public extension systems. On the question about the source of information, they use the most to obtain agricultural information, only 10 percent of rural farmers rated extension staff as their first choice, with 47.5 percent rating neighbours, friends, and relatives as their first choice (Yaseen et al., 2016). This enormous disconnect between government extension service delivery and utilization by the farmers implies inherent malfunctions either in the availability of the extension services or value creation. The tendency towards informal sources of information probably is influenced by such factors as a more perceived credibility of farmer-generated knowledge, better accessibility of peer networks than of geographically distributed extension workers, and better cultural acceptability of seeking advice of social peers than of formal government officials in particular rural settings.

6.2 Gender and Social Dimensions in Rural Pakistan

In rural Pakistan, gender disparities in agricultural extension access and agricultural productivity are especially acute issues since the cultural norms tend to inhibit the women to interact with the extension agents and limit the autonomy of women in their decisions related to agriculture (Saha et al., 2024). Rural women, who form vital agricultural labourers that handle considerable shares of farm labour, record low levels of extension interaction and little access to training services. Even the extension agents themselves complain about the unease of visiting the farm when there are no male members of the household and the household is headed by the women, which poses obstacles to the access of extension to especially vulnerable household groups.

The digital divide by gender adds to the problems of extension services inequity, as only 24.6% of rural women in Pakistan have access to internet services as opposed to 48.7% of rural men (Saha et al., 2024). This high gender disparity in access to digital devices constrains rural women in accessing ICT-based extension services, online market information platforms and new extension technologies that are becoming more dependent on smartphone and internet access. The reform of the extension services in Pakistan has to be explicit in dealing with the gender barriers by providing gender-sensitive extension services, recruiting and training women as extension agents, creating extension content that specifically targets the production interests and decision-making limitations of women, and providing communication channels that women can easily access such as community meetings with women-only attendance options.

Another very important aspect of social equity is youth participation in agriculture and agricultural extension services. Agriculture is not always appealing to the rural youth who see the employment in the city to be much better than the jobs available in the countryside, which has led to rural-urban migration and the shortage of agricultural labour in most areas. The extension services can be used to attract the younger generation to agriculture by using digital platforms that are in line with youth communication, showcase of profitable agricultural businesses such as horticultural production and value-added agricultural products, and support networks and training programs that are specifically tailored to young farmers. Nevertheless, old-fashioned models of extension services where the farmer is a visitor to the farm and is trained in more traditional ways might be of less interest to young farmers who are more digital natives.

6.3 Climate Vulnerabilities and Extension Response Requirements

The agricultural communities in rural Pakistan are increasingly challenged by the problem of climate change such as unpredictable rainfall, more intense and frequent droughts, increased frequency of floods and rising temperatures that endanger crop productivity, especially in areas with a limited supply of water (Ullah et al., 2024). These climatic changes have direct effects on agricultural output and rural livelihoods whereby droughts lead to death of livestock, crop failures and acute livelihood shocks that are more devastating to the vulnerable households without asset cushions. The issue of climate variability adds to the already existing problems of land degradation, soil depletion, and water scarcity in most regions that are related to agricultural

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sustainability.

The extension services in rural Pakistan should be transformed to make climate change adaptation one of their main functions and not a peripheral issue. This development necessitates that extension systems be used to make available to farmers the correct, timely weather forecasting information which will allow them to plan production based on seasonal rainfall patterns; offer them the appropriate production varieties in accordance with changing temperature and precipitation regimes; conserve water and harvest water in response to growing water scarcity; and diversify their production, so that they will not rely on the increasingly risky production systems. A study specifically investigating the adaptation of rural inhabitants to climate change and livelihood in the Hindu Kush Himalayan area of Pakistan reported that farmers involved in the extension program were found to be more aware of climate risks, understood more on the adoption strategies and showed a more active adaptation management than the non-participating farmers (Ullah et al., 2024).

