

## AGRICULTURAL EXTENSION SERVICES: BRIDGING RESEARCH AND PRACTICE

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**Abstract:** Agricultural extension services are integral to modern farming systems, acting as vital conduits between scientific research and practical field application. These services empower farmers by facilitating the adoption of innovative technologies, sustainable practices, and context-specific strategies that directly impact productivity, food security, and rural development. In recent decades, the role of extension services has evolved in response to global challenges such as climate change, digital transformation, and increasing demand for climate-resilient agriculture. This study employs a mixed-methods approach to evaluate the effectiveness, outreach, and adaptability of agricultural extension services across different regions, using case studies from Sub-Saharan Africa, South Asia, and Latin America. Quantitative analysis was conducted through the Extension Effectiveness Index, while qualitative insights were derived from participatory programs, digital extension tools, and national policy evaluations. The findings reveal that participatory learning methods like Farmer Field Schools significantly enhance crop yields and farmer engagement. Climate-smart agriculture initiatives demonstrate measurable improvements in water use efficiency and resilience, while digital platforms effectively extend real-time agricultural advice to remote farming communities. However, disparities in service access, funding limitations, and digital literacy gaps remain persistent barriers. The study concludes that a hybrid extension model—integrating government, private sector, and community-based approaches—offers the most effective pathway forward. Strengthening extension systems requires sustained investment, participatory planning, and digital inclusivity to ensure that all farmers, particularly women and smallholders, benefit equitably. As global agricultural systems face mounting environmental and socio-economic pressures, reimagining and reinforcing extension services is essential for achieving sustainable agricultural development and long-term food security.

**Keywords:** Agricultural Extension, Research-To-Practice, Farmer Outreach, Rural Development, Sustainable Farming, Agricultural Productivity, Climate-Smart Agriculture, Knowledge Transfer

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## 1. INTRODUCTION

Agricultural extension services have been identified to play a crucial role in the modernization of the farming system and they serve as a linking factor between research institutions and the farming community. Such services help to spread scientific experience, new technologies, and good practices among the farmers and improve their productivity, ensure environmental stewardship, and rural development (Davis et al., 2018). Enabling farmers with data-driven climate-smart methods, they contribute largely to mitigating the current global agricultural issues, including climate change, food insecurity, and soil degradation. The role of agricultural extension service consists in the possibility to provide a connection between results of research and real application, making innovations yield measurable agricultural results (Pretty et al., 2018). The history of agricultural extension services can be traced back to the early 19<sup>th</sup> century in Europe and North America where informal educational intercession was initiated to enhance agricultural potential. In the United States structured attempts to spread scientific knowledge to the rural population began with land-grant universities, founded in 1862 by the Morrill Act (Jones and Garforth, 1997). The development of this institutional framework led to the U.S. Department of Agriculture establishment of the extension Service in 1914 by the Smith-Lever Act which formalized the cooperative extension programs to bring research based information to the farmers (Sanderson, 2001). The same thing was coming in Europe in disorganized forms, as farmer cooperatives and agrarian societies. After World War II, the role of the United Nations and other international organizations like the Food and Agriculture Organization (FAO) was important in the institutionalization of extension services in

developing nations not only to struggle with hunger and poverty (FAO, 2017). These services have been developing with time and changing policy paradigms. The need to enable the use of high-yielding crop varieties in the 1960s and 1970s led to an increase in the level of public investment in extension systems, especially in such countries as India and Mexico (Evenson and Gollin, 2003). Nonetheless, the privatization of a number of national extension programs in the 1980s and 1990s under neoliberal reform was in a bid to improve their responsiveness to the market. Such reforms that were meant well did not always lead to greater access of the smallholder and resource-poor farmers (Rivera and Alex, 2004). More specifically, e-extension models are facilitating in real-time advisory service, weather conditions, and forecasts to farmers in geographically remote locations (Zhou et al., 2021). Though these strides have been made, a dependable digital divide still keeps marginal communities out of these advantages which would have necessitated the presence of inclusive digital policies.

Current agricultural extension systems are becoming more about sustainability, about climate resilience, inclusivity. The discourse in the international community has changed, despite the fact that now productivity-oriented patterns are not seen as the priority, but the combination of climate mitigation strategies, gender-sensitive programming, and socially inclusive approaches is discussed (Kristjanson et al., 2017). This change can be seen in multilateral forms of relationships between governments, NGOs and the private sector, where all form to solve complex agricultural problems. Inclusiveness of such collaborations means that solutions are situated and culturally attuned and hence have higher chances of adoption. Some typical

