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COVID-19 and the Sustainability of Agricultural Extension Models

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ABSTRACT

Agricultural extension and advisory services in information and technology dissemination and delivery are critical in a developing country's food security and sustainability. Without extension service provision, the productivity and production smallholder farmers are experiencing would have been much lower, and current global hunger and malnutrition worse. This paper assesses the effects of COVID-19 on the sustainability of agricultural extension models/approaches for smallholder farmers in developing countries. Over 60 papers were reviewed covering 2019-2021, commencing with the disease outbreak in China. Based on characteristics and usage, the findings indicate most reviewed extension models were disrupted. No single model was entirely disbanded as the impact of COVID-19 was being felt. However, each model incorporated a digital means of communication to keep farmers and service providers in touch. There is considerable criticism around the inadequacy of these extension techniques in advancing the agenda for smallholder farming's long-term viability that needs to be addressed.

Keywords: Agricultural Extension Model, COVID-19, developing country, small holder farmers

1. INTRODUCTION

Agricultural extension systems are widely regarded as educational channels that assist farmers to increase production and living standards. It provides agricultural knowledge around farming methods and practices, inventions, and advancements. But the advent of COVID-19 created many challenges across the globe. Despite the disruptions caused by COVID-19 in world activities, the agricultural extension system remains a vital instrument for communicating information and encouraging new farming technology use among rural farmers. Extension

models are theoretic and educational vehicles that extension service providers use to relay information and technologies to farmers. To achieve this, agricultural extension acts as a solid and responsive bridge between research and the farming community. However, with the onset of COVID-19, extension systems may be criticised for failing to lift most smallholder farmers out of chronic poverty in developing countries. While previously, the blame has been attributed to climate change as the main cause of poor extension service provision.

In the current COVID-19 era, the World Health Organization (WHO) has approved measures of minimising disease spread. These health measures have negatively affected the flow of information and technologies in the extension ecosystem. More recently, these guidelines have been reinforced with mass COVID-19 vaccination to contain the disease, help open up economies and increase human interaction through face-to-face sharing of extension information: human, environment, social and economic. Furthermore, mitigating strategies enacted to address the impact of COVID-19 have created unintended consequences on the already vulnerable smallholder farmers by limiting access to information and technologies. This impact on smallholder farmers highlights the need for extension models to play a significant role in guiding farmers towards attaining Sustainable Development Goals (SDGs) by 2030 without leaving anyone behind.

COVID-19 has, therefore, exposed the sustainability of the globally used agricultural extension and advisory services. Although many extension and advisory models or approaches are used in the agricultural extension system to disseminate information and technologies to farming communities, smallholder farmers' productivity and production remain low [1] and has retreated further during COVID-19 [2]. The literature reviewed indicates that in their current state, extension models cannot withstand the impact of COVID-19. Research indicates that there is no other time in history when extension and advisory service models faced unprecedented disruption in their information and technology delivery systems than this one [3-4].

Agricultural universities and colleges charged with extension and research training closed their businesses to implement COVID-19 mitigation measures [5]. For example, Alvi et al. (2021) reported that the failure of the farmer field school in India deprived many women of extension services due to the lockdowns and quarantine systems in place [6]. Researchers found the price for agricultural inputs rose, making it difficult for farmers to invest in their production, while the market for their products shrank because many customers had no income to buy farm products [7].

COVID-19 has negatively impacted all known extension models to the extent that they partially transitioned to digitalization to survive [8]. However, with the incorporation of electronic extension or digital services into the mainstream of most extension models, one wonders if this COVID-19 disruption is sustainable or temporal. Even though the acceleration of digital incorporation in the many extension and advisory models has been celebrated, some scholars have bemoaned the high levels of cost attached to the connectivity, accessibility, and affordability of technological illiteracy at farmers' levels, particularly in developing countries [9].

Despite the above challenges, improving smallholder farmers' production using various extension models remains a huge but necessary task. Understanding the effects of COVID-19 on the extension systems and different models during and post-pandemic is crucial to driving the sustainability route in agricultural development. Therefore, this study aims to review literature to ascertain the effects of COVID-19 on the sustainability of extension and advisory models for

smallholder farmers. It describes Agricultural Extension Models in terms of benefits and drawbacks in developing countries. The paper also examines the theoretical and practical use of extension models in various nations and how the digitalization of extension has helped increase knowledge transfer to extension stakeholders sustainably.

2. AGRICULTURAL EXTENSION MODELS IN DEVELOPING COUNTRIES

Over recent decades, countries and collaboration organizations globally have employed different extension models to drive information and technologies from research and services providers to farmers as the end-users. Research has identified a range of extension and advisory models used in the agricultural sector [10]. The sustainability of the extension models has received wide coverage from scholars in terms of their ability to deliver intergenerational information and technology to farmers without compromising the social, environmental, and economic components of development. Therefore, the sustainability of the extension model is the extension's ability to deliver information and technology in the ecosystem for economic, environmental, and social benefits for all players, even when faced with complex COVID-19 disruption challenges. In contrast, the term, Extension Models are the approaches that extension service providers use to deliver information and technology to smallholder farmers sustainably.