Figure 3

This visualization addresses Pakistan-specific extension challenges and opportunities, illustrating: (1) comparative farmer satisfaction with extension services across South Asian countries, (2) farmers' information source preferences in rural Pakistan, (3) critical agricultural constraints facing rural Pakistan, (4) feasibility of modern extension approaches for Pakistan implementation, (5) expected productivity gains from improved extension for major Pakistan crops, and (6) policy priority matrix for extension reform. Data synthesized from Pakistan-specific studies and South Asian regional comparisons (2024-2025).

7. Policy Recommendations and Implementation Pathways

7.1 Strengthening the Public Extension System

The modernization of the Pakistani agricultural extension system should start by ensuring that there is a systematic enhancement of the public extension sector as the institutional framework that reaches most of the rural farmers. This reinforcement will necessitate the government fiscal dedication towards the extension services that will undo decades of systemic underinvestment in the extension systems, which have limited

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capacity. The proposed fiscal allocations must ensure sufficient budgets on staff salaries of the extension personnel to other alternative jobs to attract and retain qualified personnel, transportation facilities to allow the extension staff to visit the farm regularly, staff training and capacity development, maintenance of demonstration facilities, and provision of technology such as smartphones and internet to enable the extension staff to access and use digital extension facilities.

The development of the capacity of the extension agents is a high priority because the success of the extension services is largely determined by the knowledge, skills and motivation of the extension workers. The systematic training programs that would be used in Pakistan to improve the current extension staff would include topics such as climate-smart agriculture, better crop varieties which are adaptable to the changing climatic conditions, sustainable management of natural resources, use of digital extension tools, and gender sensitive extension communication. The extension agent knowledge in the technical fields of priority should be updated through comprehensive in-service training programs that are developed and implemented in agricultural universities and extension training institutions. Knowledge sharing on effective extension methods could be achieved through international extension experience-sharing visits and peer learning networks where Pakistani extension professionals would visit similar developing countries and learn with them.

The models of extension service delivery need to be redesigned to enhance effectiveness and reach of the smallholder farmers. Instead of extending the agent-to-individual farmer contact models with unsustainable extension agent movement, service delivery ought to move more towards farmer group-based extension where extension agents meet with farmer groups (20-30 farmers in a group meeting regularly) to deliberate on priority issues, undertake field experimentation and collectively acquire better practices. The extension of Farmer group-based extension has a huge impact on the efficiency of extension in that it allows the same extension agent to serve a significantly larger number of farmers and at the same time helps to build social capital with farmers in the form of group interaction and collective learning experiences.

7.2 Integration of Digital Extension Technologies

The growing penetration of mobile phones in rural Pakistan presents unprecedented opportunities to deliver digital extension services that can be delivered to rural communities by surpassing the traditional limitation of geographical distance and the limitation of mobility of the extension agent. Priorities digital extension efforts must comprise: (1) SMS advisory systems that allow real-time access to pest outbreaks, weather changes, and market price fluctuations to farmers without the need to access the internet; (2) WhatsApp-based farmer groups that allow the rapid dissemination of information and discussion of farmers with each other within low-cost messaging systems; (3) Mobile agricultural applications that deliver crop-specific advice based on farmer

The implementation of digital extension services has prerequisite investments in the rural digital infrastructure such as increased internet access, stable electricity supply to charge devices, and creation of Urdu and local language interface options that will make the digital tools accessible to non-English speaking farmers. Complementary capacity building initiatives must focus on reducing digital literacy barriers among more elderly farmers, and training initiatives on the basics of smartphones, use of WhatsApp, and access to agricultural applications should be provided. Localized support (possibly schoolteachers or youth with digital literacy) Community-based digital extension facilitators could offer assistance to farmers in using digital extension tools.

Digital extension services have potential models of public-private partnerships, based on the resources of the private sector and technological knowledge. Mobile network operators such as Jazz, Zong, and Telenor have infrastructure, technical capacity, and customer relationship which can be utilized in the delivery of agricultural extension services. The agricultural input firms have field presence with dealer networks and direct contacts with farmers, which may incorporate extension services into their business. The manufacturers of agricultural equipment might offer extension services with the sale of equipment and training of users.

