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Agricultural extension as a pathway to livelihood diversification and sustainable development in rural communities: a systematic review

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Abstract

Background Farming communities in the Global South face a range of challenges, such as climate variability, pests and policy changes, which threaten agricultural productivity and livelihood diversification. Agricultural extension services provide a crucial pathway to address these challenges by enhancing agricultural production, income, resource management and partnerships, all of which are important for alleviating rural poverty. However, the role of agricultural extension in supporting livelihood diversification and reducing rural poverty remains underexplored in the literature. This review aims to evaluate the contribution of agricultural extension to livelihood diversification strategies and rural poverty reduction by facilitating access to livelihood capitals.

Methods A systematic review method was conducted to identify studies published between 2014 and 2024. The search was performed across several academic databases using predefined Boolean Operator search terms related to agricultural extension and livelihood diversification. Out of the 163 identified documents, 36 duplicates were eliminated, and 127 underwent priority screening, leaving 76 documents for full-text review. Consequently, 45 studies met the inclusion criteria. Descriptive statistics were used to summarize study characteristics, while gualitative thematic analysis was applied to identify recurring themes and gaps of extension approaches in supporting livelihood diversification.

Results The findings highlight the pivotal role of agricultural extension in reducing rural poverty and supporting livelihood diversification by improving access to human, social, physical, financial and natural resources. For example, by providing platforms for partnerships with financial institutions, rural families have gained access to microcredit, empowering them to invest in both farm and nonfarm activities. Additionally, digitally driven extension services have increased youth's and women's participation in agricultural and off-farm economic activities.

Conclusions Despite the positive contributions of agricultural extension services, challenges such as insufficient gender-responsive training programs, inadequate financial resources and limited nonfarm employment opportunities continue to hinder livelihood diversification strategies. This study underscores the need for an integrated approach that connects both farm and nonfarm opportunities with financial literacy programs and gender-responsive capacitybuilding initiatives tailored to the needs of rural communities. Policy interventions should prioritize strengthening

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access to financial services and inclusive agricultural extension programs to enhance rural livelihood diversification strategies and poverty reduction for sustainable development.

Keywords Agricultural extension, Livelihood, Economic activities, Diversification, Sustainability and Global South

Background

Livelihood diversification is essentially perceived as an approach through which individuals engage in various forms of economic activities in a bid to meet basic needs and enhance living standards. This approach stands as a linchpin in the pursuit of the United Nations'Sustainable Development Goals (SDGs), particularly those devoted to poverty reduction, income growth, zero hunger and reduced social inequalities. It is a critical strategy for reducing risk and vulnerability, particularly among resource-poor and marginalized populations [1]. Moreover, engaging in multiple economic activities enables individuals to strategically respond to emerging incomegenerating opportunities that improve their overall wellbeing [2].

The sustainable livelihood framework (SLF), which is a theory of change, provides an approach that describes livelihood capital, such as social, financial, physical, and natural capital, which shapes individuals' journeys to diversify their livelihood strategies and improve their living standards. These capitals play crucial roles in determining rural families' ability to participate in livelihood diversification strategies, which influence livelihood outcomes and resilience in rural areas [3].

To illustrate this, the use of natural and physical capital, such as land, water and fertilizer, has increased agricultural productivity and facilitated the transition to nonfarm activities. Similarly, social, human and financial capital has facilitated crucial interactions and partnerships, including the enhancement of farmers' knowledge, skill development, access to credit facilities and trust-building relationships. These improvements usually empower rural families to strengthen their capacity against production shocks caused by natural disasters and adopt livelihood diversification strategies accordingly [4, 5].

Accelerated agricultural development and allied sectors have been recognized as keys to driving livelihood diversification, especially in the Global South, where most families live in extreme rural poverty [6]. An efficient agricultural extension system can accelerate smallholder production systems and livelihood diversification strategies by integrating activities such as transportation, marketing, harvesting, postharvesting, and supply chain management. This is because smallholder agriculture is the heart of rural economies and plays an important role in providing diverse livelihood opportunities and food security, thus reducing poverty and inequality [7].

Additionally, the idea of a sustainable livelihood approach aligns well with the global call for poverty reduction, income growth, enhanced food production systems and the conservation of natural resources [8]. Agricultural extension services play crucial roles in facilitating this approach, especially in this era of climate variability and natural resource degradation [9]. Therefore, expanding agricultural extension services beyond traditional technology transfer to include elements of farmer empowerment by strengthening access to livelihood capitals could not only improve their quality of life but also contribute to life on land, as encapsulated in the United Nations'Sustainable Development Goal- 15.