The model of extension services is described in this study by the approach taken to deliver the information and technology. It is coined on the premise of supply or demand, top-down or participatory, or public or private service providers [11]. However, this study concentrates on assessing the effects of COVID-19 on the sustainability of extension systems. Models used include: the Technology Transfer-Based Extension Model, Ministry of Agriculture-Based Extension Model, Training and Visit (T&V) Extension Model, Commodity Specialized Extension Model, Participatory Agricultural Extension Model, Farmer Field School Model, Project-based Extension Model, Farming Systems Research-Extension Model, Cost-Sharing Extension Model, and Education Institution Extension Model. There is clear evidence that these extension models have helped navigate various crises such as climate, Ebola, and COVID-19 in the quest to feed the growing global population over many decades [4]. In light of COVID-19, stakeholders have strategized and identified a leveraging point to attack the disease at its weakness by putting resources in one pool. There has never been a time when solidarity was more critical than individualized extension business exploration [12].

These models have moved from centralized to decentralize and then to hybrid, combining centralized and decentralized into one. In response to COVID-19, these models have sped up the adoption of electronic extension to service the farming community without leaving them isolated. As a result of the change in relationship between research and the requirements of farmers in modern agricultural systems, practical methods for the supply of technical expertise to farmers are required. Due to the wide range of farmer requirements, production methods and agriculture policy need to be objective [13]. As a result, the extension evaluated and implemented over past decades has been found to utilize various models to address challenges. Over time, these extension concepts have changed, and authors have categorized them across various typologies. In general, the approaches are not mutually exclusive and are complementary in certain situations. The primary extension models in developing countries include technology transfer, specialized commodities, participatory, cost-sharing, and educational institutions. The most common extension models used in developing countries are

based on a cost-sharing and educational institution models. This evolution shows that extension systems are mitigate to COVID-19 and susceptible to its impact [14].

COVID-19 has disrupted the smooth operation of all the extension models for all market players such as input suppliers, buyers, researchers, consultants, policymakers, and implementers. The rate of death from COVID-19 amongst market players has negatively impacted production as information and technology flow became compromised.

As shown, the reduced interactions between farmers and extension service providers from the input or output market, due to lockdowns, triggered a rise in the price of these commodities. The use of digital technologies between market players was enhanced to reduce the disruption, bypassing the traditional extension delivery systems. However, the number of farmers accessing the electronic extension remained low despite the increased innovation. The COVID-19 vaccination rate remains low in developing countries, further impacting commodity prices and available resources.

The following sections offer a brief historical and overview of each of the core models in use. In order to replicate, generalize, and scale novel extension models or improve current ones, researchers and policymakers may use the lessons identified against each model.

3. TECHNOLOGY TRANSFER-BASED EXTENSION MODEL

Agricultural and rural developments lag behind in most developing countries due to the lack of appropriate technologies and information systems that increase production and productivity [15]. Even when technologies are made available, they lack environmental and user-friendly characteristics that suit the farming communities' expertise, rendering them

