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Extension models in sustainable agriculture adoption in South Asia and sub-Saharan Africa

Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, we rigorously analysed the characteristics, strengths, and limitations of various extension models, including Fee-for-Service, Farmer Field Schools, Training and Visit, and Farmer-to-Farmer approaches. This review identifies persistent barriers to the widespread adoption of sustainable agricultural practices, such as limited access to resources, inadequate training, and the lack of tailored solutions for diverse farming contexts, which stem from the inherent limitations of conventional agricultural extension models. We also discuss a hybrid approach that integrates conventional and emerging participatory, demand-driven models, customised for smallholder farmers' unique needs and constraints. This integrative strategy is suggested to enhance the dissemination and adoption of sustainable agricultural practices, thereby contributing to sustainable development and food security in South Asia and sub-Saharan Africa. We emphasise the need to leverage the complementary strengths of diverse extension models to address existing challenges and drive effective policy interventions.

Significance:

- Our findings will assist policymakers and practitioners to prioritise the development of agricultural extension strategies that are economically viable and tailored to the specific needs and constraints of smallholder farmers.
- We aim to help foster greater engagement from policymakers, enhance communication channels, and implement robust feedback mechanisms to ensure that agricultural extension services are responsive and adaptable.

Introduction

Agricultural development is essential for sustainable development and reducing poverty in South Asia and sub-Saharan Africa.[1,2] Agricultural extension services are crucial for spreading technological advancements and tackling the challenges that farmers encounter at the local level.[3,4] Despite their significance, smallholder farmers in these regions often face substantial barriers, including limited access to critical knowledge, information, and resources to improve their agricultural practices and achieve agricultural progress. Effective extension models are crucial for successfully disseminating sustainable agricultural practices (SAPs) to farmers. Sustainable agriculture is the viable management of available agricultural resources aimed at meeting increasingly complex human needs whilst restoring the integrity of the environment; enhancing the social and economic settings of farmers, their employees, and local communities; safeguarding farmers' well-being and health; and conserving renewable natural resources.[5]

The concept of sustainable agriculture, also known as agricultural sustainability, is often categorised into three pillars: economic, social, and environmental. In practice, it constitutes one of the strategies for improving the sustainability of the farming system through the adoption of various SAPs, such as soil and water conservation technologies, terraces, agroforestry, climate-smart agriculture, organic farming, climate-resilient technologies, and conservation agriculture. However, smallholder farmers in rural areas of developing countries frequently encounter difficulties in accessing SAPs.[6] To sustain their livelihoods, these farmers need a diverse range of reliable and precise information, as agricultural advancement depends on the ability to generate, share, and utilise knowledge effectively.[7,8]

Providing effective and efficient agricultural extension services remains a complex challenge, particularly for smallholder farmers. Information on knowledge-intensive SAPs in South Asia, according to Ali[9], and in sub-Saharan Africa, according to Davis[10], is provided by publicly financed agricultural extension services, which have historically struggled to cope with the changing demands of smallholder farmers. Extension programmes in rural communities serve a significant role in interfacing farmers with other stakeholders in the rural development agenda.[11] Information is transmitted by employing either conventional or traditional extension models. The fundamental distinction between conventional extension models and traditional extension models is their methodology and efficacy in supporting farmers. Conventional extension models, such as Training and Visit (T&V), are predominantly distinguished by top-down, information-driven techniques that emphasise disseminating technology and knowledge to farmers with little emphasis on interactive learning.[1,12,13] In contrast, traditional extension models, such as Farmer Field Schools (FFS), are primarily bottom-up, community-driven, and participatory techniques, focusing on indigenous knowledge and practices, fostering an integrative approach to agricultural development.[1,10,12,14] Nevertheless, the efficiency of these models may vary depending on the region's level of development, with T&V likely being more appropriate for less developed regions and FFS for more established agricultural regions.[12,15] The assessment of conventional extension models alongside FFS is imperative because it underscores the potential benefits of participatory techniques in agricultural extension. The comprehension of the viability of FFS in comparison to conventional models assists in generating extension systems that are more resilient and better tailored to the distinctive demands of agricultural communities.

Notwithstanding the recognised benefits of SAPs and significant efforts by national and international organisations to promote their adoption, uptake remains low in rural areas[16-19] and low adoption rates are primarily because of

gaps in farmers' knowledge[19,20]. The slow adoption of SAPs has raised concerns about the effectiveness of existing agricultural extension models, which have sometimes led to suboptimal outcomes.[21,22] The knowledge gaps in agricultural practices translate to yield discrepancies.[12] Hence, a large proportion of smallholder farmers in South Asia and sub-Saharan Africa frequently utilise substandard practices in agriculture owing to a lack of awareness, expertise, and management.[23] This review specifically examines the factors that influence the adoption of SAPs and the effectiveness of conventional extension models in promoting SAPs in South Asia and sub-Saharan Africa, and evaluates their strengths, weaknesses, and the overall impact of the models on the adoption rates of SAPs amongst smallholder farmers.

Materials and methods

We conducted a thorough literature analysis to examine the primary obstacles to the diffusion and adoption of SAPs amongst smallholder farmers in South Asia and sub-Saharan Africa in the context of four frequently utilised agricultural extension models: ((1) Fee-for-Service, (2) Farmer Field Schools (FFS), (3) Training and Visit (T&V), and (4) Farmer-to-Farmer Extension (F2FE)). A systematic review aims to examine empirical evidence by extracting quantitative and qualitative aspects from original research.[24,25] The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method, in contrast to the traditional review, adopts well-defined protocols.[25] The method has been utilised in several disciplines[24,26], including agricultural research[25]. We employed a four-phase flow diagram to conduct a systematic review, which included identifying studies, screening studies, examining study eligibility, and selecting studies for inclusion (Figure 1).

