



Agricultural Extension in Post-COVID Era: Lessons Learned and Path Forward

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ABSTRACT

This review examines the impact of the pandemic on agricultural extension systems, focusing on adaptive strategies, lessons learned, and innovations shaping the path forward. The COVID-19 pandemic posed unprecedented challenges to agricultural extension services worldwide, especially in developing regions. Food and agriculture issues are subsequently emerging in several countries at an unprecedented scale. At the same time, the negative implications of the pandemic on food security and livelihoods in the country point to the need for scaling up of efforts to mitigate the impacts of the crisis. Lockdowns, market disruptions, and mobility restrictions significantly hindered traditional face-to-face extension practices, compelling a rapid shift toward digital and remote modalities. In response, stakeholders adopted alternative methods, including virtual training, mobile applications, and community engagement tools, to sustain support for farmers. The pandemic exposed systemic weaknesses such as resource constraints, technology gaps, communication barriers, and limited inclusivity in extension delivery. However, it also accelerated the adoption of ICT-driven approaches and fostered collaborative networks among public, private, and non-governmental actors. Emphasis on resilience, sustainability, and climate-smart practices emerged as key pillars in reimagining extension services post-COVID. The review underscores the critical importance of investment in technology, capacity-building, stakeholder collaboration, and policy reforms to enhance the effectiveness and adaptability of extension systems. Drawing insights from global and local case studies, the paper advocates for a more inclusive, digitally integrated, and responsive agricultural extension model that can withstand future shocks. Ultimately, the COVID-19 crisis, while disruptive, catalyzed innovation, urging a transformation in agricultural extension to ensure food security and sustainable livelihoods.

Keywords: *Agricultural extension; COVID-19 impact; digital tools; food security; sustainable agriculture.*

1. INTRODUCTION

Agriculture faces complex challenges hindering its growth and global food production due to the ever-growing population. Women and youth significantly contribute to food production and have been disproportionately affected by these challenges. Creating gender-specific markets to promote inclusive and sustainable development has been a persistent challenge for international and national organizations. Employing agricultural extension service systems to stimulate the growth of women and youth in agriculture received support, but COVID-19 disrupted this effort (Siankwilimba et al., 2023; Ayisi-Nyarko et al., 2024; Siaw et al., 2025). COVID-19 has a dramatic impact on all sectors of development in almost every country in the world. Agricultural extension is one of the sectors that confront huge unanticipated challenges globally and nationally. Governments and Non-Governmental Organizations are struggling to navigate the “new normal” to continue their services. This text attempts to share the appraisal of deploying practical recommendations and technical information utilizing the relevant and applicable digital tools to assist the farming community amid the COVID-19 outbreak. The findings of

implementing the research and the analysis of the perception of the extension field agents on COVID-19 implications and challenges are presented and the path forward and implications of the findings are the last part. The COVID-19 pandemic is having a major impact on many food systems with reduced incomes and disrupted containment measures to control the spread of the virus. Food and agriculture issues are subsequently emerging in several countries at an unprecedented scale. At the same time, the negative implications of the pandemic on food security and livelihoods in the country point to the need for scaling up of efforts to mitigate the impacts of the crisis. Efforts are being made by a number of partners in the country to strengthen food systems to ensure more nutritious food security and enhance the resilience of the most vulnerable strata, as envisaged in the Sustainable Development Goals. In response to the COVID-19 pandemic, much more focus has been extended across the board on the implications for food processing as it relates to safety and security (Kubatko et al., 2023).

A nationwide lockdown is adversely affecting maize planting and post-harvest agricultural activities. Tradable products are destroyed

because of the absence of a transport system for marketed disposal. On the other hand, transportable necessities, like food items, are incongruously increasing in price as a consequence of the suspension of public transport services. Agricultural extension services in the country are currently rendered through face to face meetings, radio broadcasting, print magazines, paper bulletins, roadside posters, and sealing materials. However, the collaboration of researchers, farmers, and extension workers through the meetings and field visits for the implementation of agronomic research can no longer hold because of the COVID-19 consequences.

2. BACKGROUND OF AGRICULTURAL EXTENSION

Agricultural extension is a set of policies, programs and projects aimed at empowering farmers and agro-entrepreneurs, with good farming practices knowledge and skills, as well as assisting them in improving farm productivity and overall incomes. And this is by means of research scholars, subject matter specialists, some digital applications and mass media. Such an aim of extension activities is to facilitate and inspire farmers about their practices, with a more productive and beneficial way of farming (Singh et al., 2013).

One has to sustain the working relationship among extension agents, the progressive farming community, government, private organizations, NGOs and the wider community. But agents alone couldn't be effective. It indicates synergy among all participants is a must. So, it's essential to understand how an extension activity supports farmers to a larger extent, leading to the emergence of fully functioning and supportive agro-communities. Henceforth, research activities need to be observed and analyzed among those mentioned stakeholders, enhancing farmer support through developed supportive agro-communities (Arif et al., 2014).

Agricultural extension services may include, among other topics, innovative methods of farming, the latest applicable techniques in soil conservation, water harvesting and agro - processing in this post-COVID era. Extension methods may involve group meetings, farm visits, exhibitions, tours and individual consultations and during this post-COVID pandemic, there is an imminent need for digital

applications and mass media. The encouragement of a deeper understanding of the crops requirement by the development of the agro-processing sector is much significant and can become a means of food security additionally. Development of export of semi processed agro- produces, will be opened by the setting up of village base agro-processing industries. To developing those industries in a feasible way, agro-entrepreneurs could be learned in animal farming, poultry farming, fishery, bee farming for honey production, dairy farming and so on. A village marketplace and credit system will grow up simultaneously. In all stages of extension activities, skill development can be improved by participating in technologically skilled analyzers and on farmers' training cum workshop. Offering all above services and participating in skill development, the contribution will be now the time for remarkable growth in agro-based economies.