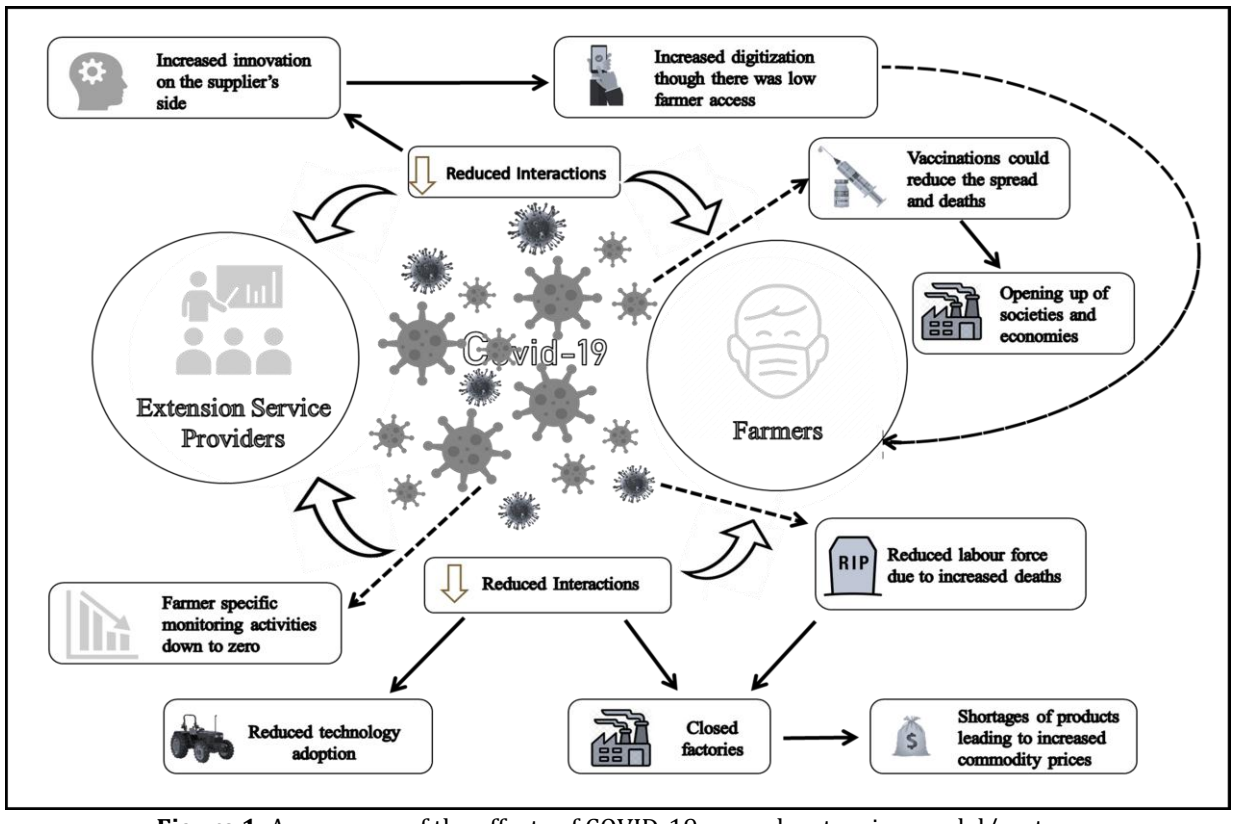

Figure 1. A summary of the effects of COVID-19 on each extension model/system

redundant. Over past decades, extension services, either public or private, have been at the centre of unpacking different technologies for farmer adoption and utilization [16]. Nevertheless, many studies have shown that different drivers are responsible for the low adoption rate and diffusion of technologies and information to smallholder farmers in developing countries [17-19]. However, apart from the well-known climate change, the world has recently witnessed the COVID-19 pandemic as a critical barrier to smallholder farmers' diffusion and adoption of technologies.

Through locked down measures, COVID-19 has limited the transfer of technologies and extension services [20] from developed countries to developing countries where they are needed [21]. Most developing countries depend heavily on imports from developed countries for improved information and farming technologies to on-transfer to smallholder farmers, affecting their extension delivery system. Trade barriers are slowing the transfer of these goods and services to developing countries due to importation restrictions [22]. While importation has been delayed, the price of the technology has gone up due to shipping charges and componentry, making it difficult for farmers to access the much-needed technology [7].

Reports indicate that extension models have not remained static in the face of COVID-19. Scholars have indicated that the onset of COVID-19 has triggered the uptake of digitalized extension services in most developing countries, especially in countries where mobile networks have been rolled out in rural areas [23]. Information technology systems have bypassed the COVID-19 induced barriers of information and technology delivery systems, which engulfed the traditional extension models. Many government and private companies have used Zoom, Microsoft Teams, and the internet via computers and smartphones to conduct research and deliver services for their clients within the extension market system [24]. In addition, television, radio, and social media platforms have been responsible for engaging women and youth in agricultural participation throughout the COVID-19 pandemic. In seeking marketing information, the block-chain platform responsible for transparent transactions has been used by many private firms worldwide as a tool to offset the impact of COVID-19 [25]. In this regard, existing technology may have been adopted, commercialized, and disseminated more quickly to accommodate the altering production and consumption patterns.

Norton and Alwang (2020) assert that the information and communication technology revolution had stretched to a tipping point, where the vast majority of farmers now have mobile phone connectivity, allowing agricultural extension and advisory systems to reach them with low-cost and timely messages, rather than letters and phone calls. Unfortunately, limited-resource farmers in developing countries remain at a disadvantage regarding mass media hardware such as computers and smartphones. However, extension and advisory systems are rapidly gaining traction among smallholder farmers through different digital platforms aiding the sharing of information throughout the COVID-19 pandemic.

As much as COVID-19 has had a crushing effect on most extension models, the technology Transfer-Based Extension Model has employed a range of information and technologies to withstand the effects of lockdown, and associated masking, hand sanitizing, and social distancing. Moreover, COVID-19 appeared in developing countries during the farming season of December 2019 to March 2020 [26]. On this occasion, agricultural inputs and extension services relative to production had already been delivered by extension staff and utilized by the farmers reducing low production in that period.

4. MINISTRY OF AGRICULTURAL-BASED PUBLIC EXTENSION MODEL

Historically, the public or government-based extension and advisory model is a top-down extension model driven by the central government through its systems and ministries [27]. It has historically been the most prevalent extension system globally, and many nations have adopted it in developing countries [24]. COVID-19 control and prevention messages are connected to the Ministry of Agricultural-Based Extension Model as they need a command extension service driven by the government considered a public good [28]. To sustain the Ministry of Agricultural-Based Extension Model in the face of COVID-19, the ministry of health provided advice on how to utilise the golden COVID-19 health guidelines developed and monitored by WHO [29]. Therefore, through the Food and Agricultural Organization of the United Nations, the ministry-based extension incorporated the COVID-19 messages into its traditional delivery systems. This helped to raise awareness of the disease among the smallholder farmers in developing countries [26].

However, before the outbreak of COVID-19 in most developing countries, these countries were already stressed and indebted, making it difficult to fund the agricultural and extension services effectively. Moreover, through the Ministry of Agricultural-Based Extension Model, the central extension system was already vulnerable to external and internal shocks, making it difficult for extension workers to transfer information at the right time and place to the right farmers [30]. Furthermore, implementing the WHO's COVID-19 guidelines of lockdown, quarantine, and social distance measures worsened information dissemination further in most developing countries [31-32]. Therefore, COVID-19 exacerbated the situation leading to low production and productivity due to a lack of timely extension communication [1].