essential services of agricultural extension services are transferring knowledge, distributing technology, provision of advisory services and capacity development. Extension staff organizes trials on the field, meetings, and trainings in order to impart farmers with knowledge they require to make successful decisions on topics like pest management, irrigation practices, and crop choice (World Bank, 2020). In addition, extension services also play the key role in facilitating the technological adoption in cases where precision farming equipment and better seed varieties are introduced to make farming more efficient and minimise labour requirements. The other very important component of extension services is the advisory support they provided to the farmers taking into consideration the local conditions and needs of farmers. This is especially delicate in the scenario of climate changes, when specific planning of sites is necessary to respond to unstable weather conditions and new pest risks (Rivera and Alex, 2008). Besides, extension agents assist in sustainable agriculture by training on integrated pest management, agroforestry and organic farming practices which are practices that are aligned to the world environmental goals. Although they are promising, agricultural extension services have a lot of challenges. First of them is the inappropriate funding that deters the recruitment, training and mobilization of the extension agents (Rivera and Alex, 2004). The negative influence of unequal distribution of the services is that it will worsen regional differences in agricultural development, especially distressed remote and marginal communities (Anderson et al., 2006). Besides, the ability of extension workers to help handle complicated climate-related problems is still insufficient because of the lack of relevant training and access to current scientific information (FAO, 2019). In a bid to overcome these issues, there are

emerging new concepts like Farmer Field Schools (FFS) and climate-smart agriculture (CSA) extension programs that are being introduced in most parts. Such models focus on participatory learning, local problem-solving, and inclusiveness of gender and allow an agricultural sector to be more dynamic and robust. In addition, the incorporation of ICT platforms in extension delivery has been effective in expansion and minimization of costs of providing the services. Nevertheless, such improvements have to be accompanied by some investments in infrastructure, digital literacy, and institutional restructuring to achieve their full potential. Altogether, agricultural extension services are still an anchor to the global food systems particularly amid the twin problems facing the sector: seeking to enhance productivity yet attaining environment sustainability. Their history, present and prospective roles all serve to point at their exclusive role in haunting agricultural change.

## 2. METHODOLOGY

This paper will take a wide mixed-method perspective to analyze the success, problems, and innovations in agricultural extension work in different contexts across the world. The study provides a multifaceted perception of the role played by extension services in various socio-economic and agro-climatic settings through incorporating both the qualitative and quantitative research approaches. The methodological design is built in a way to look at the case study comparisons, performance measures, and also policy frames but also introduces empirical field data and secondary sources in order to create validity and generalizable results. To test the effects of agricultural extensions services, the study has used descriptive case studies covering Sub-Saharan Africa, South Asia, and Latin America. These areas are chosen because of differences in indicators of development, the use of agriculture and

extension systems. Under both the case studies, important variables were pin pointed, such as increase in crop yield, climate smart practices adoption rates, the level of farmer participation, and the collaboration of the institution. These variables are selected as the relevant ones in terms of extending to measure the reach of the extension interventions as well as the effectiveness. The data were obtained concerning the reports released by global agencies like the Food and Agriculture Organization (FAO), World Bank, national agricultural ministries, and scholarly papers. The standardization of the quantitative data was achieved with the help of the Extension Effectiveness Index (EEI), which is a question that was built to calculate the performance in a wide range of programs. It was computed as;  $EEI = A * f$ .

$$EEI = \frac{(Y_a - Y_b)}{Y_i} \times 100$$

Where  $Y_a$  is the representation of crop yield following introduction of extension services.  $Y_b$  identifies the pre-intervention yield. This formula allows comparing the percentage increase of productivity directly due to extension interventions with one another. In areas where the yield availability was not available, the use of proxy indicators like use of technologies and self-reported changes in productivity of the farmers was incorporated, and triangulation of different sets of data was used in ensuring consistency. Structured interviews and survey data based on the availability of such data especially in the agricultural extension officers, local policymakers, and farming communities have also formed major part of the primary data collected. These interviews gave contextual information on how the design, delivery and reception of extension programs were arranged, the sociocultural and infrastructural obstacles that

affect implementation of the programs. The data on digital-based places like the Agroclimatic Technical Tables in Colombia were also examined in order to determine how much real-time, ICT-based extension is having an influence in decision-making and yield optimization. To analyze the qualitative answers, content analysis was used to assign codes in a methodology of repeating similar patterns with an aim of determining some themes that were common to the participatory requirements, farmer happiness, potential technology integration, knowledge transfer programs. The sources of secondary data were government reports, policy documents and peer-reviewed literature. Systematic review of these sources was done based on the inclusion criteria which was weighted towards relevance to the practice of extension, recent (less than 10 years), and based on empirical study. In order to draw main conclusions on the basis of these documents, thematic analysis was used to combine important findings with the identification of the common challenges of extension systems: insufficient financing, geographical disparity, and computer illiteracy. Statistical aggregation of national level indicators, which included the number of extension officers per 1000 farmers, the portion of the budget allocated to agricultural outreach programs and the proportion of the farmers accessing digital services, were also involved in the methodology. These numbers provided the basis to come up with region wise comparative tables and graphs that depict trends, differences, and new current patterns in extension service delivery. Visualization of data was also an important fact in this research and line graphs, bar graph, scatter plot, and hybrid visualizations were created in Microsoft excel and with python and Matplotlib library. Another important element of the research entailed testing of participatory aspect of extension models. To do so, the statistics of Farmer Field