Literature search strategy

The articles reviewed in this study were identified through searches done on Springer, Scopus, Web of Science, Science Direct, PubMed, and Google Scholar. The keywords utilised in the search for literature were based on those from previously published empirical studies: such as "Sustainable Agricultural Practices", "agricultural extension models", "public extension system", "transfer of technology", "adoption" and "innovation diffusion models in agriculture".

Inclusion criteria

A total of 750 articles were identified through the literature search. After the exclusion of duplicates, titles, abstracts, and full-text screening, a total of 46 studies were considered relevant and thus were included in this study (Figure 1). The following criteria were used to choose papers: (1) empirical research articles and conference proceedings; (2) studies published in English; (3) studies on the types of SAPs (soil and water conservation technologies, terraces, agroforestry, climate-smart agriculture, organic farming, climate-resilient technologies, and conservation agriculture) practised by smallholder farmers and the adoption rates in South Asia and sub-Saharan Africa; (4) studies focusing on factors influencing the adoption of SAPs; and (5) articles highlighting the utilisation of conventional agricultural extension models (Fee-for-Service, FFS, T&V, and Farmer-to-Farmer Extension) in South Asia and sub-Saharan Africa and their impact. The adoption rate of SAP indicators (low, tardy, medium, and abandonment), as revealed in the reviewed literature, was employed in this study to assess the impact of the extension models in the regions under review.

Exclusion criteria and study delimitation

Articles that were not accessible in full text or not published in English were excluded to avoid translation complexity. Furthermore, studies that focused on locations other than South Asia and sub-Saharan Africa, as well as non-conventional agricultural extension models, were excluded. Based on accessible literature on SAPs, the study included the following sub-Saharan Africa countries: Nigeria, Tanzania, Rwanda, Democratic Republic of the Congo, Mozambique, Ethiopia, Zambia, Cameroon, Zimbabwe, Kenya, Malawi, Gambia, Niger, Togo, Uganda, and Namibia.

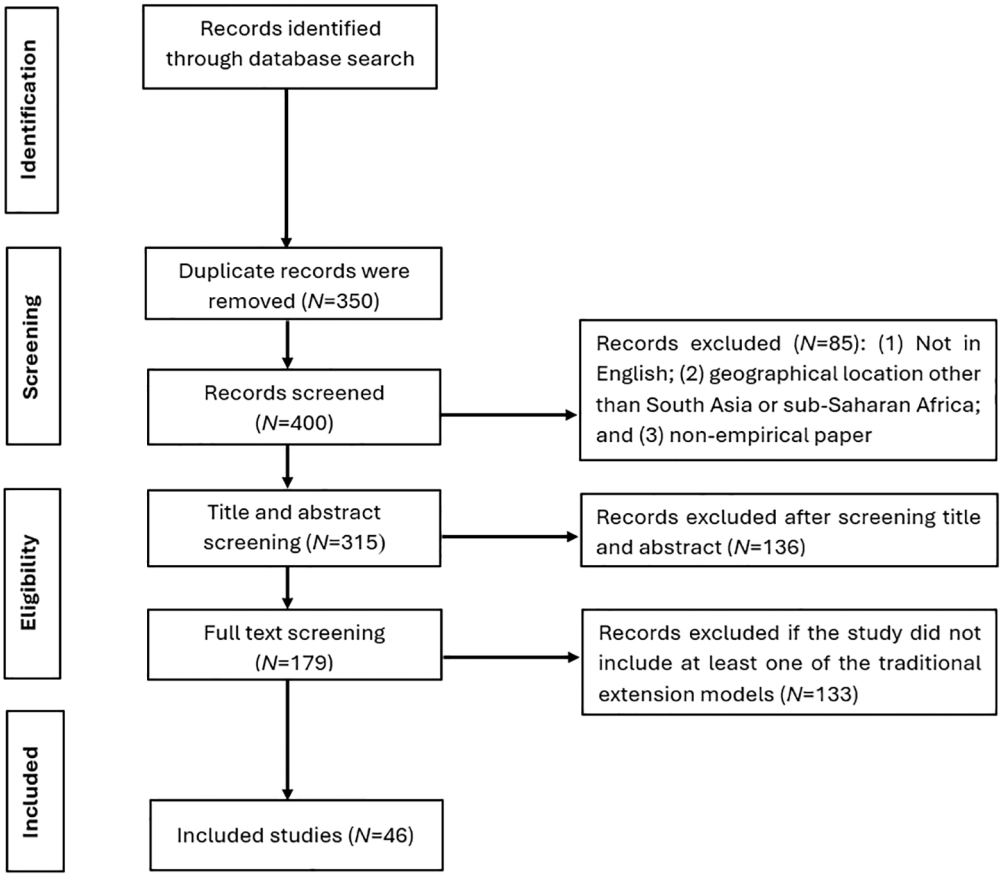

Figure 1: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart.

Bangladesh, India, Nepal, and Pakistan were the countries included in this study from South Asia. Conversely, the study's publication years span 1997 through 2023.

Limitations of the study

By limiting the review to English language studies, significant findings published in other languages, particularly from locations where the question under study is likely to be extremely relevant, were omitted. This exclusion could translate to a cultural bias, with non-English-speaking countries' viewpoints, concerns, and interventions being underutilised. Consequently, the study's findings may not adequately depict the broad spectrum of information available, thereby restricting the findings' generalisability and feasibility, particularly in non-English-speaking countries.