Because agriculture is a state topic, central governments are constantly tasked with the primary duty of coordinating agricultural extension operations. For example, in the COVID-19 crisis, the ministry of agriculture extension staff advised farmers about the danger of COVID-19 and the mitigation strategies farmers needed to follow to remain productive in the face of competing needs. These services were treated as public good, with farmers not needing to pay for them. Mapiye et al. (2021) added that one of the most significant advantages of the Public Extension Method is that the government may use it to execute national agricultural policies and development plans for smallholder farmers and many other players in the extension ecosystem without costs being attached to the recipients.

However, being a non-profitable model, the system has been criticized for poor performance and a two-way information delivery system between extension personnel and the farmers. The public extension system suffers from institutional inefficiencies caused by bureaucratic processes, a lack of accountability, and insufficient trans-disciplinary coordination depriving farmers of access to technical information during the COVID-19 crisis [30]. This has been seen in many countries where COVID-19 funds and materials donated by different stakeholders have been the subject of corruption [30].

As a platform for the technology transfer strategy, the cancellation of public gatherings such as field days, district and national shows, including exposition, have hurt information and technology sharing and transfer. Where social distancing and masking was allowed, the number of attendants was also reduced, impacting the majority of rural farmers, especially the youth and women already marginalized. However, most developing countries have invested in developing information and technology networks to encourage electronic extension

systems. Electronic extension systems aim the centralization of extension messages and then broadcast them as bulk messages to farmers in rural areas on general topics. However, this kind of extension service is a one-way route that rarely receives feedback from the farmers. In an attempt to address this, the model has also modified its traditional delivery systems using digital extension mechanisms in the face of COVID-19 [33]. The limitations are yet to be addressed, for which a two-way communication model is an option to explore further.

5. TRAINING AND VISIT (T&V) EXTENSION MODEL

The Training and Visit (T&V) Extension System Model was first developed and implemented in the 1970s in Asia as a component of two regional irrigation projects in Turkey and India. Investment in extension systems increased dramatically in the 1980s, following a period of declining attentiveness in the responsibility of extension in agricultural development during the 1960s and 1970s [34]. The model later became a widely promoted concept by the World Bank and was implemented in over 50 countries throughout Asia and Africa between 1975 and 1998 [35]. This extension model is an improvement over the Public Extension Model, which remains a top-down model, firmly promoted and funded by the World Bank [36]. Mapiye et al. (2021) claim that the T&V extension strategy is one way to structure a Ministry of Agricultural-Based Extension Model in search of better inclusive service delivery.

The T&V method was developed to help researchers transfer agricultural technology to farmers. To achieve effective and sustainable technology and information transfer, proponents argue that extension workers should visit farmers more frequently to provide corrective measures in times of crisis like COVID-19. Supervisors to the extension workers should be more involved in the T&V extension COVID-19 awareness program as an integral part of the agricultural extension system. At the field staff level, the extension workers should be provided with specialized knowledge and resources to help transfer critical knowledge on the subject matter, which is also systematically transferred to farmers at an increased rate [37]. However, these observations put the extension service providers at risk of contracting COVID-19 if taken literally in these times of crisis. As such, extension officers, though they follow a hierarchical structure and a strictly planned timetable in the T&V technique, need to observe COVID-19 guidelines [7].

With lock down and social distance mitigation measures resulting in extension workers being restricted from physically visiting and training farmers, Alvi et al. (2021) found the epidemic severely affected women farmers' access to agricultural extension and agriculture productivity, which varied depending on caste, location, education, and crop type. A comparison between the two nations of Gujarat and Dang indicate that although production was directly reduced in Gujarat, farmers in Dang cited worries about input availability and insect assaults.

Findings from the Alvi et al. (2021) study show an obvious need for establishing more resilient and inclusive agriculture extension systems to ensure that women farmers have access to timely and quality information, especially during moments of crisis. During COVID-19, several factors could limit women's participation in agricultural extension activities and programs, including women's access to assets and resources; conditions that influence women's access to information, including delivery channel, timing, language, location, duration; and women's role in agriculture.

However, the T&V Extension Model works well when there are no contagious diseases that affect the model's

very beneficiaries and associated harmful impact on the farmers' management. As such, farmers who over-rely on the training and visitation by the extension workers tend to get disoriented once the visitation and training are cut due to lock down and social distance. However, this model is more effective than the Public Extension Model, which requires larger quantities of people to be present. Nonetheless, the strategy failed to enhance farmer production or inspire extension workers in Cote d'Ivoire and Rwanda beyond the poor incentives attached [24]. These results indicate that a top-down extension models such as training and visits have failed to innovate during crises such as COVID-19. Hence, adapting group and community-based approaches to post-pandemic would be best practice. The approach has been chastised because of its lack of flexibility embedded in its top-down organizational structure and high implementation costs, which is unsustainable, leading to many countries moving away from the practice in the face of COVID-19 [38, 33].