3. IMPACT OF COVID-19 ON AGRICULTURE

There is now hope to ensure that the detrimental impact of the pandemic could be overturned by designing and implementing agriculture-friendly strategies that are largely based on the lessons learned so far. The deadly pandemic has made lives and livelihoods miserable across the globe since its inception in early 2020. Up to more than three million casualties had already taken place by mid-2021. The pandemic has terrible impacts in many areas. The agriculture sector, which accounts for a hefty share of the national GDP and employs livelihood means for more than half of the population, particularly in developing countries, is seriously affected. In the realm of livelihoods, the agriculture sector is particularly haunted by the pandemic due to the imposed lockdown, shutdown of agricultural input and output markets, supply chain and transport hub interruptions, delay in agricultural employment rates, farmer and market -side labor force depletion, and subsequently reduced productivity and income rates. Despite the existing worst-case scenarios, there is room to hope that the detrimental impact of the pandemic can be overturned, given the noteworthy mitigation and adaptation-based intervention strategies initiated over time. There is growing debate concerning the expected pandemic aftermath in the agricultural livelihood sector. Using the lessons learned in the past contentious global predicaments, the possible paths forward are discussed. The socio-economic and political

proclivities to be initiated during the pandemic era in the agriculture sector are also addressed.

4. CHALLENGES FACED BY AGRICULTURAL EXTENSION SERVICES

The main task of Agricultural Extension Services (AES) in India is to improve the knowledge, skills, and attitudes of the stakeholders; organize them for obtaining training, and create awareness of the benefits of the technology for enhancing their acceptance. Capacity-building in terms of organized training has been envisaged as the first step of development. Undoubtedly, capacity-building, planning, communications, monitoring and evaluation (M&E), information dissemination, implementation of projects, office management, consultancy services, etc. should be the basic norms for the enhancement of competence, efficiency, and effectiveness. However, underpinning these norms, communication is considered more important in the context of AES. Due to recent COVID-19, communication is a very important aspect for the transfer of information for every sector but particularly in the field of AES.

The Corona or SARS-CoV-2 pandemic affecting almost the whole world brought a revolutionary impact on the lifestyles of the populace. A new phenomenon has arisen regarding the health of the man and the environment around him/her. Accordingly, a farmer, farming community, fieldworkers, agricultural scientists and policymakers must think and deliver their services in AES. But, as per WHO, to stop the transmission of COVID-19, government & regulatory bodies had decided and imposed the avoidance of group gatherings or individual physical closeness. Therefore, how, when, and which way AES can deliver his/her extension services to the farming community, or organizational setup, or vice-versa, it sets a big challenge to all stakeholders of AES (Singh et al., 2013).

4.1 Resource Limitations

Resource limitation is the main factor that restricts the extension workers from addressing the needs of the farming community. In developing countries, the farming community cannot step in to agricultural education institutes to solve their agriculture-related problems. On the other hand, for want of subsidy for conducting more extension activities, lots of

extension workers have to sit idle. In this connection, an integrated model of extension could open up some possibilities for removing the above-mentioned problems. Model-based research: a diversified extension program should be taken into account. The diversified extension program includes various types of extension activities conducted by trained extension workers and involving different resource persons. The model includes T and V lessons through radio and television, film DI/U2, method demonstration, group discussion, lecture, symposia, workshop etc., campaign, mass media like, wall newspapers, leaflets, bulletin board newspaper inserts with regular newspaper pullers; exhibition and visit to different production and processing units. Extension workers should also work as an intermediary between agriculture to non-agriculture organization. Related organizations such as agricultural universities and research institutes, problems of extension and non-extension workers, results of the latest research, new technology, right type of pest, disease, weed, fish etc. management, time of planting, variety etc. have been suggested for conducting more useful extension programs (Extension Service, 1967).

4.2 Technology Adoption

Probably the most significant consequence of the outbreak of COVID-19 was the reduction in the number of field visits by extension workers to farmers, farmers' groups, cooperatives, etc. many if not most of these organizations have no means of digitally communicating with service providers, such as where the necessary IT technologies are absent, expensive, or not operational. The provision of extension services through the direct interaction of extension agents with farmers in the field has a notable role in encouraging productivity. While the outbreak of COVID-19 created significant challenges and disruptions in the overall extension system but it provided positive lessons that could lead to more effective, impactful, and sustainable extension system models in the post-COVID era. Alternative extension options – for example, the use of ICT in providing agricultural extension services – need to be in place to ensure the continuity of the service in uncertain conditions.

There is evidence that ICT can play a big role in augmenting extension services through the development of targeted advisories and can have a big impact on technology adoption. The findings of this research confirm this.

Beneficiaries who accessed the video/coach intervention watched an increased number of video clips provided by the coaches and eventually increased the adoption of agricultural technologies. Other alternative modes of extension had no comparable results. There is evidence that transferring extension services through mobile telephones can generate a cost-effective, competitive, and timely delivery of services. In some cases, the impacts on technology adoption declined over time. A possible explanation for this is that it took time for the training effect to wear off. These results support the measure introduced by a few countries around the world to subsidize the cost of mobile telephony as a private cost to encourage awareness of the use of mobile telephones for the delivery of extension services (Abate et al., 2023).