Data analysis

The data utilised in this study were analysed using an exploratory thematic analysis. This anaysis enabled us to synthesise existing literature by identifying and analysing recurring themes or trends amongst SAP studies. Thematic analysis aided in analysing the impacts of various extension models, resulting in a more nuanced and thorough assessment of the existing body of knowledge. Furthermore, as demonstrated in Figure 2, a word cloud analysis enhanced our ability to extract and analyse significant factors that influence the adoption of SAPs amongst smallholder farmers.

Results and discussions

Factors influencing the adoption of SAPs

Given an array of factors that influence the adoption of various combinations of SAPs, policymakers should examine numerous factors when utilising extension models for smallholder farmers to adopt multiple SAPs to ensure that farmers can optimise the benefits of SAPs. A word cloud (Figure 2) was generated to graphically illustrate factors and concepts in the data set influencing adoption of SAPs amongst smallholder farmers in South Asia and sub-Saharan Africa. This visual tool and the reviewed literature effectively aided in summarising and categorising 22 factors that influence the adoption of SAPs, as depicted in Table 1. The factors were classified into five categories: (1) socio-economic, (2) bio-physical, (3) institutional, (4) financial, and (5) technical.

Socio-economic factors

Income, gender, household size, farmers' experience, and age are positively and significantly correlated with smallholder farmers' adoption of SAPs.[11,19,27,28] According to the findings of Ali[9] and Arslan et al.[29], education, income, labour availability, and household wealth play a significant part in explaining the adoption of SAPs. Reviewed literature revealed that young farmers are more likely to adopt new technology than older farmers because they are risk-takers and have more years of education. On the other hand, education enhances farmers' ability to access, comprehend, and use technology-related information, resulting in increased adoption and sustainability of new technologies.[30] Additionally, it is evident from the reviewed literature that education and the adoption of SAPs are positively correlated. Based on the type of SAPs, household size has been noted as a determinant in households' adoption decisions (Table 1).

Bio-physical factors

SAPs as depicted in Table 1 are frequently site-specific strategies that are determined by a region's geography and bio-physical conditions. This implies that bio-physical parameters have a substantial impact on its adoption. Previous studies found characteristics such as household location, agro-ecological zone, and distance from the nearest town or market as crucial and statistically significant in influencing the adoption of SAPs.[19,27,31] Locational parameters influence adoption decisions.[30] The distance between farms and markets inhibits the adoption of SAPs in developing countries. The adoption rate of SAPs decreases as the distance between the farm and the nearest market increases. Furthermore, in terms of location, Pedzisa et al.[30] revealed that agro-ecology has a significant impact on yield and is a primary factor that influences the adoption of SAPs and prolonged use. Farmers in Zambia's drier regions, for example, adopted conservation agriculture for its water conservation features.[20,29]

Institutional factors

Membership in a farmers' group, as well as information and technical advice provided in various training programmes, positively and significantly influences the adoption of SAPs.[11,19,27,28] Extension visits coupled with access to input support from non-governmental organisations (NGOs), land tenure stability, and training are all anticipated to have an impact on the adoption of SAPs.[28,30,31] Pedzisa et al.[30] underscore that extension

Figure 2: A word cloud depicting factors influencing the adoption of sustainable agricultural practices amongst smallholder farmers.

Table 1: Categorisation of factors influencing the adoption of sustainable agricultural practices

Socio-economic factors	Financial factors	Bio-physical factors	Technical factors	Institutional factors
Education	Incentives	Distance to markets	Access to knowledge	Extension services
Age	Credit facilities	Location	Access to information	Training
Gender		Agro-ecology	Access to technology	Farmers' associations
Household size		Farmland size		Land tenure
Transportation of manure				
Family labour availability				
Income				
Household wealth status				
Farming experience				

furnishes farmers with information about the availability and attributes of new technology as well as technical skills for implementing it. According to recently reviewed studies, farmers (both from South Asia and sub-Saharan Africa) who regularly interact with the extension programme, whether through government and NGOs or farmer to farmer, have an optimistic influence on adoption.

Financial factors

The adoption of SAPs, or any technological innovation, necessitates adequate monetary assistance and access to incentives (Table 1). Lack of accessibility to credit is an enormous obstacle to the adoption of SAPs.[28,29] For example, credit-constrained farmers may be less inclined to adopt SAPs that need monetary expenditures, such as fertiliser and seed varieties, than SAPs that do not, such as manure or crop rotation.[33] The high levels of SAP abandonment are statistically consistent with anecdotal evidence from Zambia, which shows that most "adoption" was based on the anticipation of receiving free inputs, and that after these incentives were no longer given, abandonment occurred.[20,29] Therefore, access to credit and incentives through institutional or non-institutional sources is critical to the adoption of SAPs.

Technical factors

The technological adoption of ecologically sound agricultural development is a complex subject. Farmers have constantly sought new technologies to lower costs whilst increasing profits or production. The adoption of innovative strategies to improve agricultural sustainability is always dependent on farmers' knowledge and skills.[20] Farmers with easy access to knowledge and advanced technology are highly encouraged to adopt SAPs. Farmers who adopt new technologies and practices generally rely on certain information sources prior to adoption; their decision is influenced by a preference for one source over another or merely a lack of easy access to alternative sources.[32] It is therefore imperative to determine which information sources tend to be more effective in prompting adoption.

In line with the aforementioned factors that influence the adoption of SAPs amongst smallholder farmers as illustrated in Table 1, this review delved further into institutional factors, particularly those relating to agricultural extension models.