6. COMMODITY SPECIALISED EXTENSION MODEL

A Commodity Specialized Extension Model is an extension model that is a value chain farming system. Multi-nationals are extending their farming using agricultural-based commodities such as sugar cane, cotton, dairy farming, poultry farming, and other plantations whose market is in their country of origin in many cases [39]. According to Mapiye et al. (2021), such models are implemented through a coordinated set of extension methods to promote high-income livestock initiatives such as home dairying and cash crops. The Commodity Specialized Extension Model facilitates critical agricultural inputs like acaricides, crop fertilizers, and herbicides, which support the COVID-19 crisis when a farmers' revenue is constrained. In times of such health issues as COVID-19, companies enforce government recommendations on their clients to avoid closure of their business more often than an open market and the training and visiting approach.

Maples et al. (2021) indicated that COVID-19 harmed the broiler industry, as with other animal sectors. The USDA predicted 45.8 billion pounds of broiler meat output in 2020 at an average price of $0.870 per pound in February. The same research in August 2020 predicted 44.7 billion pounds of output and an annual average price of $0.704 per pound. The second quarter had the most significant drop owing to COVID-19 demand shocks and processing issues. They produced 4.5 percent (or 519 million pounds) fewer pounds than predicted in February 2020, at a 29 percent (or $0.28 per pound) lower price. The research reveals that the COVID-19 epidemic produced major disruptions in meat supply networks, including the United States (US) poultry sector, and the impact was detrimental to chicken demand owing to restaurant closures that led to supply changes impacting broiler farmers. The inter-connected nature of the broiler business poses significant problems in predicting farmer losses. Farmers who produce broiler chickens do not own the birds, and price decreases are not unswervingly felt in the same way as other produce [40].

In addition, Fuji sugar plantations have been reported to be negatively impacted. The plantations have suffered from the effects of COVID-19, which has contributed to the economic downturn. The extension systems have also collapsed, and many workers and farmers are worried about their source of livelihood. The COVID-19 pandemic caused a health and financial disaster in Fiji. Furthermore, COVID-19 has hugely impacted the Fijian economy, notably the tourist industry, causing massive trade disruptions, economic slowdowns, and significant impacts on state budgets [41].

As support mechanisms, the Commodity Specialized Extension Model or out grower schemes are well known

for their technological use and transfer to farmers involved and contracted in the scheme [42]. This rewards the farmers with high yields from their enterprise. Its advantages include high yields of crops or animals, an increase in the income of farmers, as well as an improvement in their practice and decision-making skills while simultaneously reducing the risks and concerns of farmers [43]. It may also provide small and intermediate farmers with access to profitable and ambitious markets and agricultural resources, expertise, and advice they would otherwise be unable to access in non-COVID-19 times. Although the information content is limited to the practical, managerial, or commercial aspects of the particular product being discussed whilst incorporating COVID-19 messages.

This model is, therefore, persuasive and appears to lead the available models. Research indicates that commodity-based extensions were the first to incorporate electronic extension (e-extension) for reaching farmers [33]. With COVID-19 mitigation guidelines, it became easier to expand the services in this model than other models.

7. PARTICIPATORY AGRICULTURAL EXTENSION MODEL

The flaws in the centralized extension services offered by public sector extension and the advisory system gave birth to Participatory Agricultural Extension Models [44]. It was realized that rural community challenges are complex and dynamic and require farmers to benefit most and support other key stakeholders [45-46]. Since the 1980s–1990s, community-based and participatory extension techniques have grown in popularity across farming communities. Robert Chambers was one of the pioneers of participatory or bottom-up extension systems, who believed that local people had accumulated knowledge that cannot be ignored if sustainable knowledge transfer is achieved [47]. As a result, many countries have used local communities and leadership in the health service provision, trained by either health service providers from the ministry of health or livestock.

In the fight against COVID-19, participatory methods assume that existing indigenous knowledge systems vary from scientific knowledge systems and that combining the two can benefit farmers and many stakeholders [48]. To increase productivity, farmers should learn about other COVID-19 mitigation techniques together with agricultural ones. Hence, this model increases the number of farmers actively engaging, the continuity of local extension organizations and their processes, and the financial benefits to the community.

The role of frontline extension agents is to act as facilitators, not teachers, in the participatory COVID-19 extension system [49]. The process of stakeholder engagement in participatory extension systems is a highly communicative and social activity that relies on close relationships and face-to-face meetings, but now with COVID-19, it has taken new twists. Participatory extension is also based on the level of trust between all stakeholders in the project [50]. Therefore, depending on the level of trust and engagement, many health and agricultural extension workers have started using mobile phones to solicit stakeholders to participate in the COVID-19 service delivery without face-to-face meetings.

COVID-19 is a participatory disease that has to be addressed by many stakeholders to improve extension growth as it accommodates different viewpoints to attain satisfactory results for all [51]. The agricultural extension officers' work in COVID-19 control and management activities entails meeting farmers from diverse backgrounds. This necessitates that they grasp the nature of the COVID-19 calamity and find the final solution to reduce complete food supply and production disruption. It is, therefore, necessary for extension

service providers to focus on opening dialogue in which there is continuous interaction, constructive thinking about the situation, identification of problems and solutions, and decisions about what is needed to improve the situation, as well as acting upon those decisions as mutually agreed. The participatory model was also quick to embrace the use of electronic media in order to reduce COVID-19 extension flow disruption [49]. It is posited that digitalization is the future of extension for all stakeholders involved in extension and agricultural development.