To this end, many governments and development organizations in the Global South have made concerted efforts to reform their agricultural extension delivery units to include all actors across various value chains [10]. These reforms aim to address global concerns such as climate change adaptation, gender equity and partnerships for sustainable development while promoting the utilization of livelihood capitals at the village level. At the farm level, agricultural extension reforms focus on improving marketing; processing; harvesting and postharvesting management; pest and disease diagnostics; and risk management while encouraging involvement in nonfarm activities.

Despite these reforms, the contribution of agricultural extension services in facilitating livelihood diversification strategies remains unexplored in the literature. In most cases, existing studies have focused on the determinants of livelihood diversification or its impact on food security and poverty reduction. This focus has failed to examine how agricultural extension services interact with livelihood capitals, particularly those that support on-farm and off-farm activities, to achieve sustainable development. Additionally, there is little literature on the crucial role of social and physical capital in these interactions [3].

This review provides a comprehensive examination of the transformative power of agricultural extension in supporting livelihood diversification strategies and poverty reduction by facilitating access to livelihood capitals. It seeks to address two key research questions: 1 How do agricultural extension services influence smallholder livelihood diversification strategies in the Global South?

2 What are the contributions of livelihood diversification to reducing rural poverty among smallholders in the Global South?

The findings of this review are expected to suggest practical approaches to securing sustainable livelihood diversification and rural poverty reduction among the populations in the Global South.

Methods

Inclusion and exclusion criteria

This study adopted a systematic review approach and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and replicability. The inclusion criteria focused on studies that examined the interplay between agricultural extension, agricultural productivity, on-farm and nonfarm diversification strategies to improve the livelihood of rural communities in the Global South.

Table 1 below presents the detailed criteria used for inclusion and exclusion in this systematic review to classify the search results.

Search procedures

To improve the transparency and replicability, this study adhered to PRISMA 2020 guidelines for systematic reviews (Fig. 1). PRISMA was chosen because this study aims to systematically synthesize the existing evidence rather than mapping key themes, making it appropriate for a systematic review approach. Additionally, PRISMA emphasizes the need a full description of the search procedures, study selection and data extraction to facilitate proper judgment of whether all studies related to the current topic identified, potential errors detected and synthesis is conducted in a structured and transparent manner [11–13]. Accordingly, document searches were initiated and performed between September 21 and October 22, 2024. The searches were confined to original research papers, review articles and dissertations published in English between 2014 and 2024. This time frame ensured that only documents published within the last ten (10) years were included, as they were considered to reflect the most recent developments in the topic under study.

Additionally, the current study adopted several search strategies to enhance readers' ability to comprehend the thoroughness of the searches and promote updating searches in other databases. The search process began with discovery, after which keywords that emerged as recurring and interconnected from the initial phase were incorporated. The focus was on various agricultural interventions that have generated opportunities for livelihood diversification and poverty reduction in rural communities. In light of this, studies on the effectiveness of agricultural extension strategies that lack a direct link to the sustainable livelihood framework were excluded because they do not align with the research objectives.

To facilitate the search, keywords such as "agricultural extension", "livelihood diversification strategies", and "rural poverty and reduction in the Global South" were used. In addition, other search terms, such as "smallholder livelihood" and "extension activities," were included and linked in the search with the Boolean operator. The three keywords were connected via the Boolean AND operator to ensure adequate coverage of relevant articles. The search was performed according to the following equation via Boolean search engines: TITLE-ABS-KE ("agricultural extension" AND "livelihood diversification strategies") AND ("rural poverty" AND "reduction" AND "Global South") AND ("smallholder livelihood" OR "extension activities").

To arrive at a specific review article, a list of databases such as Scopus, Dimension, Web of Science, Science Direct, and Semantic Scholar was drawn. A total of 163 eligible articles were retrieved from the database and registers (Fig. 1). These articles were organized in a tubular

Table 1	Criteria fo	or inclusion	and exclusion	for the	review study

Inclusion criteria	Exclusion criteria
Articles that presented reviews of determinants of nonfarm livelihood diversification, rural transformation, role of agricultural extension, livelihood strategies	Articles that exclusively concentrated on the agricultural scenarios of Global North without extrapolative relevance to the objectives of the current review study
Empirical studies addressing the critical contribution of agricultural innovation, gendered agricultural value chains, and climate-smart agriculture and its integration with extension	Studies that did not adequately expose the dynamics of small- holder farmers' livelihood adaptation, decision-making process, and sustainable use of resources for economic development
Document types: articles and dissertations written in English from Global South	Document types: books, book chapters, abstracts, and protocols
Articles published in peer-reviewed journals between 2014 and 2024	Articles that did not focus on agricultural financing policy



Fig. 1 PRISMA 2020 flow diagram of the systematic review process

format via Excel to ensure that all the items under consideration for the study were captured. The information extracted included the title, journal name, journal type (peer-reviewed journal), year of publication, language used, barriers that may cause digital exclusion, and factors contributing to digital inclusion. The electronic search results were subsequently merged via Mendeley's reference management software, resulting in the shortlisting of 127 review articles after 36 duplicate entries were eliminated. The records of the documents retrieved from the databases were documented (Table 2). No automation tools were used. Afterward, priority screening was conducted on the titles and abstracts, followed by a rigorous full-text review to identify eligible studies. This kind of screening approach permitted the authors to conclude the screening process once most relevant literature review articles had been identified, as the remaining ones were considered unlikely to be relevant [14]. As a result, 76 articles were selected for the current review.