Conventional agricultural extension models

Fee-for-Service extension models

Private sectors provide the Fee-for-Service extension model, in which farmers pay for extension services to make services more accessible. Generally, farmers hire extension workers to provide particular information and services.[34-36]

Pros of the model

This model provides current and relevant information to the farmers by establishing a demand-driven extension service platform that is economical, reliable, and outstanding.[34] According to studies conducted in Tanzania by Shausi et al.[37], Bangladesh by Ogunmodede et al.[38], and Nepal by Paudel et al.[39], farmers were eager to pay for agricultural extension services. In Zimbabwe, requiring payment for extension services ensured that these services were delivered to farmers who were genuinely interested in acquiring knowledge and implementing the practices.[40]

Cons of the model

Research conducted in Zimbabwe by Foti et al.[40], as well as in Rwanda and Zambia by Ogunmodede et al.[38], found that farmers had a very low interest in Fee-for-Service extension. Additionally, most governments in developing countries tend to oversupply free but ineffective extension services, leading to a lack of willingness, especially amongst smallholder farmers, to pay for commercial extension services.[40] Additionally, smallholder farmers are unable to hire services because of their low incomes.[10,22,36] This model is more capitalistic, favouring wealthy farmers over others who cannot afford to pay for services. The majority of the farmers targeted for the adoption of SAPs are smallholders who are still battling with breaking the poverty cycle and are unable to pay for extension services, hence impeding the practices' adoption and diffusion.

Farmer Field Schools

The FFS agricultural extension model emerged during the rice monocropping agricultural era. In the 1980s, Indonesia and the Philippines implemented this approach to spread knowledge-intensive integrated pest management.[12,34] FFS are unstructured schools within the farmers' neighbourhood, schools without a building, and with community-driven training in which a similarly minded group of 20–25 neighbouring farmers meets regularly with instructors amidst the crop and animal cycles.[11,14,34,41] Farmers are encouraged to undertake independent research, identify and investigate challenges, and develop solutions.

Pros of the model

The success of FFS in Nigeria is because of farmers' engagement in identifying their challenges, deciding, testing, and assessing potential solutions.[15] Programmes under FFS encourage cost sharing to maintain sustainability as well as promote a sense of ownership and responsibility.[10] The earlier study suggests that the FFS model should be prioritised to enhance the dissemination of SAPs aimed at enhancing average crop yields and improving the well-being of farming communities.[42] When appropriately integrated, FFS has been found to strengthen supply chain actors, farmers, and agribusiness champions' behaviour related to climate change adaptation at a lower training cost.[43,44]

Cons of the model

A myriad of obstacles (Table 2) impedes the implementation of FFS in South Asia and sub-Saharan Africa, notably insufficient exposure of staff to FFS tenets and operations, gender disparities, and a low level of engagement of policymakers.[11,13,36,45] In Nigeria, the model's sustainability

without outside financial backing was a significant obstacle.[15] Farmers who complete the FFS have been reported to have little success in disseminating the innovations amongst their neighbours.[46] This implies that the strategies for instruction and curriculum need to be rethought to make an impact on the intended users of the innovations being propagated.

Training and Visit Model

The T&V extension model has been extensively used as the main technology transfer approach in sub-Saharan Africa and South Asia.[14] The model was envisioned to develop a group of extension experts competent in steering farmers towards increasing productivity and revenue through ideal, viable, and reliable planning.[10,13,34,47]

Pros of the model

The T&V model was remarkably successful and effective in disseminating Green Revolution technologies in irrigated areas of Asia, particularly India, where farming systems are more homogeneous.[12,34,46-48] Furthermore, the T&V model promotes very specific packages and supports farmers to increase production and household incomes.[10] According to Davis[10], the T&V model improved linkages with research because of its top-down implementation

Table 2: Comparative analysis of conventional extension models employed in South Asia and sub-Saharan Africa

Model	Characteristics	Strengths	Weaknesses	Countries employing the model	Selected references
Fee-for-Service	Demand-driven model	Farmers pay for the service Farmers contract extension officers Cost-effective High-quality services	Failure by farmers to pay for the services	Tanzania Bangladesh Nepal Rwanda Zambia	Davis[10] Foti et al.[40] Shausi et al.[37] Ogunmodede et al.[38] Paudel et al.[39] Brown et al.[22] Brown et al.[35]
Farmer Field Schools	Demand-driven model	Discovery learning Direct links between farmers and scientists Critical thinking and creativity Cost sharing High levels of ownership Intensive training Participatory Democratic Client centred Community-based learning	Extension staff are not adequately exposed Lack of coordination at national level Gender disparities Low degree of engagement and collaboration with policymakers Financially unsustainable	India Pakistan Kenya Nigeria DRC Gambia Niger Cameroon Togo Uganda Namibia Tanzania Zimbabwe	Anandajayasekeram et al.[13] Davis[10] Ferroni and Zhou[12] Abdullah et al.[42] Ajani and Onwubuya[15] Cipriano et al.[21] Maulu et al.[11] Mapiye et al.[14]
Training and Visit	Supply-driven model	Increased geographical coverage Improved linkages with research Promotes very specific packages Aids farmers to enhance output and income Extension officers are knowledgeable and updated	Lacks appropriate feedback mechanisms Financially unsustainable Extension agents lack communication skills Too rigid and costly One-way information flow Farmers are passive Too hierarchical Gender insensitive	Kenya Rwanda Ethiopia Cameroon Nigeria Mozambique India Nepal Zambia Tanzania	Anandajayasekeram et al.[13] Cunguara and Moder[47] Davis[10] Ferroni and Zhou[12] Ekumankama and Anyanwu[50] Dhital[1] Mitti et al.[51] van den Ban and Mkwawa[53] Maulu et al.[11] Mapiye et al.[14] Buehren et al.[49] Taye[48]