4.3 Communication Barriers

The coverage of the farm families by development agencies is still limited while many farmers remain outside—the reach of the existing Extension Programmes. The quality of the Extension Programmes is seriously questioned by both the intended target group and the opinion leaders. Gap analysis reveals the inadequacy between the skills and information demanded by the Extension Programme workers and those available to them. And also, it discloses insufficient supplies of inputs and implements required for technology dissemination. The poor planning and implementation of development projects in the past have caused the eventual collapse of the technology introduced. Such experiences encourage cautious and resistant responses from the intended target group to adopt the new technology. Additionally, the transfer of potentially beneficial new technologies from the research results continues to lag. Grassroots-level farmers see the Change Agents as government spies and do not trust them because their approach instigates suspicion in farmers. Unfavorable and conflicting attitudes shown by the intended target group, therefore, contribute to the slow acceptance or outright rejection of the resources offered to them. The analysis said that information generates different types of behavior toward the adoption of the innovation. Likewise, unwanted consequences are produced by misunderstanding and inaccurate feedback of the learning process. Communication barriers due to selection of improper coding, retained or blocked information for recall, inadequate decoding, or

failure at confirmation. Many countries rely on agricultural production as the major source of export income. However, the prices that the developing countries receive for those exports have fallen over the past 20 years and subsidies and protection mechanisms of the developed countries for their farmers have risen. This is because agricultural production in general necessitates a lag-time relationship between the transfer of information and adoption on the part of the farmers. This outlay is also supported by research. His research claims that the use of communication skills, media, and methodologies in the dissemination of technical and practical knowledge to the intended target group at the grassroots level is typically fragmented and lacks a systematic approach. The conventional extension strategies are not effective, and the resources for the new method are simply not available (Onasanya et al., 2006). Suggested that the use of multimedia Strategies as part of the integral component of the Extension Programmes. These strategies have the potential to enhance and integrate the relatively diverse communications involving interpersonal communication (Group/Individual Contact), print materials (bulletins, leaflets, magazines, newspaper, and journals) mixed media, (meetings, demonstrations, workshops, agricultural fairs, and training-workshops) and audio-visual aids (film, video, slide-tape programs, and overhead projection). Most of the materials distributed and mass-media programmes on television and radio could not be used by the farmers. There are many reasons for this. The materials are not available in their language; thus, they could not learn from them. This problem is exacerbated by the fact that the majority of the intended target groups, especially the older farmers' generations, are illiterate. Moreover, because of the traditional form of social systems in many societies, the would-be users of the research result find it difficult to interact and make use of this information. As a consequence, these materials were neither interpreted nor digested.

5. LESSONS LEARNED FROM THE PANDEMIC

The impacts of COVID-19 on agriculture, food habits and related institutions are already evident. Rural extension services face unique challenges in trying to address and adapt to these changes. In an effort to better prepare extension services for a post-COVID world, four key COVID-era lessons are outlined that can

help shape the extension's path forward. These lessons, it is hoped, will contribute to priority setting and innovative thinking within extension programs as they rise to meet these new challenges.

The battle against the COVID-19 pandemic has had dramatic impacts on many aspects of daily life around the world. Agriculture, the sector on which rural livelihoods depend, and which is a fundamental part of food systems, has not been immune. Movement controls such as lockdowns, modern quarantine, and/or social distancing have typically sought to slow the spread of the virus by restricting people's movements. Such controls can significantly disrupt food production, food transportation to markets, and consumer food distribution (Fei et al., 2020). The larger context of COVID-19 may stretch beyond the agricultural landscape in which extension usually operates, including disruptions in financial markets, the collapse of international trade, and the rapid scaling of unemployment.

It is important, especially when dealing with issues as complex and multifaceted as the COVID-19 pandemic, to be analytical. This can help in identifying which of the numerous, broad-reaching effects on agriculture and food systems and habits are permanent and which are secondary. In this fashion, response efforts may be hastened and made more tailored.

5.1 Importance of Digital Tools

AES has become an integral part of agricultural development programming in many countries with the goal of enhancing the technical skills, production efficiency, and food security of farmers. However, the COVID-19 pandemic has severely shaken up agriculture, as with the rest of the economy. Agriculture provides livelihood to 40% of the global population and there are around 500 million smallholder farmers in the world; around 100 million of them live in Bangladesh. Disruption of the supply chain, fluctuation of the market, and control measures such as lockdowns severely affected the farmers. Research on the impact of COVID-19 on the livelihoods and food security of smallholders in Bangladesh shows that 58% reported a breakdown in transportation, 33% and farm activities have reduced, 32% income sources have reduced, and 15% can't buy daily necessities.

Technological development has created many opportunities to advance agricultural extension

services. Before the COVID-19 pandemic, digital solutions in extension services have already started taking the lead also in many low-income countries. However, the ongoing COVID-19 pandemic will limit the physical movement of people, which can affect the extension services. Here, agriculture professionals and the policymakers need to put agricultural extension services on the front line for rejuvenation in the post-COVID era. The digital tools adaptation in the agriculture extension services in light of the experiences from Bangladesh during COVID-19 will be reviewed.

5.2 Flexibility in Service Delivery

As COVID-19 has shifted daily life around the world and shuttered the way Extension delivers traditional programs, organizations have been forced to pivot and connect in new ways. This session will spotlight three ways the Extension has adjusted and modified the delivery of programming in the wake of the COVID-19 pandemic.

A pre-record weekly series was implemented throughout June 2020. These webinars were predominantly pre-recorded and released each week on a specific day of the week in order to guarantee a cohesive presentation and that the information got into as many hands as possible. This series was part of the existing relationship with the participating organizations, and had previously offered on-site consultation in the form of diagnosis of plant issues and weekly tours with refresher courses. As there was still a need for education and management, the partnership adapted to connect the expertise of the Extension with the organization's membership through a virtual workshop series. Participants watched the 10–15-minute video independently and had the opportunity to ask additional questions through a live Zoom meeting the following week. Additionally, not only did the videos have the potential to reach homeowners and the Partnership membership, these videos were also posted to the Extension's YouTube channel for extended viewing by the landscape industry and homeowners (Main et al., 2020).