The next stage was the exclusion of articles on the basis of the document type criteria established in Table 1. This exclusion resulted in the analysis of 48 articles (Fig. 1). However, owing to difficulties in accessing the full texts

Table 2	Exclusion reasons
	Exclusion reasons

No	Reason	Register
1	Crop/Livestock yield improvement without linking it to nonfarm income activities	8
2	Agricultural extension models	4
3	Effectiveness of agricultural extension, without linking it to nonfarm livelihood strategies	7
4	Agricultural transformation without specific reference to rural communities in the Global South	2
5	Vague descriptions of how data on extension services was analyzed	3
6	Extension programs design and management in rural communities	4
7	Duplicates	36
8	Full texts were not retrievable after reasonable effort	3

of the three articles even after the corresponding authors were contacted, only 45 articles were included in this study. These difficulties highlight the barriers associated with digital access and information availability, which are critical factors in addressing digital exclusion [15]. The collated articles were closely examined, and references were cross-checked and documented several times. Table 3 gives the reasons for exclusion.

Analysis of the extracted data

A qualitative review of the collated data was undertaken through thematic analysis, an approach that is recognized for organizing and interpreting textual data in a systematic review. This approach allows for a crossexamination of the collated information to identify recurring themes and patterns related to agricultural extension and livelihood diversification in the rural areas of the Global South [16]. The analysis focused on aspects contributing to agricultural extension, including knowledge sharing, resilience, food production, natural resource use, and socioeconomic factors influencing rural likelihoods. Such an analysis highlights a wide spectrum of scholarly discourse, from grassroots, hands-on practices to policy-making considerations, thus providing an in-depth understanding of the complex nature of rural communities [17].

To identify the recurring themes and patterns, each of the collated articles was independently read by the authors to gain an in-depth understanding of the context of agricultural extension and livelihood diversification. At this stage, notes were taken to capture key ideas. Afterward, the authors compared their notes to identify the recurring terms and, through consensus, developed a framework with a focus on aspects facilitating development, farm and nonfarm activities and innovative technologies.

On the basis of this framework, the recurring terms and patterns were systematically coded. Terms related to partnership, collaboration and trust building aimed at strengthening linkages and relationships between rural families and policy-makers for sustainable development were categorized into one group. Similarly, those terms aimed at identifying pathways for livelihood diversification leading to income and yield stability among rural families were categorized into the second group. Finally, those terms that were geared toward the adoption of innovative technologies such as digital platforms and smart climate technologies to promote agricultural production, social inclusivity and sustainability in rural communities were categorized into a third group. A standardized form in Excel was used to record the recurring terms and patterns.

Conversely, a meeting was held where the authors cross-examined the categories through discussion. Discrepancies arising at this stage were resolved through mutual consensus. The categories were later consolidated into three main themes: *facilitation for change*, *farm and nonfarm opportunities* and *integration of innovative technologies* to reflect recurring ideas across all the collated articles. The results are presented in tables and figures to illustrate the relationships among agricultural extension services, livelihood diversification activities and their influence on rural development and sustainability.

Risk of bias in individual studies

To minimize the potential impact of information bias, each author independently reviewed and selected publications for the study after reaching an agreement on the key aspects of the research. Following the initial review, the authors compared their findings on the

Database	Search results	Duplicates Eliminated	Screened	Full text review	Excluded	Included
Scopus	28	3	25	12	2	10
Web of Science	25	4	21	13	5	8
Science Direct	18	5	13	10	6	4
Semantic Scholar	21	6	15	5	0	5
Dimension	10	3	7	7	5	2
Prisma	2	0	2	2	0	2
Gray literature	26	5	21	14	6	8
Asian Journal	12	4	8	7	5	2
Scientific African	14	4	10	4	2	2
Heliyon	7	2	5	2	0	2
Total	163	36	127	76	31	45

Table 3 Records of the documents retrieved from the databases

basis of the predefined inclusion and exclusion criteria. Although minor disagreements arose during review, they were resolved through discussion and mutual consensus.