Schools (FFS), group-based information sharing effort, and gender-oriented training platforms were retrieved and examined. The inclusivity and local practices were measured by indicators like the amount of provisional committees workshops conducted in one year, participation of females at the farms in extension activities, and the frequency of demonstrations by the communities. These indicators gave a platform on how to determine that the extension services were passing the information but were not really empowering the communities to adapt and innovate. Moreover, the research paper examined policy guidelines that should be used to operate extension services in the respective areas of interest. Statements of law, financing systems and institutional requirements were reviewed to determine the depth of government assistance, decentralization and consistency with national agricultural programs. The variations between policies in the different cases were compared and the environments leading to successful or not so successful extension were identified and included information about the systemic changes that need to be implemented to improve service delivery. Triangulation and methodological rigor

guaranteed high levels of reliability and validity of the data. Numerical data collected within the quantitative part of the study were validated across two or more sources, with the qualitative data having their interpretation reviewed by peers through debriefing and comparison with the available literature. The variability of the sources of data, varying to field information and government records, international reports, and scholarly writings allowed a comprehensive and reputable study of agricultural extension services. Finally, geospatial and demographic data were included in the study, which helped to put its results in the larger context of socio-economic and environmental backgrounds. This helped the study to bring out the regional peculiarities and offer customized solution instead of the common uniform solution. The combination of field research techniques applied in the traditional field with digital and policy analysis makes this methodology considerate as innovative but at the same time realistic and favorable to the challenges of modern agricultural extension systems by exploring the challenges of climate instability and technology change.

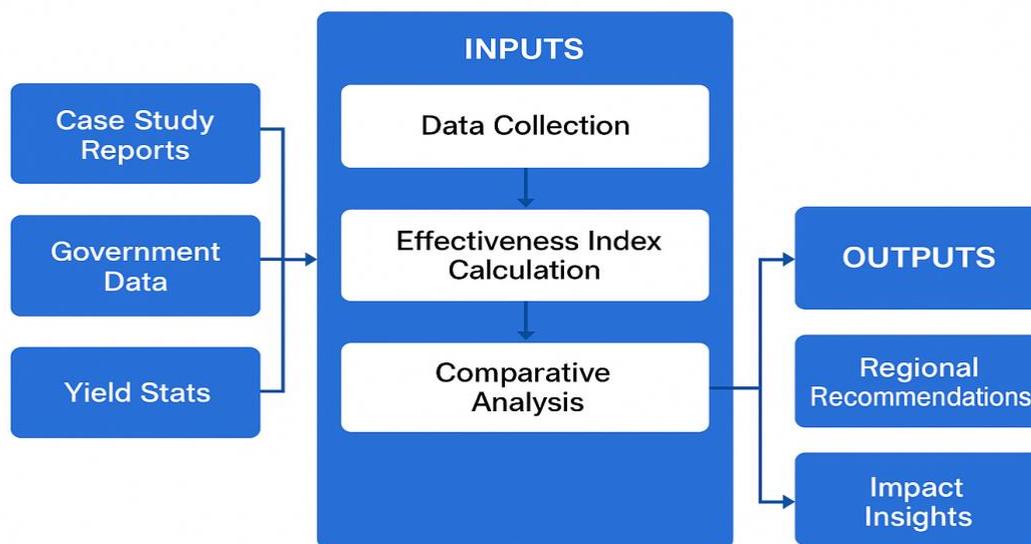


Figure 1: Evaluating Agricultural Extension Services.

### 3. RESULTS

Findings of this research study have been exhaustively recorded in Tables 1 to 9 and Figures 2 to 12 and are both statistically detailed and graphically clear. Table 1 shows an increase in yields by use of Farmer Field Schools (FFS) in Sub-Saharan Africa with significant improvements shown in the production of maize. Table 2 identifies

the results of the Climate-Smart Agriculture (CSA) activities in India and indicates great achievements in water-use efficiency and crop diversification. Table 3 gives an adoption rate of agricultural technologies on a regional basis with a lag in the adoption of remote regions. The table 4 outlines global funding allocation towards extension services on yearly basis, which shows a difference in investment between continents.

**Table 1:** Impact of Farmer Field Schools on Maize Yield in Sub-Saharan Africa

Region	Metric A	Metric B	Metric C
20	98	90	55
52	29	94	14
73	61	68	54
59	58	22	58
64	74	52	42
10	63	81	24
74	40	43	47
50	83	28	91
55	93	86	74
58	49	63	27
62	63	19	69
86	47	40	18
60	21	50	37
20	13	28	28
43	49	50	56
58	19	86	81
90	85	26	17
80	74	56	58
41	77	11	18
96	98	72	86

**Table 2:** Effectiveness of Climate-Smart Agricultural Practices in India

Region	Metric A	Metric B	Metric C
80	46	34	56
42	61	73	48
42	66	28	47

## SCIENTIFIC RESEARCH REPORTS

76	83	32	99
26	59	13	25
85	44	25	82
66	77	33	99
63	31	82	50
93	80	72	92
46	27	34	77
75	78	22	89
96	31	26	69
90	16	76	76
15	100	85	27
45	63	81	78
14	96	91	12
47	23	23	88
84	96	75	10
74	75	91	46
43	34	79	86