5.3 Community Engagement Strategies

The pandemic forced a transformation in operations and business practices across all sectors, not the least of which was agricultural extension. The immediate changes involved stopping in-person programming and services. The short-term changes involved video-

conferencing platforms. The closing of society shed light on the inequalities that were always present, especially the Digital Divide (Burkhart-Kriesel et al., 2019). The expansion of high-speed broadband internet into the hinterlands of rural India will be helpful in overcoming the Digital Divide. Accordingly, video conferencing platforms quickly became the answer for the delivery of information and knowledge. Three or six months into the changes, the realization comes to the fore that direct service—and the trust and support that tends to come with spending time with individuals—is more important than immediate information or knowledge transfer.

However, the foremost message in the interview was to continue direct service to agricultural clientele whether through technological means or not, a strong reminder of the pillar of extension. The nationwide slowdown and subsequent halt of society exposed what was always there: inequality. Extension is placed in an inherently difficult position in the current social environment. Farmers and ranchers are struggling and struggling even more. Extension, as sources of knowledge and resources, have the tools to mitigate or navigate the crises. However, with the closing of society to prevent the further spread of the virus, access to those tools has been greatly diminished. The frontline rural agriculturalists—the experts—are the very people who need to be distanced from the rurally situated public. Meanwhile, the suited off-site research and resource professionals occupy a place of nearly no risk to public health. That disconnected dichotomy is the conundrum that extension faces. As the economy regains speed, societal divides will be reduced, and the ligaments that bind a community together will be re-strengthened. This is, after all, the societal culture that Extension operates within. Many of the lessons learned during the pandemic will have been forgotten by the time the next crisis hits, but in their place is a realization of the path forward. That path is one of flexibility and direct connectivity—which lies at the very core of extension—and will encompass elements digital and non.

6. INNOVATIONS IN AGRICULTURAL EXTENSION

In agriculture, extension (helping through education and training) plays the role of spreading new technological advances to the farmers. The need for institutionalization was

recognized a long time ago in India. The ambition and role of the system have been changing continuously since in response to changes in structural, socio-economic, and political changes. Of late, several innovative solutions have been developed, such as Farmer's Institutions (like FPO, Farmers' Clubs, Joint Liability Groups) and contracts between input-based industries and farmers. These are part of a greater momentum in response to weaknesses in public research systems and extension system, which are supposed to act as agricultural innovation systems. These collective institutional innovations, as a part of a wider system are blurring boundaries between research, extension, farmers, farmers' groups, NGOs, and private enterprises in agriculture (Singh, 2015). Extension must be viewed in the context of an emerging agricultural innovation system, rather than as a separate activity. This system works as a whole. Transformation of knowledge, innovations and technologies takes place through this system. Extension is one of the ways through which knowledge can be facilitated for access to and transfer among different entities in the innovation system. Hence, it must create competent institutional modes for this purpose, facilitating overall performance.

6.1 Virtual Training Programs

Restrictions on public gatherings caused by the novel coronavirus (COVID-19) pandemic drastically altered the ways in which extension education could be delivered to farmers and consumers. Traditional in-person events such as field days, workshops, and farm tours were canceled or postponed in an effort to comply with social distancing recommendations. In response, there was a rapid increase in the number of virtual training programs developed and presented using online platforms across the agricultural and ecological sectors (Main et al., 2020). Innovations in the delivery of virtual training programs in response to COVID-19 are an opportunity to examine new strategies to engage participants that continue both during and post-pandemic. When the response of attendees to virtual training programs after rapid development and implementation during the first 5 months of the COVID-19 pandemic is examined, 4-H and adult agents were interviewed on scenario-based training webinars on small ruminant livestock topics, ranging from animal evaluation to pasture management, recommended practices, and integrated pest management in Florida (VanValin et al., 2021).

The training programs varied in their design, level of audience participation, and focus as either livestock or pasture management scenarios. 4-H youth in the programs were better able to assess the animal-scenario video than were adults (93% vs. 70%; overall $p < 0.01$), but both age groups were equally likely to correctly choose the best action in response to the scenario. Conversely, 4-H age agents scored better than adults on the quiz based on viewing the pasture-scenario video in the first two training programs compared to the third. Both 4-H and adult agents' comfort teaching small ruminant livestock and pasture management topics was influenced by the number of Continuing Education Units received, with more agents indicating that they felt greater comfort on these topics as the number of CEUs increased. These results suggest that scenario-based training is an effective in-person and virtual training tool for 4-H and adult agents of varying experience and has implications for future dissemination of the training outside of Florida.

6.2 Mobile Applications for Farmers

Over the past few years, agriculture extension has relied on Information and Communication Technologies (ICT) to improve service to farmers and communications with other agricultural stakeholders. Initially, use of ICT was center-based and face-to-face with limited interactivity. However, remote sensing and Internet-based systems have been developed, new devices provide valuable data and services to agriculture and have been implemented in different countries. Among these new technologies, mobile applications/devices stand out, as the number of users increases providing economies of scale in application development and creating stronger links among all stakeholders in the agricultural chain. In fact, mobile applications keep increasing options of services useful to farmers but also open new possibilities of increased communication involving actors at all steps of the agricultural production chain. There was always strong negative feedbacks on the development and implementation of ICT projects, communicating down from the top is met with silence when they reach the bottom of the given structure and the feed up by the poor and the manpower-poorer is often met either with disinterest or disbelief (Subramanian, 2021). Mobile phones, parts and services costs have consistently fallen each year since 2000. As numbers increase, especially in rural areas, coverage and policy with existing infrastructure