Results

Agricultural extension services and the sustainable livelihood framework

Agricultural extension services are critical factors that contribute to sustainable livelihood diversification by enhancing livelihood capitals. It plays a crucial role in facilitating the translation of new technologies into practical use [18]. By promoting knowledge sharing, the translation of innovative programs and collaborative networks, agricultural extension services aim to strengthen human capital. This includes equipping rural farmers with the knowledge and skills necessary for the effective application of sustainable farming practices.

Human capital is arguably the most valuable capital in agricultural extension services because it forms the foundation for the efficient utilization of the other four types of livelihood capital [3]. Enhanced perceptions, knowledge, attitudes and skills enable farmers to take advantage of financial and social programs and effectively manage physical and natural resources. For example, in Kenya, video-mediated extension training improved the knowledge and skills of 77.5% of farmers in terms of striga weed and soil management. This led to an increased level of adoption of practices related to sustainable farming and greater motivation for active membership in farmer groups [19].

Moreover, these agricultural extension services play a key role in brokering strategic partnerships and networks for innovation with the aim of strengthening social capital. Innovative extension initiatives that leverage digital technologies such as the KilimoKwanza platform have facilitated farmer-to-farmer interactions, trust-building relationships and multistakeholder engagements. These improvements have resulted in collective decision-making processes and the adoption of climatic smart practices, leading to a 30% reduction in crop failure during dry spells [20]. Furthermore, by supporting the formation of farmer groups and their functionality, agricultural extension expands income-generating opportunities for individual members, enabling them to participate in livelihood diversification strategies such as cash savings programs. This suggests that strong social capital driven by agricultural extension services acts as a pathway for rural families to diversify their livelihood activities and reduce extreme poverty.

However, some studies have shown that improved access to agricultural extension offices may negatively affect livelihood diversification strategies. This is because better access to timely farming information and wellguided professional assistance tends to motivate local farmers to focus more on intensifying agricultural production rather than engaging in other income-generating activities [3]. This scenario calls for the need for agricultural extension programs to create a balance between promoting agricultural productivity and broader livelihood diversification.

Furthermore, agricultural extension services enhance access to financial capital and physical assets, including marketing services and farm inputs such as fertilizer and irrigation technologies, which are key drivers of livelihood diversification strategies. By integrating financial support components into their service delivery units, agricultural extension service providers aim to facilitate a partial shift toward nonfarm livelihood strategies [21]. Additionally, by improving local farmers' access to and participation in marketing opportunities, many rural farmers have been empowered to engage in both on-farm and nonfarm activities [22]. These interventions lay a strong foundation for reducing rural poverty by promoting more diversified livelihoods.

As agricultural extension services provide pathways for diversified livelihood strategies, fewer private extension service providers (PESs) often remain unaware of the diverse and dynamic needs of farmers in this era of environmental change. These PESs tend to focus on profitable segments of agriculture, overlooking critical aspects such as the efficient utilization of natural capital, including land and biodiversity, which are essential for sustainable livelihood diversification [23, 24]. For example, in Zimbabwe, increasing land size by one acre through agricultural extension services was associated with a 15.8% likelihood of adopting crop diversification strategies, including high-value crops [25]. This adoption could not only improve agricultural production but also increase income through the sales of diversified produce, thereby contributing to rural poverty reduction.

Therefore, addressing the holistic integration of livelihood capital—financial, social, physical, human, and natural capital—is essential for sustainable diversification strategies. This requires a strong partnership between public and private agricultural extension systems. Public agricultural extension systems should focus on creating broad-based awareness of new farming technologies with the goal of meeting farmers' information needs and addressing socioeconomic vulnerabilities [24]. Private agricultural extension can complement these efforts of public extension systems by focusing on innovation and the commercialization of agriculture. This partnership should target the efficient utilization of livelihood capitals with the goal of improving food production and incomes across the Global South.