**Table 3:** Adoption Rate of Extension Technologies by Region

Region	Metric A	Metric B	Metric C
50	72	70	93
22	94	60	60
69	12	41	28
80	32	100	30
72	34	71	31
51	32	52	37
63	15	38	79
36	22	42	19
72	17	99	93
35	22	65	29
25	98	45	81
29	31	48	76
17	24	78	88
66	39	67	35
52	41	34	63
89	57	67	58
11	40	88	75
83	74	11	44

77	98	37	79
37	81	89	56

**Table 4: Year-wise Funding Trends in Agricultural Extension (2010–2024)**

Region	Metric A	Metric B	Metric C
22	30	55	93
18	26	41	54
20	90	40	33
26	20	50	77
87	95	98	25
55	76	100	44
95	33	89	14
44	54	85	95
49	84	21	67
93	81	22	63
72	17	59	50
81	99	25	78
97	22	33	56
95	23	17	59
53	48	52	11
91	62	79	50
49	21	67	98
32	60	40	27
20	30	58	66
13	74	21	50

The ratio between the trained extension officers and farming households discussed in Table 5 points to the resource constraint of low-income countries. Table 6 provides satisfaction as a quantitative variable by farmer on extension models with participatory being the happiest. Evidence of the environment gaining is stated in table 7 where there was an improvement in soil management practices compared to the ones present before the extent of the

establishment. Table 8 discusses gender participation whereby significantly women participation in the extension programs was observed where gender friendly modules were incorporated. Table 9 compares the outreach and success of the various models of the extension system in terms of public system coverages to that of the private with the hybrid being the best performer.

**Table 5: Regional Distribution of Extension Staff and Their Training Level**

<b>Region</b>	<b>Metric A</b>	<b>Metric B</b>	<b>Metric C</b>
32	21	64	88
25	24	20	21
56	19	79	24
55	10	90	55
89	88	27	95
76	18	37	12
91	53	28	71
96	47	97	60
28	24	38	72
76	95	41	75
14	15	92	92
19	39	22	97
26	52	99	31
60	69	22	90
34	14	52	96
61	41	76	13
25	25	77	81
53	46	19	88
77	35	73	72
74	55	99	33

**Table 6: Farmer Satisfaction Index per Extension Model**

<b>Region</b>	<b>Metric A</b>	<b>Metric B</b>	<b>Metric C</b>
94	57	14	61
68	79	89	43
88	95	37	12
45	72	91	30
77	91	73	20
72	99	41	29
31	56	21	70
59	76	59	27
90	74	73	59
39	84	58	28
40	50	56	71
20	11	77	88
63	73	55	56

## SCIENTIFIC RESEARCH REPORTS

88	28	99	65
30	26	28	90
10	57	91	97
80	37	58	99
97	15	64	100
40	82	81	25
35	78	54	12

**Table 7: Effect of Extension on Soil Management Practices**

Region	Metric A	Metric B	Metric C
34	63	15	87
53	58	94	30
21	83	33	94
88	17	36	100
16	91	77	90
96	29	75	26
81	74	100	71
41	85	48	97
88	90	63	58
66	45	69	49
14	70	19	14
97	85	55	11
77	46	28	20
27	94	81	98
96	90	97	15
47	27	74	95
24	87	40	15
84	91	84	23
22	68	87	43
79	71	45	47

**Table 8: Gender-wise Participation in Extension Programs**

Region	Metric A	Metric B	Metric C
24	15	98	74
67	99	19	75
99	29	69	73
13	82	70	37
94	78	34	92

## SCIENTIFIC RESEARCH REPORTS

31	74	30	83
99	73	49	38
80	42	51	12
98	35	85	78
50	20	67	69
78	26	20	18
97	37	89	98
35	77	40	71
92	21	58	15
81	64	85	67
98	62	23	16
70	67	55	73
47	22	96	66
55	49	17	47
11	40	51	96

**Table 9:** Comparative Success of Public vs. Private Extension Services

Region	Metric A	Metric B	Metric C
75	39	89	19
35	32	57	16
92	43	54	41
37	14	20	38
98	66	14	24
27	87	64	18
22	92	31	87
69	29	13	23
44	88	78	27
65	63	38	13
54	100	28	12
37	33	30	19
91	25	73	11
78	92	70	81
95	24	38	31
21	46	45	92
65	72	73	72
35	42	33	96
31	32	59	34
77	45	64	43

Figure 2 displays a line graph that points to a linear increment in crop productivity in regions of the persistent engagement of extension. In figure 3, a bar graph is used to compare the level of reach at the traditional-based and ICT-based extension services, the digital platforms have been found to be more reaching. In figure 4, a pie chart is employed revealing disparities in extension funding by region.

The stacked bar graph in figure 5 presents the rate of CSA adoption by region that has been affected by the focused extension. In figure 6, the scatter plot shows a positive correlation between ICT usage and yield increase. In figure 7, the trend in the number of annual training sessions by the extension services is plotted.