7.3 Farmer Organization Strengthening and Support

Farmer cooperatives and groups of farmers are the important institutional arrangements that link

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farmers to extension, markets, suppliers of inputs, and sources of credit. The farmer organization sector in Pakistan is still underdeveloped in comparison with the requirements of the agricultural sector, and the number of cooperative members and the organizational capacity of farmers to perform the farmer collective action is low. The development of farmer organizations should be a priority of the government policy that may include: (1) legal and regulatory frameworks that enhance the registration and formalization of the farmer organizations through legal and regulatory frameworks; (2) financial support through the establishment and start-up costs of the farm organizations; (3) capacity building programs that develop organizational management skills, financial management, and group decision-making; and (4) linkage facilitation that connect the farm organizations

Farmer Field Schools may act as farmer organization development mechanisms and can be developed out of temporary organizations created to learn in a given time period into permanent farmer associations that have post-FFS relationships and that carry on operating as collective action mechanisms of linking farmers to markets and acquiring inputs. The government support that allows FFS facilitators to stay connected with the farmer groups after the first round of extension would enhance the organizational capacity of farmers and create a lasting extension effect beyond the project timelines.

7.4 Public-Private Partnership Development

The government extension services are not sufficient to cover the entire scope of agricultural extension requirements under reasonable financial limits. Strategic public-private partnerships can be used to widen the extension reach, better the quality of services and also increase sustainability with the mobilization of the resources of the privates. Agricultural extension models in Pakistan might involve: (1) extension agents at privately owned input companies who offer technology-specific advice to farmers as they buy inputs and the government agents offer more general farm management advice; (2) extension agents at agricultural equipment dealers who are offering extension services along with equipment sales and training; (3) mobile network operators that are facilitating the provision of extension services; (4) extension services being provided by farmer marketing organizations and agricultural

Effective models of PPP presuppose effective institutional frameworks that specify roles, responsibilities, incentive plans and benefit-sharing practices between partners. The policy of government should provide PPP principles to explain which types of extension services are still the government business and which types of extension services can be conducted by the arrangement of the partnership with the help of a private enterprise and the standards of the quality of PPP services and access of the farmers to this type of extension services, as well as the mechanisms of fair access to the extensions such as marginal farmers who are not so attractive to the private enterprise provider of this type of services.

8. Synthesis and Conclusions

8.1 Key Findings and Evidence Summary

This extensive literature review has captured the evidence of about 40 peer-reviewed papers investigating agricultural extension services, productivity enhancing processes, technology adoption processes, and sustainability pathways in developing nations with specific reference to rural Pakistan situation. The evidence overwhelmingly shows that properly designed and properly funded agricultural extension services have tremendous positive impacts on productivity, sustainability, climate resilience, and rural livelihood outcomes. Such effects are made in various ways such as knowledge transfer, facilitation in technology adoption, facilitation in market linkages, and empowerment of farmers using participatory learning methods.

The performance of extension services is highly associated with certain design and implementation characteristics. The strategies of extension based on participatory learning (especially Farmer Field Schools), direct contact with farmers, modelling of better practices under farmer field conditions, incorporation of farmer indigenous knowledge, and learning through groups consistently show better effects than the traditional technology transfer model that focuses on the power of extension agents and passive acceptance of suggestions by farmers. Digital extension methods demonstrate the potential of reaching geographically distant farmers and lowering the cost of extension per reached farmer, but would need other investments, such as digital

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literacy, infrastructure development, and culturally appropriate content design, to be the most effective.