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Model	Characteristics	Strengths	Weaknesses	Countries employing the model	Selected references
Farmer-to-Farmer Extension	Demand-driven model	Model farmers train and share local information Low cost and effective Wide coverage Improved sustainability and accountability Inclusive of marginalised farmers Farmers are active High credibility Harness indigenous leadership Participatory Principle of voluntarism Enhanced feedback mechanisms from farmers to extension officers	Model farmers lack communication skills Conflicts between lead farmers and their followers Bias in selecting model farmers Gender imbalance Inadequate backing from local institutions Absence of relevant training resources Limited technical expertise amongst farmers High expectations from farmers regarding financial and non-financial rewards High dropout rates amongst participants	Ethiopia Zambia Kenya Nepal Zimbabwe Pakistan Rwanda India Malawi Uganda Bangladesh Cameroon DRC Mozambique	Hailemichael and Haug[54] Kiptot and Franzel[56] Scarborough et al.[55] Simpson et al.[57] Habanyati et al.[20] Tessema et al.[65] Kiptot et al.[59] Kumar Shrestha[63] Dube[69] Baloch and Thapa[67] Sah et al.[62] Cipriano et al.[21] Brown et al.[22] Maulu et al.[11] Kansiime et al.[58] Meena et al.[61] Meena et al.[60] Fisher et al.[64] Chaudhary et al.[66] Martini et al.[43]

strategies and increased geographical coverage, particularly in locations where extension officers were readily available (Table 2).

Cons of the model

Although the T&V model enhanced linkages with research by promoting highly specialised packages, studies revealed that it is unreliable, ineffective, devoid of equity, financially untenable, and ultimately led to many countries being burdened with insurmountable levels of debt.[13,34] In India, the withdrawal of the World Bank culminated in long-term financial commitments for state governments.[46] In Ethiopia, Kenya, Rwanda, Côte d'Ivoire, Cameroon, and Nigeria, the communication system between contact farmers and the rest of the community did not operate as intended; the model was eventually declared unsatisfactory.[10,13,46,49,50]

Studies in India by Ferroni and Zhou[12] and Zambia by Mitti et al.[51] contend that, as a supply-driven system, the T&V model supported ideas developed by researchers, with minimal input from farmers, and genuine technology adopters. Furthermore, it has been argued that in Nepal the model primarily focused on production, neglecting postharvest and agribusiness operations, such as value addition, credit, and marketing; frequent monitoring; and communication infrastructure.[1] In Zambia, as highlighted by Mitti et al.[51], the model was expensive to operate, inflexible, lacking appropriate feedback mechanisms, gender insensitive, and personnel tended to lack focus. Overall, it is concluded that the T&V model did not fulfil its promises and expectations.[12,52] However, the T&V approach could be more effective in Tanzania if it were more participative and demand-driven.[53]

Farmer-to-Farmer Extension Model

Farmer-to-Farmer Extension (F2FE) is based on the principle of voluntarism, often through establishing a network of farmer promoters and trainers, who are expected to educate and share information with other farmers.[54-58] Studies conducted in the Democratic Republic of Congo and Mozambique by Cipriano et al.[21] and in Rwanda by Kiptot et al.[59] found that, under F2FE, volunteer farmers are recruited, trained, and then mentored by other farmers on improved agricultural practices. Depending on the location, farmer trainers are often known as lead, innovative, volunteer, master, model, or community knowledge workers.[11,20,55-57,60] The F2FE model's popularity was influenced by flaws identified in previous models, such as the engagement of contact farmers in the T&V model.[56] The F2FE model is prominent for extension and advisory services in sub-Saharan Africa.[57]

Pros of the model

When the fundamental principles for extension delivery are upheld, F2FE is an effective model.[43,54,56,61] The F2FE has proved to be more viable in regions with strong social assets, minimal social strata, and strong community confidence.[54,56,62] Studies highlighted that the F2FE model was cost-effective, had improved the accountability of the local government to the farmers, and enabled marginalised communities who are frequently excluded from mainstream assistance to have greater access to extension services.[63,64] In Ethiopia, F2FE was more valuable in farmers' adoption of SAPs and advocated for the continued use of model farmers in innovation dissemination.[65] Model farmers, on the other hand, associate the benefits of their role with an enhanced reputation, personal fulfilment, and the opportunity to receive various incentives.[20,54,56,57]

Cons of the model

The F2FE model has been proven to be ineffective when model farmers are chosen only on their abilities, without considering their capacity to communicate and transfer their knowledge to others.[22,54,56,62,66] Additionally, a study conducted in Pakistan by Baloch and Thapa[67] found that an insufficient number of field-based extension workers, each responsible for 2000–2400 households, proved ineffective despite the workers being well equipped with the necessary knowledge. In other circumstances, as

observed in Ethiopia, follower farmers often found it difficult to confidently replicate the practices of model farmers, as technology may remain exclusive or be predominantly utilised by early adopters.[54] The lead farmers were in conflict with the farmers under their leadership owing to the incentives benefitted, ultimately prompting others to abandon or not even adopt SAPs.[20,68] Ineffective model farmer selection procedures, marginalisation of smallholder farmers, and a lack of widespread support all contribute to F2FE's failure.[54,56] The F2FE model in Nepal lacks a clear pro-poor focus on agricultural extension and decentralisation strategies.[63] As a result of some of these identified challenges, a study found that only 43% of the sampled farmers in Zimbabwe utilised the F2FE extension approach, which was below the expected target.[69]