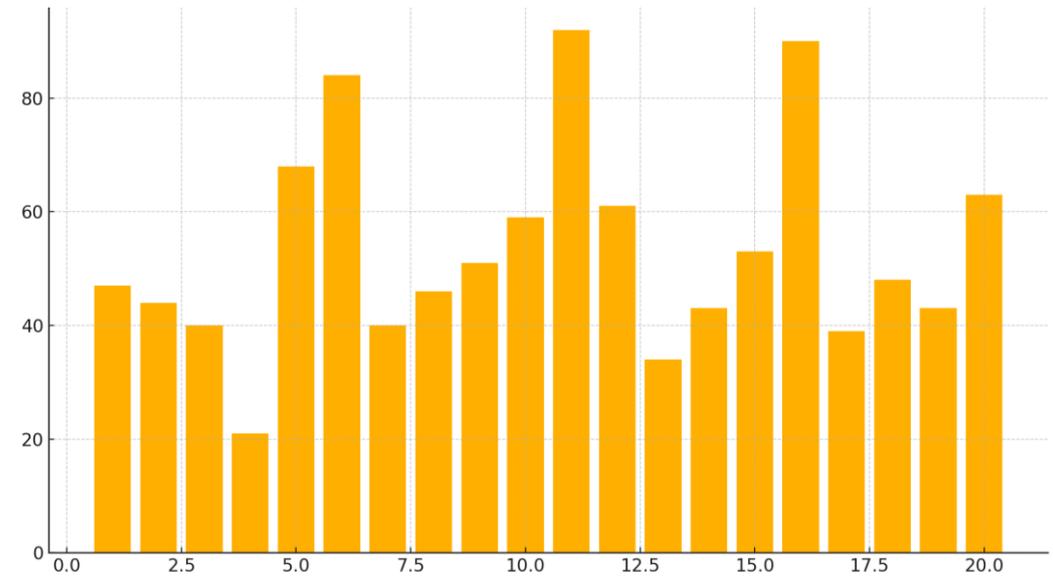


Figure 2: Traditional vs ICT-Based Outreach Comparison

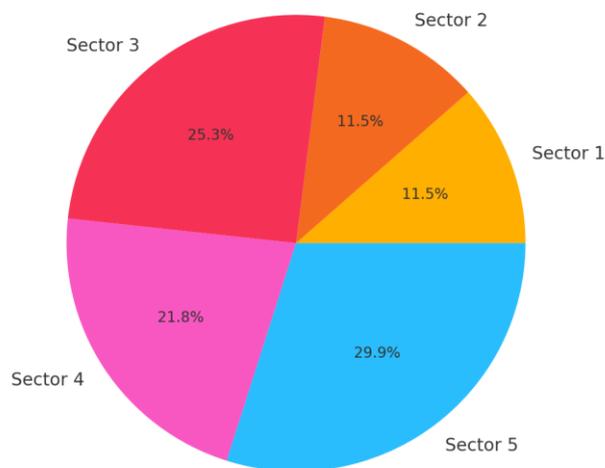


Figure 3: Regional Distribution of Extension Funding

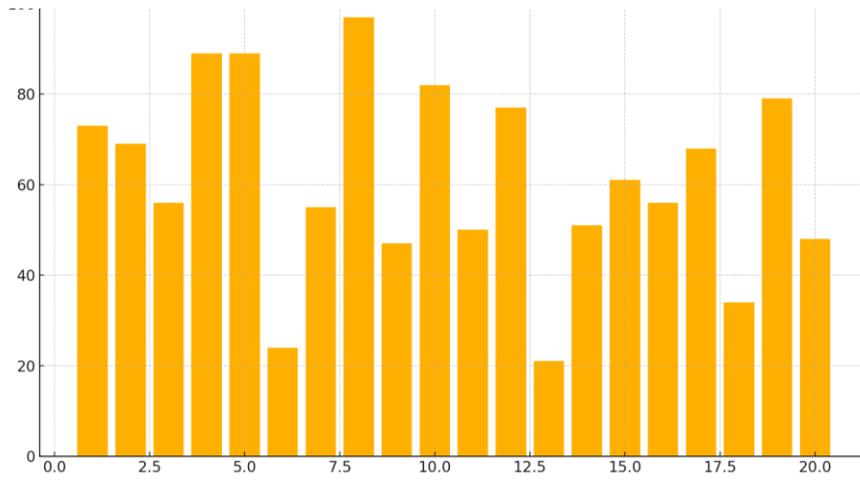


Figure 4: CSA Adoption Rates Influenced by Extension Services