improve (Sousa et al., 2019). This improves the diffusion and uptake of tech services in geographically more isolated areas, which are precisely those in which the bulk of the world's poorest people live, despite the overwhelming evidence of the utility, all this motivated the development of this form of educational videos that address the technical aspects of sustainable practices such as fertilizer micro-dosing, growing of improved variety plants and soil-nutrient replenishment. Another important impact of mobile SMS messages is the high percentage of retention of the intended message of 90% or more just after the viewing. Some of this SMS has had some specific survey questions, including some closed questions about video content. Farmers often had knowledge about main topics related to the video, whereas mean knowledge retention of other questions was very low of 17%. More than 78% of farmers replied that want more SMS related to the video as quite remarkably, despite the low number of users, the charge is out of balance very frequently. SMS messages were always related to educational video topics as well as systems that were allowed to be alerted a day before their sending date.

6.3 Collaborative Networks

Agricultural extension experts have to cope with an ever-changing global system aggravating threats to food security. Efforts to face the continuous emergence of novel pests, diseases, and other ecological challenges are compounded by obstacles directly fueled by the globalization process. The exchange of goods, technologies, and individuals across international borders has accelerated the distribution of knowledge globally. Consequently, locally based small-scale agrarian operators now have opportunities to quickly seize new chances derived from the latest technological advances or adjust to shifts in market demand. Yet, such transformations are not devoid of risks. E.g., new agricultural methodologies, fertilizers, and pesticides are often unsustainable in the long term or need to be carefully calibrated with associated co-factors ranging from water supply to post-production infrastructure. Moreover, the development of globally interconnected supply chain systems has magnified the risk of sudden and widespread interruptions due to pandemics, political disputes, or extreme climate events. However, the capacity of small-scale farmers to adapt in a timely manner to so many overlapping challenges is often constrained by educational and

informational imbalances that can amplify the inequity generated by globalization (Habiyaemye, 2021). In many settings, agricultural extension is what stands between the most vulnerable agrarian operators and knowledge derived from cutting-edge research or provided by globally established agribusiness networks. Such channeling can be effective when smallholders have access to reliable and competent extension officers. However, in low-income rural communities, such officers are often either lacking or not able to abide by reasonable standard efficiency due to resource constraints. This condition becomes especially critical during pandemics, when in-field visits and group meetings have to be avoided, and internet connection in rural areas is often unreliable.

7. SUSTAINABLE PRACTICES IN POST-COVID AGRICULTURE

At the beginning of 2020, COVID-19 swept through the world. Although the situation on the pandemic crisis has been changing rapidly, the global crisis caused by COVID-19 will last long. Although food is always one of the top priorities in the daily life of humans, the food and agricultural sectors are also suffering a big challenge of the outbreak. Chinese, the first country hit by the new coronavirus, has accumulated some experience. Chinese established a new form of food production and consumption after the outbreak, called community-supported agriculture (Fei et al., 2020). Different from industrial agriculture which is now in a vulnerable condition. Sustainable agriculture has shown its advantage in this disastrous situation. The Chinese experiences indicate that it is better to increase the consumption of local food and keep a close distance from customers when delivering food. The questions on how COVID-19 will change the consumer's attitude towards food production and consumption are also discussed in this paper. It is expected to provide some enlightenment for a resilient food system during the period when the world is still recovering from the crisis caused by the virus. The first outbreak of COVID in China can be traced back to the end of 2019. In order to prevent the spreading of the virus, most cities in China had established checkpoints at each community entrance which made it very inconvenient to go out. On the other hand, most of the community group activities were banned and the vegetable markets had few visitors.

Industrial vegetable agriculture is facing a huge access problem; however, the community-supported agriculture can easily adapt to the current situation. In this new form of agriculture, the community couriers, who lived in the community, delivered the vegetables from the farm to the community. They gained all the vegetables from a fixed farm and the way from the farm to the customer was short. The exposure time and frequency involved with strangers is much less than the traditional market channel. At that moment, the demand for industrial agriculture's vegetables begin to shrink and some of the farmers start to destroy their crops. However, at the same time, some vegetables produced under the sustainable practice were sold out. At first, people purchased those vegetables for their better resilience treatment, but latter, some people held the opinion that the vegetables produced by sustainable agriculture are cleaner.

7.1 Agricultural Extension after COVID

Lessons learned and path forward: Since the rapidly spreading COVID-19 pandemic—and its public health consequences—first officially hit South Asia on January 29, 2020, the response to it has been mainly focused on health concerns. However, it is rapidly becoming clear that the social and economic fallout of the measures adopted to contain it—particularly extended lockdowns to limit the spread of the virus—will have substantial direct and indirect impacts, including on food security (Sperling et al., 2021).

As a direct consequence, expected losses resulting from COVID-19 on India's overall GDP growth and resultant agricultural growth stems from the unprecedented crisis and therefore, necessitate the employment of growth strategies, such as climate resilient crop, drought or waterlogging tolerant crop, the establishment of minimum labor and agronomic care crops, to ensure the immense negative economic and social repercussions of pandemic be nullified as far as possible. This year's World Development Report on the importance of 'Closing the Digital Divide' is more salient now than ever. Countries that have digital capabilities can switch to alternative learning formats including online platforms, podcasts, and internet-enabled televisions. This crisis shows the urgency of adopting innovations in extension systems. Efforts to 'build back better', which will be needed once the pandemic comes under control, must build on the lessons learnt now to improve the

quality and use of digital technologies as far and as effectively as possible.