Impact of extension models on the adoption of SAPs

The central focus of extension services is the adoption of technologies and improved practices like SAPs. In agricultural extension programmes, the acquired knowledge and information is an output, whereas the adoption of technologies is an outcome and the ultimate impact is the change in productivity.[48] The reviewed agricultural extension models have been employed to promote SAPs to farmers. The T&V and F2FE models are amongst the most dominant and frequently utilised extension models, and their degree of success varies depending on the context (Table 3 and Figure 3). The adoption rates of SAPs are predominantly classified as "Low (small proportion of farmers adopting in a given area)" in all selected nations, with occasional instances of "Low and

Table 3: Sustainable agricultural practices (SAPs) and their adoption rates

Country	SAPs	Adoption rates	Dominant extension models	Selected references
Nigeria	Improved seed varieties	Low	Farmer Field Schools Training & Visit	Oyetunde-usman et al.[19]
Tanzania	Soil and water conservation technologies	Low	Fee-for-Service Training & Visit	Tenge et al.[16]
Rwanda	Terraces	Low	Fee-for-Service Training & Visit Farmer-to-Farmer Extension	Hammond et al.[72] Nahayo et al.[28]
DRC	Conservation agriculture	Low	Farmer Field Schools	Cipriano et al.[21]
Mozambique	Conservation agriculture	Low and tardy	Training & Visit	Nkala et al.[18] Cipriano et al.[21]
Ethiopia	Organic farming	Low	Training & Visit Farmer-to-Farmer Extension	Teklewold et al.[33]
Zambia	Conservation agriculture	Abandonment	Fee-for-Service Training & Visit Farmer-to-Farmer Extension	Habanyati et al.[20] Arslan et al.[74] Ng'ombe et al.[31] Nkomoki et al.[73]
Cameroon	Agroforestry	Low	Training & Visit	Nkamleu and Manyong[27]
Pakistan	Climate-smart agriculture	Low	Farmer Field Schools Farmer-to-Farmer Extension	Mazhar et al.[70]
Nepal	Climate-resilient technologies	Medium	Fee-for-Service Farmer-to-Farmer Extension Training & Visit	Kumar et al.[32]
India	Organic farming	Medium	Farmer Field Schools Training & Visit	Singh and Sharma[77] Brown et al.[35] Chaudhary et al.[66]
Zimbabwe	Conservation agriculture	Abandonment	Fee-for-Service Farmer-to-Farmer Extension	Pedzisa et al.[30]
Kenya	Agroforestry	Low	Farmer-to-Farmer Extension Farmer Field Schools Training & Visit	Mwaura et al.[71]
Bangladesh	Organic farming	Low	Fee-for-Service	Sarker and Yoshihito[75]
Malawi	Conservation agriculture	Low	Farmer-to-Farmer Extension	Fisher et al.[64]

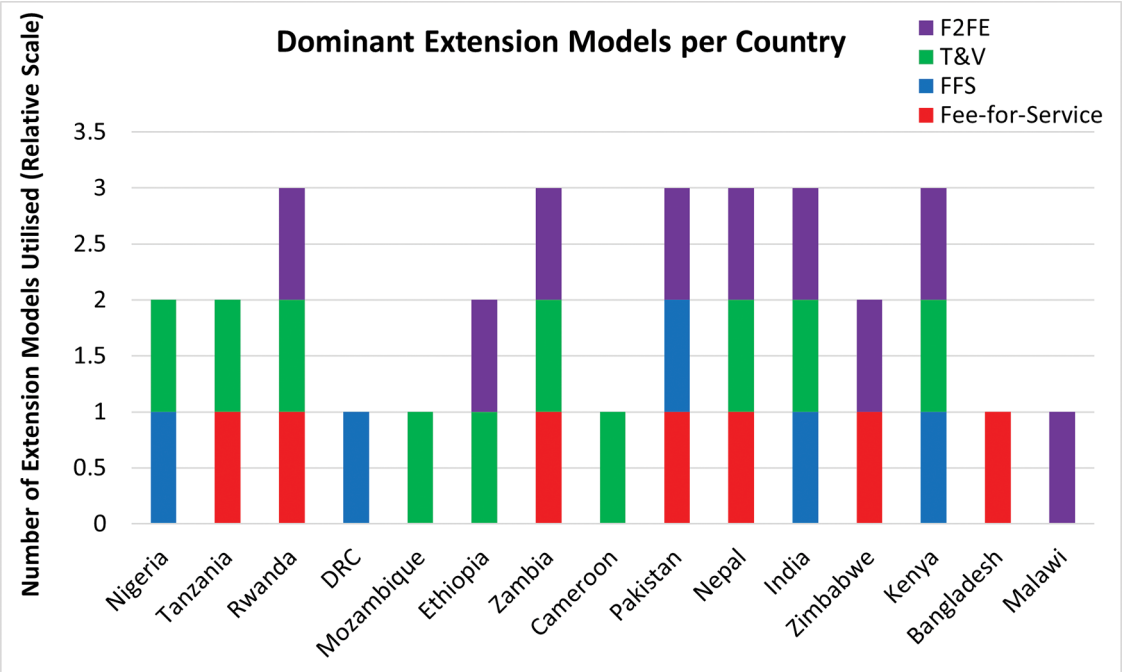

Figure 3: Dominant extension models utilised in the sampled countries: Farmer-to-Farmer Extension (F2FE), Training and Visit (T&V), Farmer Field Schools (FFS) and Fee-for-Service.