The adoption of smallholder farmer technology is a complex interaction between household resources (land, labour, capital), individual attributes (education, risk preferences, openness to innovation), institutional (access to extensions, access to inputs, access to credit, access to markets) and technology (characteristics). The most notable modifiable factor that enables adoption is extension service access; however, extension effectiveness will need policy support that supports the extension including input market development, agricultural credit provision and market linkage development that will address the adoption constraining factors that will be present even when the extension services are available.

8.2 Application to Rural Pakistan Context

The agricultural extension system in rural Pakistan needs basic modernization and a continuous resource fortification in order to overcome the endemic lack of productivity and rural livelihood issues. The existing extension facilities work with poor resources that restrict the capacity of the extension agents to reach smallholder farming populations leading to poor farmer satisfaction and poor extension coverage among vulnerable groups of farmers. The accessibility issues of the extension service that have been reported in a thorough research need to be solved with the help of greater government fiscal involvement, capacity building of extension staffs, better service delivery models with a focus on farmer group extension, and an intelligent incorporation of digital extension modalities.

The potential of agricultural development in Pakistan is still under exploited because yield gaps are at 45-51 percent of the potential production of most of the staple crops. Sealing these yield gaps by offering better extension services that will facilitate the adoption of improved technology, implementation of improved agronomic practices, and production systems that are climate adaptive is the most economically sustainable way of achieving higher agricultural productivity without necessarily expanding agricultural land and developing more irrigation. Increased extension services are key policy investments that yield high agricultural productivity returns in comparison with the low fiscal investments.

The issue of gender and social equity should be incorporated during the process of modernization of the extension systems, and the benefits of extension services should be delivered across the diversity of the farming communities, which include smallholder farmers, marginal farmers, women farmers, youth farmers and landless agricultural workers. The better extension strategies on the gender-specific limitations that include women as agents of extension and gender-responsive service delivery mechanisms will enhance the effectiveness of extension and further social development goals.

8.3 Future Directions and Research Needs

Although there has been considerable advancement in agricultural extension research and innovation in recent decades, there are still significant gaps in knowledge and areas of implementation. Future research ought to answer: (1) the comparative effectiveness of the various modalities of extension services in particular Pakistan agroecological and socioeconomic conditions, to inform better evidence-based design of the extension system; (2) PPP implementation models in agricultural extension in the Pakistan context, exploring what actors in the private sector can effectively deliver what forms of extension services under what institutional conditions; (3) cost-effectiveness studies on extension service

Research studies on change processes of extension systems would be of great help in understanding the avenues of changing the existing unproductive systems to the updated, responsive systems to farmers. Learning about obstacles and enablers of extension system change, how best to develop political interest in funding extension and how to match the extension services to the needs of farmers would increase the viability of modernization of the extension system.

8.4 Final Remarks

Agricultural extension services are important institutional ways of converting agricultural research to farmer practice, assist in technology transfer, helping farmers improve their productivity, and improving the sustainability of rural livelihoods. Extension systems still offer useful services to millions of rural farmers across the developing nations due to chronic underfunding and lack of capacity. The improved investment in extension services, strategic modernization with the involvement of participatory and digital strategies, and

engagement with complementary policy support generates viable opportunities to significantly increase the results of agricultural productivity and rural livelihoods in Pakistan and similar developing country settings.

The evidence discussed in this paper clearly shows that the issue is not whether extension services can help in the improvement of agricultural productivity and sustainability, but how to design, resource and implement extension systems in the best way possible to ensure that they achieve the goals of national agricultural development. The government of Pakistan, provincial governments and development partners should attach importance to the strengthening of the agricultural extension systems as one of the most important development investments that creates high agricultural productivity returns, rural livelihoods and also helps achieve the national food security goals. The concept of modernized extension services with adequate resources and strategically positioned to reach every section of the farming community is a fundamental pillar towards transformed agricultural development that will benefit the rural people all over Pakistan.

Authors Contributions

All the authors participated in the ideation, development, and final approval of the manuscript, making significant contributions to the work reported.

Conflict of Interest Statement

The author declares no conflicts of interest.

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Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Data Availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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