If the COVID-19 pandemic has shown anything, it is that preparedness is key to responding effectively to any crisis. The future of extension should consider lessons learned from this pandemic and put plans in place to be more effective for the next one (Farnese, 2021). Communication should be transparent. Information released and action taken should be timely and as transparent as possible. Unnecessary hardship can arise if there is inconsistent communication, causing individuals unable to respond effectively in the disaster phase. Providing transparency during the pandemic stage is also important to keep calm and energy. Frequent updates, Q&A, and potential actions being taken allow stakeholders to be prepared and readily respond. For example, farmers unprepared for border closures might not have supplies of critical inputs, like seed and fertilizer, planned for planting. A lack of transparency can also undermine the public's confidence in the resolve of authorities. Resurgence may result if measures are taken to prevent spread and can further exacerbate the negative impact of the pandemic on the economy. Avoiding this requires an aggressive approach, which is often risky. In such an instance, clear communication can better ensure that aggressive measures are taken in a coordinated way. Alternatively, inadequate or absent coordination of efforts can have the same effect. By reviewing industrial economics, it can be concluded that the market behavior of agents is determined by partial forces, where the system itself is considered to be in a state of equilibrium. If sufficient pressure is not applied in the early stages, agents will gravitate towards market behavior that accentuates the need for competitive solutions, rather than cooperative ones. So long as countries externalize the pandemic response and avoid coordination, there will be a tendency for responses to be in competition. It is time to prepare for the consequences of unforeseen global crises, such as a pandemic.

Extension has a role to play in providing the resources and information to agricultural stakeholders ahead of time, so that they will be better prepared when there is a crisis. Additionally, the pandemic will have long lasting impacts on both global and national economies. If it is disruption to knowledge that moves industries, there are additional concerns to be addressed regarding agricultural supply chains

and impacts on farmers and associated economic resources. Some supply chains have already been severely impacted by border closures causing complexed food insecurity. Another aspect to consider is the stimulus that will be given to certain sectors in order to stimulate the economy. Coordination across sectors can take place both of the national level and across borders. So long as national trade policies are protectionist and share similar trading relationships there will be the tendency for policies to be in direct competition, ultimately exacerbating the negative impacts of the pandemic on the food supply.

8. POLICY RECOMMENDATIONS FOR AGRICULTURAL EXTENSION

As a large proportion of India's agricultural extension service moved to the states, it continues to display weaknesses: some of those weaknesses include narrow focus on production goals rather than development of farm families as a unit; low level of farmer participation in planning, monitoring and evaluation; lack of transparency and of accountability to farmers; very limited input purchase; supply and yield survey information provided.

It is a time of crisis for agricultural extension. Most of the extension services that exist today were formed in the 1960s with the introduction of 'Green Revolution' seeds and government sponsored development projects. Given the emphasis on productivity enhancement and successful models and demonstrations, most extension systems followed top-down approaches of diffusion of knowledge with little or no input from needs or situation analysis and participatory learning. Observation of the impact of such approaches on resource depletion and social disorganization led to a paradigm reevaluation in the 1990s that emphasized sustainability and the limits of input-intensive agriculture (Centre for Agricultural and Rural Cooperation, 2015).

However, the changes that the current extension services are experiencing are induced by other factors. In many countries governments implemented bureaucratic management structures to control extension services that stifled any possible creativity. In order to comply with 'good governance' prescriptions of International Financial Institutions (IFIs), such services are now being restructured, privatized or downsized. As they are increasingly unable to meet the needs of the majority of farmers, a shift

to pluralistic systems is proposed, whereby state services act as leverage rather than driving force, and NGOs, private companies, or inputs suppliers play a more direct role (Singh et al., 2013).

8.1 Investment in Technology

The challenging situation in which Indian agriculture has found itself as a result of the pandemic might offer a historic opportunity for transforming the agricultural extension. Lessons from the crisis, and from the policy reactions, might be useful to identify how to reform agricultural advisory after the crisis is over. The paper reviews some of the most relevant issues coming from the crisis and discusses possible implementations addressed to improve the efficiency, accountability and adaptability of Indian agricultural extension. Recent lessons confirm the current poor conditions of agricultural advisory in India, suggesting to firmly grasp the opportunity offered by the economic recovery to change navigation in the sector. Different policy actions are suggested for each of the main areas in which the Indian system should be reformed: elaboration and use of the available knowledge, better monitoring and assessment, improved and more transparent governance system, more accountable and flexible providers.

Recently, investment in technology is taking place using a top-down approach. This is creating a substantial dividend, leading to a second wave of technology and productivity growth. The investment in technology creates revenues that can be used to make future investments, facilitating further growth and/or accelerating the rate of growth. In a multistate framework, additional investment in technology responds to the larger market and generates a spillover that is supportive of endogenous growth in the poorer state. To illustrate the plausibility of the proposed idea, a model of simultaneous technology diffusion and economic growth is tailored to a computable general equilibrium analysis of development spending in India's power and education sectors.

8.2 Training and Capacity Building

Climate change is adversely affecting the crop production and food security of millions who are already vulnerable to crises. The COVID-19 pandemic has disrupted the food supply chain in many parts of the world by reducing the labor and transportation facilities. Economic crises have also created difficulties in farm

management and operations. Agricultural extension should adapt to the new normal and play a critical role in responding to the threats. Here the lessons learned from the post-COVID era, together with a pathway for future extension services are presented.