8. FARMER FIELD SCHOOL MODEL

The Farmers Field School (FFS) Model was developed in Asia to teach integrated pest control and management. The FFS is an excellent example of a participatory extension model used in different developing countries where it has been successfully implemented over many decades. This extension service model employs non-formal education group-based methods that incorporate iterative and interactive adult learning activities such as scheduled meetings, observations, and experiential learning to foster innovation development and transfer. The five East and Southern Africa case studies indicate that FFS has helped participants alter their attitudes and views, and helped establish new partnerships between farmers, researchers, extension workers, and community development staff [24, 52].

However, with COVID-19 appearing in 2019, this model has reduced the number of farmers coming together to learn due to restrictions issued by WHO [6]. As a result, there has been a report of reduced field days at local, district, national, and international levels. The reduction in the number of farmers and gatherings has denied inclusive, practical research, analysis and testing of agricultural problems, and the development of sustainable solutions. For example, in many developing countries, commercial and agricultural shows have been cancelled in 2019, 2020, and 2021 by the Ministry of Agriculture, as directed by the Ministry of Health [53].

With COVID-19 eliminating successful farmers' field schools being held across developing countries, farmers are using traditional extension information they learnt in past years. If COVID-19 continues, a gap will develop in the advancement of knowledge over the next two to three years [54]. The other drawbacks of the FFS Model include high implementation costs, labour-intensiveness, and limited reach. Mapiye et al. (2021) claim that a poorly directed participatory FFS strategy harms community gains in many instances. Therefore, exclusive farmer needs may result in technologies or services that are typically of short-term relevance to the agricultural community without addressing longer-term externalities such as environmental deterioration. It is also likely that the reduced FFS resulted in young farmers, female-headed households, and high-literate levels since the model came in.

9. PROJECT-BASED EXTENSION MODEL

Studies show that many integrated extension models exist aimed at specific objectives for a specific group of mainly marginalized people for a specific timeframe [55]. Usually, such project extension models can be either participatory or top to bottom approaches or a combination of both, depending on the sponsor's design.

The World Bank, Food and Agricultural Organization of the United Nations, Japan International Cooperation Agency (JICA), African Development Bank, Swedish International Development Agency, and United States of America International Aid Agency are some of the funders that support different project extension models in agriculture and livestock, and broadly health to mitigate diseases of national economic importance, among other focus areas [11]. Since the onset of COVID-19, these international agencies have funded the fight against the disease in many facets. For example, many

developing countries recently received the additional US assistance through USAID COVID-19, pledged the support of more than the $US18.5Million to mitigate the effects of diseases [56]. However, even while foreign development organizations provide considerable financial and technical assistance, project-based techniques may need to be managed centrally because they show the potential of new technologies and processes that are extended and sustained beyond the project life span [24].

10. COST-SHARING EXTENSION MODEL

The Cost-Sharing Agricultural Extension Model emanated from a critical review of government-managed extension's failure to fund the extension services in the 1990s sustainably need [57]. As part of economic restructuring programs undertaken by most developing countries, as advised by the World Bank and IMF there was a need to involve the farmers and many beneficiaries of the provided extension as part of the cost-sharing. However, most countries have failed to support and sustainably subsidize extension services due to indebtedness.

This model sits well in most of the other extension models dealt with in this paper, such as the Farmer Field School Model, Farming System Research-Extension Model, Participatory Agricultural Extension Model, and Public Extension or Ministry of Agricultural-Based Extension Model. In addition, the Cost-Sharing Extension Model has worked well in the past, training farmers in disease management such as HIV/AIDS and fighting illiteracy among smallholder farmers [58-59].

Donors around infrastructure development grants have used the Cost-Sharing Extension Model. Usually, farmers must raise 25% of the total funding, which could come in terms of labour, locally sourced materials, and infrastructure security, while the donor meets the remaining 75% [24]. The Cost-Sharing Extension Model provides sustainable empowerment through project ownership by the farmers. COVID-19 cost-sharing mitigation investment between the funders and farmers seeks to building sustainable human capacity through education that hinges on the effective creation and use of knowledge in agriculture, especially in developing countries. As a result, the next generation may be built on a solid market principle of paying for the services and products they demand in their business, which will continue to spur innovation and wealth by enhancing human potential and fostering a continuous learning environment. Cost-sharing for masking and quarantine extension Techniques have been effective in several nations, notably in Asian and African countries [60-61].

Learning from the decades of cost-sharing on HIV/AIDS drugs, nutritional foodstuffs, and other prevention measures, many families have become more responsible, thus avoiding further contracting of the disease [62]. This cost-sharing could be reflected in engagement with farmers in developing countries on the issue of COVID-19. This will be a hard lesson because the process involved results in the loss of life through the gradual learning process. However, the message of being a steward of one's health and life would have been sustainably inculcated in many farmers.

11. EDUCATION INSTITUTION EXTENSION MODEL

Learning from the early universities in the US and Ireland that entered into agricultural extension service provision at the beginning of the extension system, many universities are currently involved in extension and research service provision for rural development [62]. In addition, many donors such as USAID, JICA, Swedish, UKAID, Chinese Aid and many others have been in the driving seat of sponsoring different education institutions from their countries to invest in research and extension in developing countries. For example, Michigan State University and Maryland University have

been at the helm of providing research and extension in African rural areas to fight different diseases and agricultural-related challenges. Oxford University has tried to research vaccines to reduce the COVID-19 infection rate, which helps to open up the farmers' knowledge transfer.