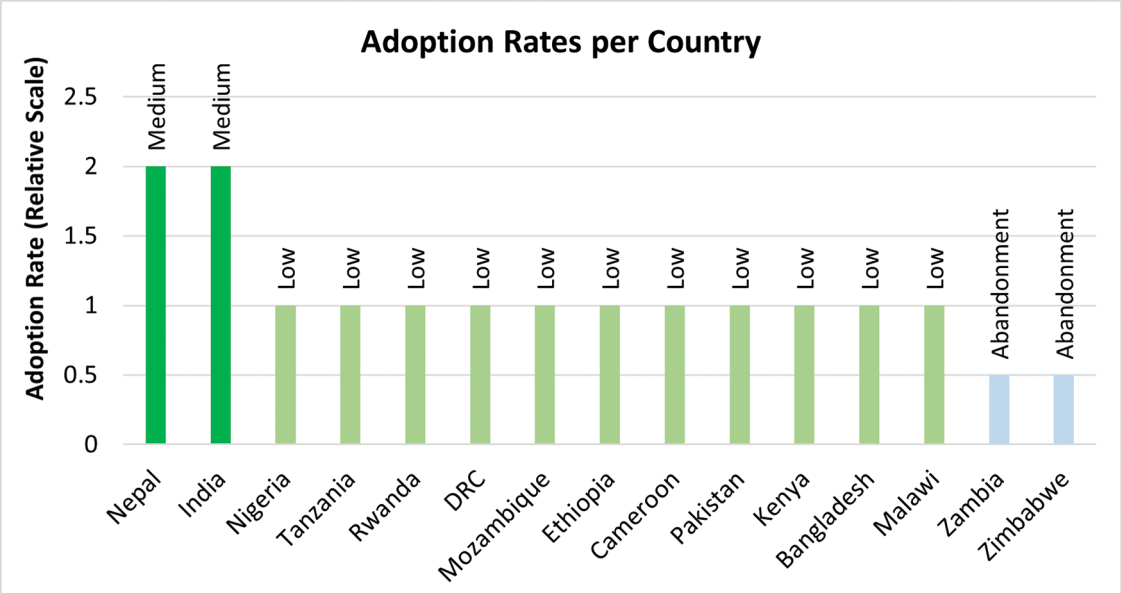

Figure 4: Adoption rates of sustainable agricultural practices per country.

tardy (delayed beyond the right or expected time)", "Medium" adoption, or "Abandonment". Notwithstanding their benefits, profound global concerns, and the desire to achieve the Sustainable Development Goals by 2030, the adoption rate and extensive utilisation of SAPs are still low in rural regions of developing countries.[17,31,33,41,68,70] The T&V model is supply-driven and enables wider geographical coverage and research links, but it has been criticised for being economically untenable, restrictive, and gender-insensitive. The T&V model, as indicated in Table 2 and Figure 3, is prominent in Nigeria, Mozambique, Ethiopia, Cameroon, Tanzania, Zambia, and Kenya, where the adoption rates of SAPs remain low with abandonment being experienced (Figure 4), most likely because of these constraints. Research in Nigeria by Oyetunde-usman et al.[19] found that despite the utilisation of the T&V model, the adoption of SAPs (improved seed varieties) was low (14%). The primary cause of low adoption of SAPs (agroforestry) in Kenya is a lack of knowledge regarding farmers' adopting behaviour towards the technique.[71] Similarly, the SAPs (agroforestry) were not widely adopted in Cameroon, where the T&V model has been in use for many years.[27]

The F2FE model is demand-driven, cost-effective, leverages local leadership, optimises sustainability, and is broadly inclusive, enabling lead farmers to train their peers in their farming zones (see Table 2). However, constraints such as bias in recruiting lead farmers, contentions between trainers and trainees, insufficient training resources, and high dropout rates thwart its impact. These shortcomings are prevalent in countries such as Ethiopia, Zambia, Kenya, Nepal, Zimbabwe, Pakistan, Malawi, and Rwanda, where F2FE is employed but adoption rates of SAPs remain low with abandonment being experienced in some countries (see Table 3 and Figure 4). Farmers in Rwanda expressed concern about the inadequate availability of extension services and practical knowledge to sustain them, resulting in low adoption rates of SAPs (terrace).[28,72] In Ethiopia, Teklewold et al.[33] noted that the adoption rates of SAPs remained lower than expected.

Although conservation agriculture holds great potential, its adoption by farmers in Malawi remains low, and some basin-based conservation agriculture abandonment has been documented.[64]

As depicted in Table 2, the Fee-for-Service model is demand-driven and efficient in influencing smallholder farmers' adoption of SAPs. However, because of the fact that it entails farmers to pay for advisory services, many smallholder farmers cannot afford it, limiting its impact. This underscores why, despite the availability of this model, the adoption of SAPs remains low in countries such as Pakistan, Bangladesh, Zambia, Rwanda, Zimbabwe, and Tanzania, as highlighted in Table 3 and Figure 4. Research conducted in Zambia revealed low adoption rates of SAPs (conservation agriculture) despite being promoted for over 15 years.[20,31,73,74] Similarly, in Tanzania, Tenge et al.[16] reported that notwithstanding the usage of T&V and Fee-for-Service model, the adoption rate of SAPs (conservation of soil and water) is low, and soil erosion persists as a threat. Regardless of the national promotion of SAPs (organic farming), the idea of SAPs was new to Bangladesh farmers, and adoption rates remained low.[75]

Unfortunately, in Zambia, despite the utilisation of the Fee-for-Service model, Habanyati et al.[20] and Arslan et al.[74] found that there were high levels of abandonment (around 95%) of SAPs amongst smallholder farmers, with anecdotal evidence indicating that most "adoption" was in anticipation of receiving free inputs and that once these incentives were no longer delivered, abandonment occurred. Pedzisa et al.[30] observed significant levels of conservation agriculture abandonment in Zimbabwe amidst the utilisation of the Fee-for-Service model, arguing that such abandonment does not occur in conventional agriculture. Brown et al.'s[22] study in Africa showed that many farmers adopt conservation agriculture because they have a mindset that they will receive some incentives to do that. But when the perceived incentives are not provided, they underperform. A significant number of respondents depended on project support to implement conservation agriculture-based sustainable intensification.[66] However, their adoption of this approach ceased when the support was withdrawn.