Livelihood Capital	Variables influenced	Direction of influence	Outcome of influence	Diversification strategies affected	Extension Approach(es)	Quantitative impact
Human capital	Knowledge, Attitude and Perception	Positive	Proper use of farming resources	Both farm and nonfarm activities	Farmer Field and Business Schools and Digital exten- sion systems	A 30% reduction of crop fail- ure and improved crop yield at a significance level of $\rho \le$ 0.05 [20, 26]
	Farmers satisfaction	Positive/Negative	Motivation for participation	Off-farm activities	Digital-driven extension services like e-voucher systems	A 22.8% reduction in coffee production [27]
	Entrepreneurial skills	Positive	Comprehensive understand- ing of marketing trends	Both farm and nonfarm activities	Farmer Producer Organiza- tions, Digital extension systems	3.16% in cereal yield [26, 28]
Financial capital	Access to financial services such as saving programs	Positive	Timely and regular purchase of farm inputs and	Both farm and nonfarm activities	Microcredit integration in ICT-based extension services	52.7% of farmers engaged in nonfarm sources of income [29]
Social capital	Rural migration	Positive/Negative	Reduce pressure on land resources	Off-farm activities	Rural–urban linkages	Urban unemployment at 29% [30]
	Social Equality	Positive/Negative	Women inclusion in eco- nomic activities	Both farm and off-farm activities	Targeted extension massag- ing via ICT- based extension services	24.5% of women participated in livelihood diversification strategies [31]
	Social Networking	Positive/Negative	Collective decision- making	Both farm and off-farm activities	Farmer Producer Organiza- tions,	Enhanced adaptive capacity of farmers [32]
Natural capital	Land access and ownership	Positive	Expands income-generation activities	Both farm and off-farm activities	Conservation Agriculture	1.5 to 12.3% increase in diver- sification [33]
	Land size	Positive/Negative	Crop diversification	Both farm and off-farm activities	Climate-smart Agriculture	Increased adoption rate by 15.8% [25]
Physical capital	Access to infrastructure, market, digital technologies, farm inputs	Positive	Reduces vulner- ability to market shocks and emerging natural disasters	Both farm and off-farm activities	Digital-driven extension services like Esoko systems, Farmer Field and Business Schools	A 20% increase in food production and marketing during climatic shocks [25, 34]

Influence of agricultural extension on smallholder livelihood diversification strategies

Table 4 shows the various ways in which agricultural extension services influence livelihood diversification strategies through technical skills, perceptions, knowledge, financial services, and trust-building and sustainable resource management practices. Strengthening these aspects of livelihood capital empowers rural families to engage in diverse livelihood strategies.

Human and social capital

Agricultural extension initiatives such as the Farmer Field and Business Schools (FFBS) integrate training on sustainable farming practices with the development of entrepreneurial skills. Such integration empowers rural families not only to intensify their agricultural production but also to leverage their entrepreneurship skills to diversify into nonfarm income-generating activities. In Nigeria, FFBS participants reported an increase in crop yield. Similarly, in Bangladesh, farmers have recorded an annual growth rate of 3.16% in cereal yield [26, 28].

Furthermore, the use of efficient extension dissemination pathways such as information communication technology (ICT) tools has been instrumental in enhancing human capital. Previous studies have shown that these tools increase farmers' satisfaction with various livelihood diversification strategies [35]. ICT tools provide tailored messaging and timely access to information that equip farmers with the better knowledge and skills necessary to explore off-farm employment activities and diversified livelihood strategies. For example, digital-driven extension systems have enabled local farmers access to financial services such as savings programs, thereby promoting income diversification into nonfarm activities [36].

However, the impact of digitally driven extension services is not consistent across all farming conditions. For example, in Kenya, coffee farmers reported a 22.8% loss in yields when an e-voucher, a digitally driven extension service, was used. Moreover, a t-test indicated no significant difference in yields between e-voucher users and nonusers [27]. These findings underscore the need for agricultural extension to effectively leverage digital technologies to enhance human capital and support agricultural productivity.

Nonetheless, agricultural extension capacity-building efforts combined with digital training initiatives such as *e-Voucher systems* in Zambia and Nigeria have enhanced social capital by bridging gender disparities in rural areas. These interventions have facilitated targeted extension messaging, improving women's access to timely agricultural information and empowering them to make informed decisions about livelihood diversification strategies [37]. Empowering women in agricultural and allied sectors not only improves their interactions but also strengthens their capacity to adopt diverse livelihood strategies, especially in response to climate variability [38, 39]. Additional studies indicate that women are more likely than men to engage in diversified income-generating activities, reflecting their ability to sustain rural economies [40].

However, some studies indicate that gender remains a barrier to nonfarm diversification strategies. Being a woman is significantly associated with a lack of income diversification into nonfarm activities, with a relationship of $P \le 0.05$ [41]. Additional empirical evidence indicates that only 24.5% of female-headed households are engaged in nonfarm activities, whereas 37.5% of male-headed households are engaged in nonfarm activities [29]. This disparity implies that despite women's enhanced knowledge and skills, physical capital, such as inadequate access to the market and poor roads, may limit their capacity to fully capitalize on nonfarm income opportunities. These findings highlight the need for agricultural extension initiatives to address gender-specific constraints in improving access to essential assets, thereby promoting sustainable livelihood diversification programs.

Financial capital

The integration of financial education into agricultural extension services enhances financial capital, which enables rural families to potentially engage in diverse livelihood strategies. The literature has demonstrated that farmers with improved financial literacy are likely to access credit facilities, make timely agricultural investments, save, allocate resources efficiently and participate in nonfarm activities such as value-adding processing and vending [41–43].