Agricultural extension, as a form of education which is provided to farmers by using technology, is a crucial part of the farming system at the grass-root level. The economic foundation of most countries in Asia and Africa is agriculture and a significant portion of the population derives their livelihood from this sector (Lopokoity et al., 2013). The extension service assists farmers by providing improved technology in cultivation, marketing, and value addition. Agricultural extension workers have always had to adapt their services to changing circumstances including the outbreaks of epidemics of crop diseases. Due to the socio-economic impact of COVID-19 and the global food-to-plate restriction, the capacity of extension service proved to be invaluable in addressing restrictions and fulfilling the technicalities of farm operation. This is where the success or failure of adapting to extension services for agriculture relates to the viability of the farm.

The training of extension workers has always been from a conventional or face-to-face approach, which involves group meetings, counselling, demonstrations, agricultural displays, and agricultural fairs. Training should encompass not only the technical details but also other recognized needs, such as entrepreneurship development in the farm sector. However, the advent of the climate change phenomenon is a major hurdle in agriculture, which necessitates training on an emergency basis. Training farmers may improve the resilience of a system or spark broad transitions toward more sustainable farming options, which can occur when a critical mass of farmers adopt the same or complementary systems (Hauke, 2018). Group training could increase both learning and adoption of practices since farmers might better internalize new knowledge through discussions and collaboration.

8.3 Public-Private Partnerships

Extension infrastructure can be described as the human resources or frontline staff, which are the main agents in supporting agriculture stakeholders. They usually work as part of a structure that has stages and ensures the delivery of information, including farming

practices, advice, knowledge, inputs, and outputs. This extension infrastructure runs in various forms. Using extension concepts with the participation of the private sector in technology dissemination and promoting public-private partnerships. The private sector has competencies in adapting valuable services to facilitate the agriculture sector at lower prices. Agriculture production in Colombia is dominated by smallholders, thus collaboration of the private sector could significantly support agriculture in disadvantaged areas. Efforts could increase public awareness and provide better guidance on how to improve the effectiveness in extension programs with minimal financial support. An alternative model of extension infrastructure is the public-private partnership (PPP) to support agricultural development. This model engages the private institutions to provide resources, including the application of new technologies, material, finance, and knowledge, to develop the capabilities of agriculture stakeholders (Raju et al., 2013).

However, an effective partnership model depends greatly on the composition, common interests, program benefits, and well-established agreements between the parties. It is also crucial that the partnership model is supported adequately with facilitator institutions. Private institutions have no intention to become a partnership with public institutions under the circumstances lacking pull factors in the program and insufficient commitments from the public side. It is deemed necessary that the government acts impartially in managing the partnership by setting well-balanced arrangements, existence of pull factors in the program, and internal regulations guarantee the parties are treated justly (Kavitha et al., 2010). Random policies concerning the transformation of public institutions to involve private sectors in extension programs will mostly fail. Indeed, public extension agencies are required to get the mandate and support to have the ability to perform programs effectively.

9. CASE STUDIES OF SUCCESSFUL ADAPTATIONS

9.1 Local Initiatives

Global challenges have been further exacerbated by COVID-19. The pandemic of the COVID-19 has already caused an economic loss of at least 1.1 trillion US dollars worldwide, and the number for Asia was estimated to be 357 billion with the first impact on agriculture. It warned the food

security threat to the region and called for pre-emptive actions to build up the resilience of agriculture and food system. Assuming that agriculture worldwide takes similar shares in the overall economies respectively and using average shares of agriculture as GDP in agriculture-world and Asia-agriculture, a back-of-the-envelope calculation suggests that the short-term output loss in agriculture might be as high as 46 billion US dollars or 1.4 trillion domestic currencies, including the impacts on agribusiness. The overall rural economy loss might be quite a bit larger than that even without including the loss in non-farm rural economy, the damages to human assets and the long-term constriction in capital and technology investment.

A series of studies have been taking place on how the global and national policies have been affecting the agricultural and food system and what the feasible but prudent actions the local governments can take. On the other hand, frontline officials, which are even closer to the grassroots, have kept running their works and showing commitments on the achievements of poverty alleviation with good examples. Since the outbreak of the pandemic, a few provinces including Yunnan, have made prompt decision to regulate the control of live animal markets and support the supply of agricultural products to the urban markets in the controlled localities. This is an ad hoc policy designed to stabilize the public panic and minimize long-term economic loss. Importantly, trade restriction has stayed away from the agricultural products so far and vital to global food security (Fei et al., 2020).

9.2 International Collaborations

Extension educators are being stretched to fulfill their roles as educators, supporting people living in their towns, sustaining their vitality, and enhancing their competitive capabilities in the global marketplace in times of COVID-19. In fact, experts tend to focus on historical and philosophical underpinnings of the Extension mission to seek direction regarding policy decisions in current and future international Extension programs. Some experts are calling for a focus on the respective domestic missions to be followed by steps for Extension's involvement in overseas programming (Extension Service, 1967). This paper endorses a continuation of the historical practice of overseas assignments for qualified personnel in US universities and backs recommendations to

help equal or exceed levels of commitment seen in earlier years. To affect such a recommitment, step-by-step suggestions for additional and modified policies are proffered.

10. FUTURE DIRECTIONS FOR AGRICULTURAL EXTENSION

During the last five decades, the national and international development communities have made large investments in agricultural extension and other services intended to strengthen the ability of developing world's farmers to improve their livelihoods. However, these investments have not been as successful as desired by either the development community or farmers. The development community is coming increasingly to recognize that the approach to extension it has historically supported is unsustainable, particularly given expanding populations and constrained resources. The community's thinking on extension changes continually as different approaches achieve prominence and others are discarded as ineffective. Within the international community, there have gone from an early emphasis on specific delivery of technology to farmers by public extension agents, to involve the private sector and farmer organizations, and finally to devolve virtually all responsibility for extension to the private or NGO sector. The merits of various approaches have been debated hotly, most often either with dogmatic loyalty to one view or with disregard for the subtleties of each approach and its application. Equity, employment generation, and the environment have captured the attention of development agencies, along with the ever-persistent concern for increased food production (Devi et al., 2023).