The FFS model emphasises discovery learning, community involvement, and farmer-led training (see Table 2). It fosters farmers to critical thinking and problem-solving. However, significant barriers exist, including financial unsustainability, gender inequality, and a lack of policy support. These oversights related to the FFS help explain the low adoption rates of SAPs, notwithstanding its widespread use in Pakistan, Kenya, Nigeria, and the Democratic Republic of the Congo (see Table 3 and Figure 4). The SAPs have been promoted through FFS in the Democratic Republic of the Congo and Mozambique, notably through conservation agriculture; nevertheless adoption rates are low.[21,22] Despite the benefits of conservation agriculture, its adoption in Mozambique has been tardy and low because of farmers' lack of vital skills, knowledge, and equipment, as well as inadequate extension services and poverty.[18]

The quest for the widespread adoption of SAPs (climate-smart agriculture) was found to be complicated in Pakistan.[70] In Nepal, Kumar et al.[32] found that the United States Agency for International Development (USAID)-led Knowledge-Based Integrated Sustainable Agriculture in Nepal (KISAN) recipient farmers adopted SAPs (climate-resilient technologies) instead of KISAN non-beneficiary farmers. SAPs (organic farming) are progressively more widespread with low-to-medium adoption and are stable in India.[2,76,77] However, smallholder farmers continue to cultivate less than 1 ha of land under SAPs.[76] Similarly, a study in Zambia by Habanyati et al.[20] revealed that smallholder farmers who had adopted conservation agriculture were cultivating tiny portions of land whilst larger portions were under conventional agriculture. This scenario is a reflection of imperfections identified in the extension models implemented in these particular countries. The research results reveal that no specific extension model is adequate on its own, and that to generate impactful adoption rates of SAPs across the selected regions, a more integrative and contextualised strategy is imperative.

Strategies to enhance adoption rates of SAPs amongst smallholder farmers

To enhance the adoption of SAPs amongst smallholder farmers, a holistic strategy is essential, addressing financial, educational, biophysical, technological, social, and institutional constraints. Governments and nonprofit development institutions ought to invest in resources and facilities to assist extension workers. This entails allocating financial resources, demonstration trials, as well as training infrastructure to enhance the efficacy and impact of extension services, which are vital in fostering both traditional and new SAPs.[30] Kumar et al.[32] emphasise that extension services should prioritise education, access to resources, financial support, interpersonal relationships, climate awareness, and tailored techniques. Education has been found to significantly impact the adoption of SAPs by improving farmers' knowledge and capacity to effectively execute new practices.[19,30]

Local agricultural communities' distinctive needs and circumstances should be taken into consideration whilst designing extension services. Extension programmes should emphasise farmer-centred capacity building by showcasing the efficacy of SAPs[10,46] through collaborative learning networks, FFS, and on-farm demonstrations. Real-time information on climate-smart practices, soil health management, and organic farming methods can also be provided via digital extension channels, including social media platforms, SMS alerts, community radio shows, and mobile applications.[9] Enhancing the involvement of women and youths in agricultural extension can also lead to greater adoption rates, guaranteeing that sustainable developments benefit all segments of the farming community. Extension services can significantly improve smallholder farming systems' viability and productivity by tackling these issues. By assisting smallholder farmers in overcoming market obstacles, financial limitations, and knowledge gaps, these extension initiatives can eventually increase the adoption rates of SAPs.

Conclusions

Our findings reveal that the adoption rates of SAPs amongst smallholder farmers are typically low across the selected countries, except for organic farming and climate-resilient practices, which exhibit medium adoption rates. This demonstrates that the extension models employed in the selected countries have not had the anticipated impact. Notwithstanding the noted shortcomings with the extension models, the T&V and the F2FE are the most dominant and extensively utilised in South Asia and sub-Saharan Africa. Models such as Fee-for-Service, FFS, T&V, and F2FE have shown variable success but often fall short of the transformative impacts in disseminating SAPs. Persistently low adoption rates and frequent abandonment of SAPs underscore the need for a more integrated and context-sensitive approach to extension services. To overcome these challenges, it is essential to combine conventional extension models with innovative, participatory, and demand-driven approaches. Enhancing the participatory nature of the FFS model by involving farmers can increase their relevance and effectiveness. Policymakers and practitioners should prioritise the development of extension strategies that are economically viable and tailored to the specific needs and constraints of smallholder farmers. This includes fostering greater engagement from policymakers, enhancing communication channels, and implementing robust feedback mechanisms to ensure that extension services are responsive and adaptable.

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Data availability

The data supporting the results of this study are available upon request to the corresponding author.

Declarations

We have no competing interests to declare. We have no AI or LLM use to declare.

Authors' contributions

E.J.H.: Conceptualisation, literature search, methodology, writing – original draft, writing – review and editing. S.P.: Conceptualisation, writing – review and editing, supervision. Both authors read and approved the final manuscript.

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