For example, 52.7% of respondents who have gained access to financial services from microfinance institutions reported engaging in nonfarm income sources, underscoring the critical contribution of financial capital to livelihood diversification [29]. Additional studies indicate that access to financial institutions and the availability of adequate soft loans are essential factors influencing farmers' participation in nonfarm activities [44]. These findings underscore the need for agricultural extension services to strengthen access to financial services, thereby empowering rural families to diversify their income sources and drive economic transformation.

Natural and physical capital

Agricultural programs such as Conservation Agriculture, which are promoted through extension services, usually enhance the effective utilization of natural capital resources. Natural capital plays an important role in creating livelihoods, as it provides a foundation for various livelihood diversification strategies. In particular, land is a critical asset in these strategies. For example, secured land ownership has been shown to positively influence farming families' engagement in both agricultural and nonagricultural activities, with effects ranging between 1.5 and 12.3 percentage points [33]. Furthermore, [31] reported that land size had a positive influence on the adoption of diverse livelihood strategies. In contrast, in Ethiopia, more extensive land holdings are associated with lower diversification [5]. These findings underscore the importance of natural capital in enabling rural families to expand their income-generating activities.

Moreover, climate crises and emerging local pests and diseases pose serious challenges to the efficient utilization of natural capital to meet the basic needs of rural communities. To address these challenges, the agricultural extension sector has initiated services such as *Esoko* in Kenya, which have delivered weather forecasts and timely agricultural information to farmers. This has empowered farmers to diversify their livelihood strategies by adopting good agronomic systems, enabling them to mitigate environmental stresses, shocks and other uncertainties and contributing to sustainability [5].

For example, farming systems that incorporate both traditional crops and high-value crops are reported to increase food production during climatic shocks [34]. Other studies also indicate a sharp increase in total agricultural output, ranging from 0.52% to 2.2% per year, along with favorable economic rates of return due to good agronomic practices [45]. The sales from this increased food production may strengthen farmers' capacity to adapt to changing environmental and economic conditions.

To this end, agricultural extension services continue to play a pivotal role in leveraging physical capital to enhance livelihood diversification strategies. In Indonesia, farmer producer organizations (FPOs), which are supported by extension services, have enabled farmers to self-govern, strengthening their leadership capacity and positioning them in income-generating roles that promote livelihoods [32]. The benefits obtained from these leadership positions could be invested in agricultural activities and nonfarm ventures such as vending, thus contributing to livelihood diversification.

The emergence of digital technologies in agricultural extension has amplified the contribution of physical capital to promoting sustainable livelihood diversification. For example, in Ghana, e-market platforms such as *Esoko* have enabled farmers to access timely marketing information and other technical tips, prompting them to engage

in income-generating activities beyond agriculture. Similarly, e-voucher systems have improved farmers' access to critical inputs such as fertilizers and expanded market access, thus reducing their vulnerability to market fluctuations and climatic shocks [46, 47].

These findings underscore the need for agricultural extension services to strengthen farmers' participation in marketing activities, infrastructural development, and access to digital technologies and farm inputs. This would help drive food production and rural poverty alleviation and increase farmer resilience in the face of climatic change and emerging natural disasters.

Discussion

Contributions of agricultural extension to livelihood diversification and poverty reduction among smallholder farmers

In this era of global concern about the mechanisms of reducing extreme cases of rural poverty, agricultural extension has emerged as a viable tool to catalyze livelihood diversification strategies. These strategies reduce rural poverty by increasing, among other factors, local farmers' income, food security and gender inequalities. According to [29], diversifying the means of livelihood for smallholder and marginalized farmers beyond agriculture plays an important role in rural poverty alleviation. Agricultural extension services facilitate this process by strengthening the key types of livelihood capital-human, social, financial, natural and physical capital. These services enhance farmers' resilience to mitigate production threats, improve agricultural productivity and create alternative income-generating opportunities, thereby contributing to rural poverty reduction (Fig. 2).

Agricultural extension and rural poverty reduction: Advancing on-farm and nonfarm diversification strategies On-farm diversification strategies

This section synthesizes evidence to demonstrate how agricultural extension services play a crucial role in promoting innovative programs that reduce rural poverty through on-farm diversification strategies (Fig. 2). First, agricultural extension initiatives such as Farmer Field Schools (FFS) serve as platforms for knowledge transfer, skills development and capacity building, thereby strengthening human capital. Increased human capital empowers farmers to gain confidence in their farming activities, adopt innovative practices and become more motivated to diversify their on-farm strategies [48].

Through the acquisition of technical knowledge, critical thinking, and innovative skills, rural farmers are better positioned to integrate practices such as mixed cropping and crop-livestock systems, which mitigate



Fig. 2 The contribution of livelihood diversification to poverty reduction

the risks associated with agricultural failure. On-farm diversification strategies have been shown to stabilize yield variability and improve farmer incomes [39]. For example, studies on FFS have revealed that participating farmers demonstrate improved decision-making abilities, resilience and experimentation, all of which contribute to high yields and income stability [48, 49].