Universities were the first to migrate to digital electronic learning for their clients and, more specifically, to cater for learning for extension workers. As a result, many training institutions resorted to supervising trainee staff via remote methods such as tele-supervision [28]. Higher education institutions can reach farmers and other partners via virtual meetings such as Zoom, Microsoft Teams, Google Meetings, telephones, and other forms of communication. However, although supervising trainee staff via remote methods such as tele-supervision is suitable it does not align with accreditation standards [20].

Due to the abrupt appearance of COVID-19 in 2019, the norms of farming and human connection have been drastically altered in an environment of infection danger. As a result, people worldwide have been urged to be model citizens to 'flatten the COVID-19 curve' [63], especially in developing countries with imminent pre-disposed conditions [64-65]. This has been accomplished through various control measures, including population lockdowns, social distancing, and travel restrictions. Thus, COVID-19 has accelerated the evolution and transformation of the agricultural extension and advisory models.

12. COVID-19 - A BARRIER TO SMALLHOLDER EXTENSION AND ADVISORY DELIVERY SYSTEMS

The status of smallholder farmers globally can be described by many threats and barriers to which COVID-19 unfortunately adds weight. Research has highlighted how COVID-19 has disrupted the global economy, the environment, and social institutions, which ultimately have not spared the agricultural sector worldwide [66]. Agricultural extension systems are managed by trained people to be improve their health, both physical and spiritual. However, COVID-19 has affected the health and spiritual well-being of the people involved in the extension delivery ecosystem across the spectrum since its onset [67]. Reports indicate that farmers and other market players have had a psychological impact on the COVID-19 crisis [68]. The effects of the death of loved ones have encroached on the very fibre of farmer's and market player's existence. Massive levels of death have robbed many smallholder farmers, the beneficiaries of extension services and producers of crops and livestock products, threatening household and national food and income security.

When COVID-19 set in, smallholder farmers were already grappling with droughts, water and feed shortages, poor breeding management techniques, and insufficient animal welfare and health abilities, being some of the environmental difficulties that threatened the extension delivery systems. In addition, many developing countries were already struggling with climate change-induced load shedding and debt which has crippled the agriculture sector, particularly the dairy sector that depends on electricity for cooling the milk and the irrigation systems for crops [69]. The lack of access to formal, high-value output markets constrained smallholders' economic growth and development when COVID-19 took its toll.

An extension system is meant to minimize the agricultural sector's risks brought by COVID-19, especially those associated with causes of income fluctuation. For example, poor and fluctuating income results in farmers failing to manage health issues and pests, which ultimately lead to reduced yields, and in many cases, post-harvest losses which later leads to lower market prices. Therefore, uncertainty about the markets, inconsistency in prices, and incorrect grading

Table 1. Effects of COVID-19 guidelines on extension models

Extension Model	Impact from			
	Social distancing	Lockdown	Masking	Technology usage
Ministry-Based or Public Extension	• Reduced gathering, training and number of interactions • Increased social mistrusts	• Increased commodity prices • Reduced sales of commodities	• Disrupted the COVID-19 effects • Increased pollution of environment due to mask material	• Increased use of cell phones and radios • Virtual training, monitoring and research
Training and Visit (T&V) Extension	• Reduced number of visits and trainings • Increased social mistrust	• Increased commodity prices • Reduced sales of commodities • Less access to extension information	• Disrupted COVID-19 effects • Increased pollution of environment due to mask material	• Increased use of cell phones and radios • Virtual training, monitoring and research
Technology Transfer-Based Extension	• Increased use of digital platform • Reduced number of workers due to machinery	• Inaccessible and affordability of technologies • Import restrictions	• Disrupted COVID-19 effects • Increased pollution of environment due to mask material	• Increased use of cell phones and radios • Virtual training, monitoring and research
Commodity Specialized Extension	• Reduced access to extension services • Reduced number of farmers accessing the market	• Reduced export of products • Increased use of e-commerce through digital platforms • Close of trade between the buyers and sellers	• Disrupted COVID-19 effect • Increased cost of masking materials • Increased pollution of environment due to mask material	• Increased use of cell phones and radios for extension services • Virtual training, monitoring and research
Participatory Extension	• Reduced access to extension services • Reduced number of farmers accessing the market	• Reduced export of products • Increased use of e-commerce through digital platforms • Close of trade between the buyers and sellers	• Disrupted COVID-19 effect • Increased cost of masking materials • Increased pollution of environment due to mask material	• Increased use of cell phones and radios • Increased Virtual meetings, training, monitoring and research
Farmer field School	• Reduced access to physical extension services • Reduced number of farmer field school i.e field days, expositions	• Inaccessible and affordability of technologies • Import restrictions and closure of farmer field schools	• Disrupted COVID-19 effect • Increased cost of masking materials • Increased pollution of environment due to mask material	• Increased use of electronic learning • Increased Virtual meetings, training, monitoring and research
Project based extension	• Reduced number of extension services to the farmers • Reduced number of farmers accessing the market	• Reduced export of products • Increased use of e-commerce through digital platforms • Close of trade between the buyers and sellers	• Disrupted COVID-19 effect • Increased cost of masking materials • Increased pollution of environment due to mask material	• Increased use of electronic learning • Increased Virtual meetings, training, monitoring and research
Education extension	• Reduced number of extension services due to reduced trained extension staff • Reduced number of farmers accessing the institutional products and services	• Reduced number of trainers and trainees being trained • Training material cost surge	• Disrupted COVID-19 effect • Increased cost of masking materials • Increased pollution of environment due to mask material	• Increased use of electronic learning facilities • Increased Virtual meetings, training, monitoring and research
Cost sharing extension	• Reduced funding leading to reduced extension service provision • Reduced farmers accessing products and services	• Increased cost of importing information and technologies • Closure of extension services	• Termination of contracts between the services providers and farmer organisation • Disrupted COVID-19 effect • Increased cost of masking materials • Increased pollution of environment due to mask material	• Increased use of electronic learning facilities • Increased Virtual meetings, training, monitoring and research