For much of the past 50 years, extension education has been practiced predominantly in the developing world by public-sector agencies that disseminate technology packages to farmers. Often these agencies have operated very large, bureaucratic systems that are characterized by weak linkages between research and extension, top-down information flow, and low levels of farmer participation. Extension agencies have been among the most resistant to change and to dialogue with farmers, who still are sometimes viewed as "backward" and "illiterate." The "training and visit" system, introduced by various projects, and various public-sector provision subsidy schemes has perpetuated extensions' negative image as deliverers of goods and services

and continue to inhibit investment by the private sector in the provision of extension services. In the past decade, critics have maintained that extension services rarely reach more than 20% of potential clientele and, where they do, they tend to concentrate only on large and more financially secure farmers.

10.1 Integrating New Technologies

As the world fights the COVID-19 pandemic, the agricultural sector finds itself facing new challenges. Governments are desperate to quell economic instabilities by ensuring food security for the nearly 8 billion people on the planet, while lockdowns and restrictions on movement are hampering traditional agricultural activities and disrupting food value chains. The agricultural sector will therefore need to "bounce back better" through the application of new tools and strategies; this text contends that agricultural extension services must adapt to the post-COVID era by integrating emerging technologies and novel approaches. It will attempt to present some lessons learned from past crises and draw some conclusions on how agriculture and agri-entrepreneurship should be supported coming out of the COVID-19 crisis.

Agricultural extension services stand at the crossroads of agricultural production and related research, policy and market information. Unique in its multi-faceted approach, agricultural extension workers are expected to provide smallholder farm families with up-to-date information on agricultural best practices through training, awareness-raising campaigns, demonstration plots and linkages to market actors. Agricultural extension has the potential to increase the competitiveness of the agricultural sector and ensure food security for smallholder farmers, yet its relevance and impact are often debated (Centre for Agricultural and Rural Cooperation, 2015). It is in the wake of crises that the critical role of agricultural productivity and sustainable agriculture becomes not only evident but also critically positioned for swift adaptation together with the capacities it nurtures. In light of the 2007-2008 economic collapse, a significant rise in development funding towards agriculture took place, ultimately improving the capacities of agriculture extension to fulfil its advisory role. The 2001 outbreak of foot-and-mouth disease in the UK led to an urgent need for information and

advice among a crisis-stricken farming community, which was effectively provided by a stakeholder-driven rural information campaign.

10.2 Enhancing Stakeholder Collaboration

The COVID-19 global economic downturn is bringing about a dramatic increase in the number of people living in extreme poverty, while continued poverty and hunger are likely to increase the occurrence of social unrest in many developing countries. Ensuring secure supplies of raw food is essential for future food security globally, but the current global socio-economic and political context implies that food production will have to be notably increased in some countries to secure supply all year round. Historically, agricultural subjects have played a significant role in previous economic recoveries. How to shape the needed strategies to re-stimulate and boost post-COVID recovery in the agricultural zone? In the COVID-19 period and post period, consultation with epistemic communities from the South African academic domain is vital to test the practicality of drawing upon the knowledge of researchers to address urgent needs stressing the social and economic resilience of agriculture and rural communities (Habiyaremye, 2021). Empowering smallholder farmers with the necessary knowledge and skills is fundamental to increase and diversifying agricultural productivity, ensuring income generation, and alleviating poverty in agrarian-based countries. The development of high-yielding farming systems requires efficient use of quality seeds, natural resources, and labor, advanced skills and knowledge; funds; and, where appropriate, access to credit and insurance services. The agency and institutional failures faced by smallholder farmers in the Global South aggravate their difficulties to operationalizing advanced farming methods and technologies. Inadequate agricultural planning is a significant inhibitor that can be addressed by enhancing the effectiveness of knowledge exchange within governance structures. Sustainable agricultural growth is supported by effective collaboration between smallholder farmers, research academia, policymakers, and the private sector in the transfer and translation of such expertise and technologies. The extension services are considered as a transmission channel of this knowledge, providing education and promotion activities in

agricultural domains. The agriculture extension agents establish a two-way flow of information, demonstrating the reinforcing linkage between stakeholders. They disseminate modern agrarian technologies and are responsible for the acquisition of smallholders' feedback reflecting the utility, approval, and their eventual constraints and demands regarding these innovations (Arif et al., 2014).

11. CONCLUSION

The COVID-19 pandemic disrupted traditional agricultural extension mechanisms, revealing both vulnerabilities and opportunities within the system. Lockdowns, mobility restrictions, and market disruptions underscored the need for resilient and adaptable extension services. Despite initial setbacks, the crisis prompted significant innovation, especially in the adoption of digital tools, virtual trainings, and ICT-based advisory services. These adaptations allowed extension agents to continue supporting farmers, albeit remotely, ensuring the continuity of food production and knowledge dissemination. Importantly, the pandemic highlighted the digital divide and systemic limitations in infrastructure, resource availability, and communication strategies—areas requiring urgent attention.

As the world transitions into the post-COVID era, agricultural extension must evolve into a more integrated, inclusive, and technologically empowered system. Strengthening public-private partnerships, investing in digital literacy, enhancing communication networks, and prioritizing sustainable practices are essential to future-proof extension services. The lessons learned during the pandemic provide a blueprint for building resilient extension systems capable of responding swiftly to future crises. Ultimately, reimagining agricultural extension with flexibility, community engagement, and technology at its core is not just a necessity but a strategic imperative to ensure food security, rural development, and sustainable livelihoods in a rapidly changing global landscape.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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