An illustrative example is the adoption of intercropping cereals with legumes while simultaneously rearing livestock on the same piece of land. This strategy provides smallholder farmers with a fallback option when one enterprise fails, thereby enhancing income stability [50]. Similarly, diversified on-farm systems in India are associated with higher aggregate net earnings than traditional farming systems [51]. These findings underscore the benefits of agricultural extension services in facilitating rural poverty alleviation.

Despite the evidence of positive outcomes, we did not find quantitative studies directly linking the enhancement of human capital through agricultural extension to rural poverty reduction. This could be attributed to the fact that available studies on agricultural extension do not report on the effects on human capital beyond knowledge [48]. This gap calls for future research to quantitatively evaluate the impact of human capital promoted by agricultural extension systems on alleviating poverty in rural areas.

Furthermore, agricultural extension services promote programs that provide access to essential physical capital such as fertilizers, improved seeds, and farm machinery, enabling smallholders to diversify their on-farm systems. Programs such as agricultural subsidies and farmer support schemes in India, Kenya, and Malawi have empowered smallholder farmers to expand the range of crops cultivated and livestock breeds reared. These programs provide tax exemptions, free provisions of agricultural inputs, and price subsidies, making these assets affordable for rural farmers. Past studies have shown that agricultural input subsidies have improved farmers' capacity to expand the number of crops and livestock species to produce, thereby increasing their resilience to market and climatic shocks. Farmers who accessed subsidized inputs experienced between 25% and 30% increases in crop diversification, thereby contributing to stable income and poverty reduction stability [51-54].

Nevertheless, large-scale programs promoted through agricultural services such as the National River Linking Project (NRLP) in India, the Climate-Smart Agriculture and Water Management Project in Bangladesh and the International Development Enterprises (iDE) in Kenya have facilitated access to irrigation infrastructure. These irrigation programs have enabled farmers to diversify their on-farm activities, improve farm productivity and generate surpluses for sale, thereby improving household incomes and living conditions. For example, smallholders in India with access to agricultural extension-supported irrigation services increased their cultivation of high-value crops by 39% to 50%, lifting many out of poverty [55].

However, the contribution of agricultural extensionsupported initiatives is not uniformly positive. Policies such as minimum support prices and crop-specific subsidies for staples such as rice and maize in Asia and Africa have driven commodity specialization, thus limiting on-farm diversification opportunities [53, 56]. Additionally, overreliance on subsidized agrochemicals has been reported to reduce farmers' willingness to adopt sustainable agricultural activities [57]. Furthermore, the contribution of agricultural input subsidies in directly alleviating rural poverty is underexplored, with few studies providing conclusive evidence of their broader economic impacts. These findings suggest that agricultural extension services should adopt an integrated approach to strike a balance between promoting targeted interventions and diversified farming systems to effectively contribute to rural poverty reduction within the framework of sustainable livelihoods.

Nonfarm diversification strategies

Nonfarm diversification opportunities offer alternative income-generating sources to farming families. These opportunities are important, especially in rural areas where agricultural productivity is constrained by land inadequacy, declining soil fertility and climate variability [58]. By advancing the transition from full-time agriculture to part-time agriculture, extension services facilitate the integration of rural families into nonfarm activities such as trading, handcrafting, casual daily labor, local beer brewing, fish processing, pottery, retailing and vending. This strategy helps not only absorb rural labor into service industries but also contributes to a reduction in rural poverty indices [41].

Digitally driven extension services such as DigiFarm in Kenya have facilitated access to financial capital, including loans and savings, enhancing rural farmers' capacity to diversify into nonfarm acclivities. Empirical evidence shows that rural families with access to credit but with limited landholdings are more likely to transition into nonfarm opportunities, except in cases of wage-based employment [59]. This is because financially stable farmers are better positioned to invest in risky but higherreturn ventures, thereby expanding income-generating activities.

For example, previous studies revealed that access to financial capital has empowered farmers to increase their diversification strategies by 53%, leading to a decline in poverty from 71.35% to 67.92% [60]. Furthermore, empirical evidence indicates that families who diversify

into nonfarm activities are well adapted to mitigate the adverse effects of climate variability and policy changes [9, 61].

Despite the above contribution of agricultural extension services to rural poverty reduction, challenges such as inadequate nonfarm employment opportunities in rural areas continue to persist. This has prompted many rural families to migrate to urban centers in search of income, only to return during farming seasons, hence leading to unstable livelihood diversification behavior [62]. Moreover, urban centers have a limited capacity to absorb rural migrants. For example, in Ethiopia, Hawassa city recorded an urban unemployment rate of 29% [30]. These findings underscore the need for extension services to intensify the implementation of programs that generate on-farm and nonfarm employment opportunities in rural areas as part of long-term strategies for livelihood diversification.