and classification of produce contribute to supply chain disruption when smallholder farmers are grappling with crisis such as COVID-19 [70].

With poor innovation and entrepreneurial skills, smallholder farmers are further disenfranchised from the commercialization of their business enterprises. In addition, the public sector is one of the most flawed

sectors because of its attachment to poor funding, causing serious service inefficiencies [71]. Despite these challenges, the extension has been a force in maintaining food production for smallholder farmers throughout COVID-19, preventing many from going hungry. The World Bank, Food and Agriculture Organization of the United Nations, and many developing countries report that agricultural extension and advisory services are critical to changing and supporting rural development through smallholder agriculture, even in crises such as COVID-19 [72].

If it had not been for agricultural and advisory services transferring information and technologies from the sources to the users, COVID-19 would have wholly collapsed the food supply chain. Because of the sustainability of the messages transferred to smallholder farmers, the farmers retain the information for life, increasing their resilience. Despite many criticisms for not delivering enough outcomes, extension is seen as the backbone of the source of education aimed at reducing the illiteracy gaps between the formally educated and the farmers in rural areas [50]. Even during a crisis such as COVID-19, agricultural extension systems have presented options, such as electronic extension (e-extension) through computers and mobile phones, for smallholder farmers. These models are not static but dynamic. Given this background, many extension and research officers from agriculture and livestock have been on the front line researching how to minimize the impact of COVID-19 through different models.

13. COVID-19 AND ALTERNATE POLICY

COVID-19 has altered the structure of agricultural extension systems. As a result, many countries have had no choice but to accommodate and fight to reverse these unintended causes that created profound structural changes experienced. Through the effective extension provision model, smallholder farmers' policy and resource allocation are critical to attaining positive, sustainable changes in fighting COVID-19. Bartholomew and Diggle (2021) contend that the most effective approach to guaranteeing this efficient reallocation of resources may be via broad policy, which tolerates periods of above-target inflation [73].

It should be noted that inadequately supportive demand-side policy is the most significant danger to the recovery from COVID-19 and the major probable cause of prolonged harm to the agricultural economy's supply side. In past economic crisis, literature indicates that a policy blunder was responsible for the sluggish economic development, which cost the agricultural sector's growth. It is easy to envisage similar mistakes being made again. Poor funding for the extension and advisory service over many years has been revealed as another crisis responsible for softening the structure of extension systems in most developing countries [74]. There is also the possibility that crisis-fighting and economic instability, more generally, leads to a loss in impetus behind structural reform objectives, with trade liberalization particularly vulnerable in this aspect.

14. CONCLUSION

Agriculture and the extension system are constantly faced with complex challenges that deter its progression when emerging disease such as COVID-19 take centre stage. COVID-19 has continued to threaten the very existence of mankind globally. As a result, extension will remain critical in delivering mitigation messages in addressing threats to our existence on earth. Many extension and technology delivery models exist for farmers to use and will continue to exist in hybrid forms as technology and culture evolve. The sustainability of these extension models entails offering solutions to farmers at any time and in any geographical setting.

Extension models cannot be used in isolation but need to be combined to develop a hybrid that suits the

implementers and the recipients of the information and technologies. The majority of models designed to transform extension were developed quickly and implemented in the field but had little or no impact on individual farmers. Therefore, no single best model can be recommended to an individual farmer by any implementing organization because these can be used interchangeably to achieve the best results suitable for a particular setting.

The new extension system should prioritize resource-constrained smallholder farmers, rural women's empowerment, and farmer and extension agent engagement in adaptive research. As shown in the face of COVID-19, the inefficiency and ineffectiveness of each model give way to creativity and innovation for that particular society. COVID-19 has pushed most extension models to accelerate the incorporation and use of digital technology into their components. This is in line with the digital and information economy, which thrive on quick, transparent, democratic, and effective communication among stakeholders in the extension market system.

The necessity of proactive demand and supply-side strategies to guarantee a speedy and robust rebound in activity, while also allowing for the allocation of resources that will increase productivity, will be needed to move the extension onto a sustainable and responsive pathway. We emphasize investment in education catch-up, retraining programs, infrastructure expenditure, demand management frameworks that mandate the restitution of lost nominal activity, and a robust competition environment for developing countries.

A study to assess how COVID-19 has impacted each extension market player would be welcome in building the knowledge gap that exists in literature among the smallholder farmers, with a focus on women and youth on nutrition and food production.

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16. CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest.

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