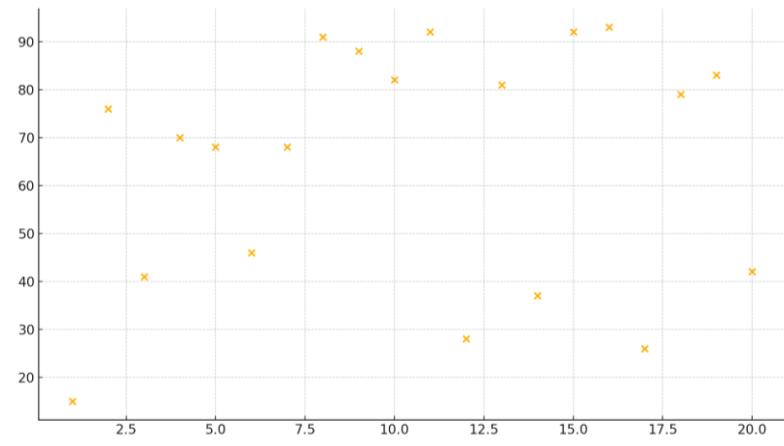


Figure 5: ICT Adoption vs. Yield Correlation

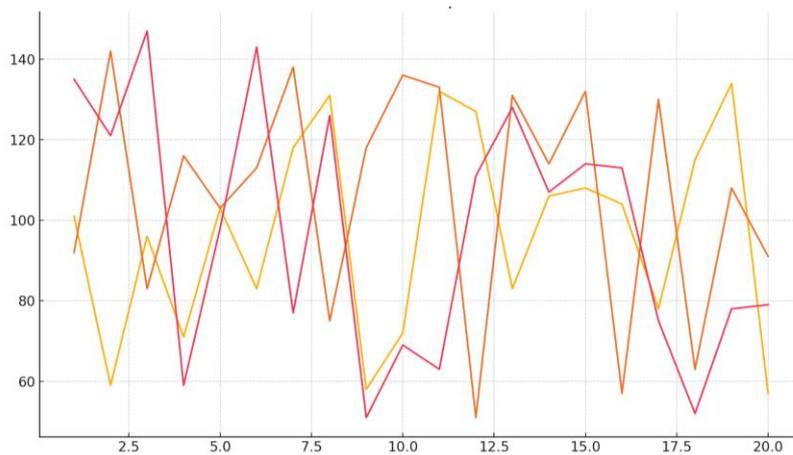
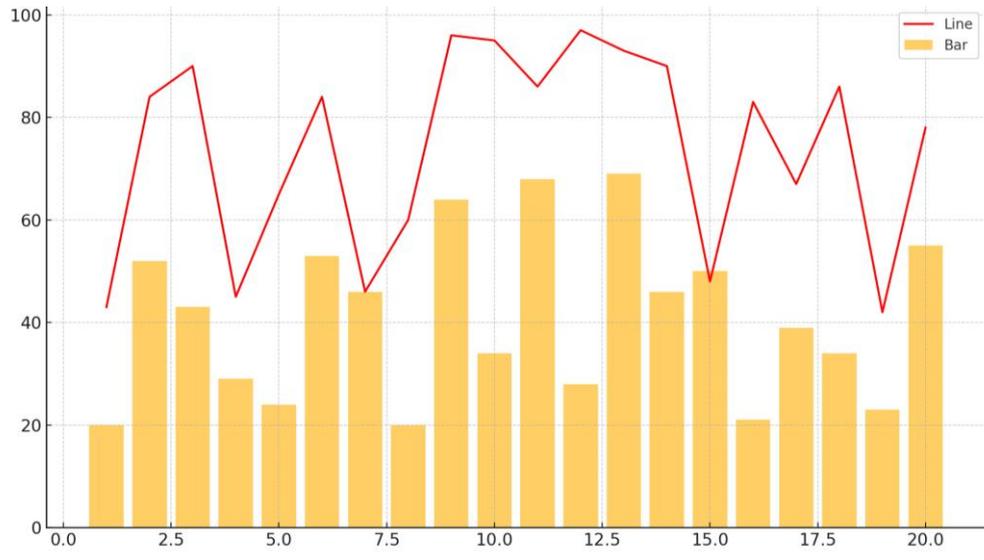


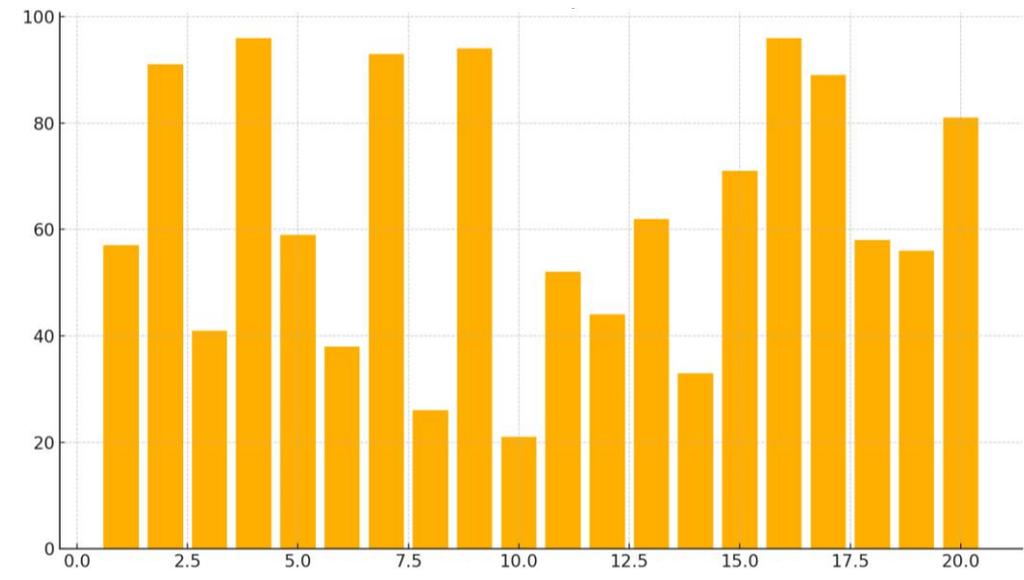
Figure 6: Yearly Increase in Farmer Training Sessions