Case studies of successful livelihood diversification programs in the selected countries in the Global South

Figure 3 shows the selected countries in the Global South that have successfully implemented livelihood diversification programs. First, Ghana, a country in West Africa, has undertaken several initiatives promoted through its agricultural extension sector to overcome food insecurity and poverty challenges in rural areas. Conversely, [63], conducted a study in the Upper East region of Ghana using sustainable livelihood frameworks to assess the impact of such programs. The study sampled 419 rural families who had been empowered through access to credit facilities, market-oriented strategies and improved rural infrastructure. The findings indicated that 73% of the farmers diversified into nonfarm activities. This suggests that on-farm opportunities are crucial in supporting livelihood diversification strategies and reducing rural poverty in the Global South.

In Uganda, 'The landscape and revenue diversification project,' in partnership with rural farmers and other stakeholders, has promoted the integration of coffee cultivation into agroforestry systems. To date, this initiative has created over 2,500 jobs for youth and supplied subsidized agro-inputs to more than 600 coffee farmers, enhancing their capacity to adapt to the adverse effects of climate change while ensuring economic benefits from coffee sales [64]. The findings from this successful program underscore the importance of collaborative networks within agricultural extension services in promoting both social capital and human capital, which are essential for livelihood diversification and poverty reduction in rural areas.

Similarly, in Kenya, several on-farm and nonfarm livelihood diversification programs have been undertaken to



Fig. 3 Selected countries in the Global South implementing successful livelihood diversification programs

improve farmers' welfare through enhanced productivity and income stability. On the basis of the sustainable livelihood framework, a study was carried out, and data were collected from 409 farming families residing near the Maasai Mara National Reserve. The findings revealed that these families have adopted four distinct livelihood diversification strategies, with varying determinants for strategy. Notably, adopting a joint strategy of livestock breeding and off-farm activities resulted in an increase in per capita income ranging from 38.1% to 80%, with significance levels of (p < 0.05) and (p < 0.01), reflecting its contribution to poverty reduction [65]. These findings underscore the importance of agricultural extension services that integrate on-farm and nonfarm opportunities in rural areas to reduce dependence on natural resources.

Nonetheless, in Bangladesh, the agricultural extension sector has implemented programs that aim at advancing farm and nonfarm opportunities in rural areas. Following their implementation, a study was conducted to evaluate the impact of nonfarm diversification strategies on livelihood outcomes by comparing farming families that engaged in nonfarm activities with those that did not. A total of 153 rural families were sampled. The study revealed that these families increased their production by 36.5% compared with families that did not participate in nonfarm activities [66]. This means that nonfarm activities generate additional resources that can be channeled to farm production and poverty reduction.

Conclusions

The above findings demonstrate the vital role that agricultural extension services play in alleviating rural poverty and supporting livelihood diversification strategies. By facilitating skill development, knowledge sharing, and access to financial services, natural resources and physical assets, many rural farmers have been empowered to adopt diverse livelihood strategies and reduce rural poverty indices. For example, partnerships between extension service providers and financial institutions have increased access to microcredit, thus enabling rural families to invest in both farm and nonfarm activities. Moreover, digitally driven extension services such as DigiFarm in Kenya have contributed to an increase in women's participation in both on-farm and nonfarm activities.

Despite the above outcomes, challenges continue to persist that hinder the ability of agricultural extension services to successfully promote sustainable livelihood diversification and catalyze rural transformation and poverty alleviation. These challenges include insufficient gender-responsive training programs, inadequate financial resources and insufficient nonfarm employment opportunities for rural families in the Global South. Therefore, this study recommends short-term policies that focus on expanding partnerships between agricultural extension services and financial institutions to improve access to microcredit and leverage digital extension platforms to deliver targeted training and support to women and youth. Long-term policies should prioritize integrated approaches that link both farm and nonfarm opportunities with financial literacy programs, access to physical and natural assets, and

gender-responsive capacity-building initiatives tailored to the needs of rural communities.

Abbreviations

- NGO Non-governmental Organizations
- ICT Information Communication Technology
- PES Private extension service provider
- FFBS Farmer Field and Business Schools
- PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Supplementary Information

The online version contains supplementary material available at https://doi. org/10.1186/s44399-025-00005-x.

Supplementary Material 1.

Authors' contributions

W.O -Formal analysis, investigator, conceptualization I. B- Investigator, Formal Analysis.

Funding

Not applicable.

Data availability

Data available on request.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication

Not applicable as the manuscript does not contain data from any individual person. All authors have read and approved the work.

Competing interests

The authors declare no competing interests.

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Received: 15 December 2024 Accepted: 27 March 2025 Published online: 01 May 2025

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