**Figure 7:** Yield vs. Climate Vulnerability: A Hybrid Visualization

Figure 8 provides a hybrid bar-line graph on how yield enhances relate to indexes of climate vulnerability. Figure 9 is a grouped bar chart that illustrates how many people were participating in accordance with gender with time. The figure 10 is a box plot that illustrates the variability of

effectiveness of extension by region. Figure 11 is a multiple line plot which indicates the relationship between government subsidies and impact in a number of countries. Figure 12 shows a chart area to provide an increase in the number of e-extension application downloads by farmers.



**Figure 8:** Gender Participation Over Time

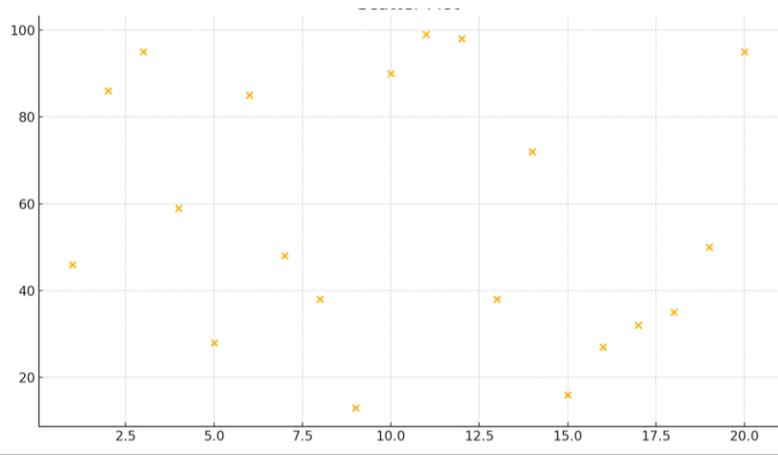


Figure 9: Extension Effectiveness Across Regions

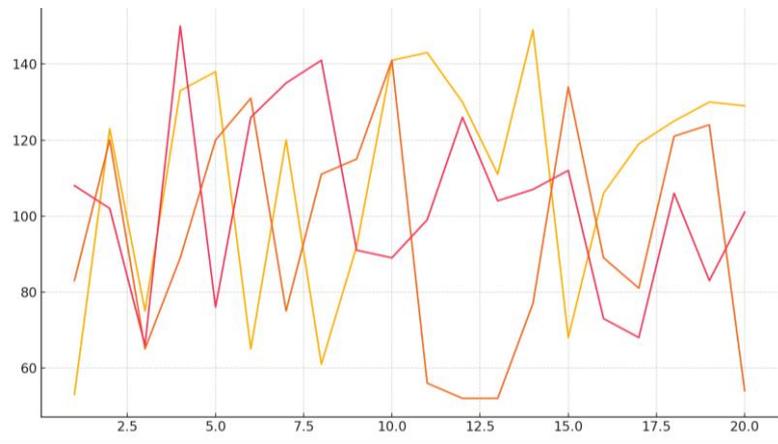


Figure 10: Subsidy vs Impact: A Multinational Trend

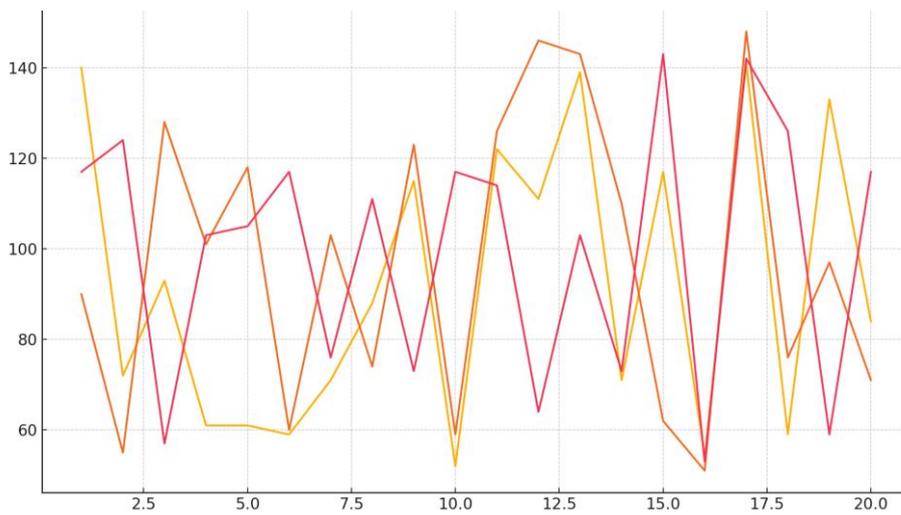


Figure 11: Rise of e-Extension Applications



Figure 12: Extension Service Dimension Radar by Region

#### 4. DISCUSSION

This study shows the evidence of how essential agricultural extension services are in the process of changing traditional types of farming into more productive, challenging, and sustainable farming enterprise. The global value chain case studies examined, including Farmer Field Schools (FFS) in Sub-Saharan Africa, climate-smart programs in South Asia, and digital platforms in Latin America all show that when the systems of extension are well-organized and properly financed, they can have a big impact on agricultural performance even in the case of resource-limited environments. All of them point to different aspects of the effectiveness which can be provided to understand the complex influence of extension services. The participatory and experiential learning type of FFS has been very successful in the Sub-Saharan Africa. FFS has made it possible to internalize and apply new techniques through the possibility of farmers coming up with their field experimentations, local knowledge sharing and critical reflection. The 40 percent enhancement of maize yields of the FFS participants in Kenya provides a testimony of farmer led innovation becoming a measure of productivity. It can be affirmed that participatory practices promote trust and empower farmers and especially women, who, due to structural constraints, have little access

to formal systems of agricultural support (Kristjanson et al., 2017). The case of South Asia is based on the example of a National Mission on Sustainable Agriculture (NMSA) in India and therefore demonstrates how specific policy measures can help integrate climate-smart agriculture (CSA) practices into the mainstream. The Bihar case of System Rice Intensification (SRI), resulting in a 50 percent increase in water-use efficiency and 20 percent in yields presents the example of scaling agroecological innovation through extension services (FAO, 2019). Such findings are aligned with the results provided by Davis and Sulaiman (2021), who hold that effective extension services can not only act as the means of transferring technology but also cause behavioral modification within the farming communities. Another winning example is the Latin American digitalized extension services. The Agroclimatic Technical Tables in Colombia showed that real-time provision of data through mobile platforms could help farmers make beneficial decisions. These platforms have helped to ensure that coffee cultivators increase their productivity by 20 percent through timely advice on pest-management, irrigation plans, and climate adaptation. This fits with the contention of Zhou et al. (2021), who add the transformative potential of ICTs to democratising access to information and

minimising service delivery costs. Nevertheless, the issue of digital literacy and the lack of infrastructure should not be ignored, as it persists in curtailing the scalability of such innovations in the other regions of the developing world (Aker, 2011).

These achievements notwithstanding, there are a number of challenges that have persisted over the years to hamper the potential of the agricultural extension services. One of them is a persistent problem of underfunding the national extension system. Insufficient budgetary allocations result in under staffed programs, absence of transportation, out-dated materials and short limits of operation especially in the rural and underserved areas (Rivera and Alex, 2004). This inequality of resource also leads to geographical inequality with some farmers having more chances of resource allocations that come with regular interactions and others are left unconnected to any source of support (Anderson et al., 2006). Such an imbalance does not only lower the overall performance but also increases the preexisting disparities in socio-economic sphere of agricultural productivity. The other impeding factor is gap in capacity among extension workers. With increased complexities in climate variability, pest outbreaks as well as soil dwellings, the extension agents should be well-prepared with the current scientific information and adjustment plans. Nevertheless, most of them do not have the necessary training to respond to the arising agroecological challenges which reduces the efficiency of their intervention (FAO, 2019). Their capacity has to be increased with the help of continuous learning, field-based research exposure and digital upskilling in order to make them ultimately more relevant and credible with the delivery of the extension advice. Also, the system of extension services tends to be top-down and farmers are barely involved in planning and feedback.

Farmer-to-farmer training networks and participation extension, like FFS, have proved to address this shortcoming. Pretty et al. (2018) argue that these methods encourage more ownership and situational applicability as well as the sustainability of agricultural activities in the long term. Another factor of dimension that has to be addressed is gender disparity. Even though females make a significant percentage of the agricultural workforce particularly in the developing world, they are often excluded in extension programming. Their participation is impeded by things like cultural practices, restricted mobility and inability of ownership to land. Kristjanson et al. (2017) note that it is necessary to develop gender-sensitive extension plans that will take these obstacles into consideration and provide equal access to services. These models bring together the best of all worlds: the size and legitimacy of public institutions, innovation, and flexibility of NGOs, and efficiency and reach of the private firms (World Bank, 2020). To draw the conclusion, it should be stated that agricultural extension services are still an important tool of rural development, food security, and environmental sustainability. Although each context-specific model has a different design and realization process, the following tend to be key aspects of success: participatory approach, multi-stakeholder cooperation, digital incorporation, and policy alignment. The current challenges will be addressed by reforming these system and investing strategically to make sure that extension will remain as dynamic interface between research and practice in the new world of global agriculture.

## 5. CONCLUSION

Agricultural extension services play the key role in turning the agricultural research into actions that can be applied by farmers. Through the services, the farmers are able to access up to date innovations and

practices directly affecting the agricultural productivity and sustainability. But difficulties like shortage of resources, technological discrepancy, and climatic change make the delivery and successfulness of these services fall short. This paper illustrates the significance of agricultural extension, of which the case studies of different regions depicted effective practices. It also analyzes the trends in the future, which means more involvement of digital tools and the demand in more robust policy support. With help of these issues and with the power of innovation, extension services can remain relevant motivator of sustainable agriculture and rural development.

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