Role of ICTs

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Applying agricultural ICTs solved many obstacles related to the production process, such as maintaining precision farm management (25.6%), product marketing (23.6%), and access production inputs (16.1%).

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1. Introduction

Globally, the agricultural sector (crop and livestock production) accounts for approximately one-third of the total gross domestic product [1]. In addition, agriculture is the main source of income for farmers in most developing countries. Moreover, it provides human food and raw materials for many industries and contributes to environmental ecology. Approximately 60% of the world's population depends on agriculture for survival [2]. Recent statistics announced by the Food and Agriculture Organization (FAO) and United Nations revealed that the pressure on the agricultural sector is increasingly growing, as the current world population (7.3 billion people) is expected to increase by approximately 33% and to reach 9.7 billion by 2050 [3], with around 113 million people suffering acute severe food insecurity [4]. Furthermore, agriculture can play a role in zoonotic disease epidemiology by changing land use (deforestation) and biodiversity. For example, intensive livestock production systems, which encompass large numbers of animals with low genetic diversity, may amplify pathogens and provide them with an opportunity to mutate and become transmissible to humans [4][5]. The emergence of the ongoing coronavirus disease 2019 (COVID-19) pandemic caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its concomitant difficulties in production and trading management has worsened the challenges faced by the agricultural sector, compromising the sustainability of the agricultural sector and exposing the workers in this sector to lose their livelihood source.

2. Knowledge of Agricultural ICTs before and after the COVID-19 Pandemic

The results of the present cross-sectional study reveal that regardless of the emergence of the COVID-19 pandemic, most respondents working in the agricultural sector had sufficient knowledge of agricultural ICTs and their benefits. These results reflect the global direction toward using agricultural ICTs, the Internet, big data analysis, and other technological services in different economic and social sectors as an ongoing trend of globalization [6][7]. Farmers and other agricultural stakeholders now have a good awareness of the new agricultural ICTs and their beneficial returns on their farming systems. They believe that digitalization is a new path, which can fundamentally change the way of communication among suppliers, processors, manufacturers, retailers, and other stockholders involved in agro-livestock farming systems. This concept is supported by our findings, as approximately 50% of the respondents indicated that they used at least one of the agricultural ICTs as a routine application in their agribusinesses even before the emergence of the COVID-19 pandemic. The same conclusion can be made on the basis of the availability of agricultural ICTs and the ease of handling, as most respondents scored high values (very easy, easy, and intermediate) for these variables. However, the subgroup analyses of our data revealed the need to pay further attention to some categories to develop their skills toward agricultural ICT use and to improve the affordability of different agricultural ICTs for them. Stakeholders belonging to developing countries, small holders, and laborers expressed some difficulties in the use and availability of agricultural ICTs. These findings are in agreement with those of other previous studies that reported the importance of supporting vulnerable groups, specifically in developing countries (South Africa [8], Sub-Saharan Africa [9], and China [10]), and how such support can ensure the transformation and integration of digital technologies necessary for readiness and innovation process [10].

Interestingly, a high percentage of these categories revealed that they started to use agricultural ICTs after the emergence of the pandemic. Thus, the emergence of the pandemic has encouraged such categories to use agricultural ICTs to solve production obstacles and maintain their agribusinesses sustainability while maintaining social distancing instructions. In

general, during the pandemic period, digital technologies have emerged as essential tools to disseminate and share information through various digital platforms and social media as solutions for social distancing measures [11][12].

Notably, a high percentage of the respondents, who had not previously used agricultural ICTs, shared that they did not use agricultural ICTs due to high prices, unaffordability, and/or their ignorance about these technologies. Increasing the investment in digitalization technologies can support the agricultural sector in developing countries and help small-scale farmers yield far-reaching benefits long after the pandemic has passed. However, it requires increasing efforts and strong partnerships among governments, businesses, and farmers, including a regulatory environment, to ensure that technologies remain affordable and accessible, either under normal or extreme conditions [13]. The transfer of agricultural ICT approaches must adopt flexible and adaptable strategies, which can be initiated by applying simple strategies, such as regular extension programs and on-farm trials [14].

The revolution of agricultural digitalization has led to the development of different ICTs with a wide range of applications, which can be applied along the agricultural supply chain to support the resilience and sustainability of all key elements of this chain. Currently, several innovative agricultural ICTs may be applied in the agricultural sector, including cloud computing/big data analysis tools, artificial intelligence, machine learning, digital communication technologies (mobile phones), digital platforms (e.g., ecommerce platforms, agro-advisory applications, and e-extension websites), precision agriculture technologies (sensors and wearable devices), advanced imaging technologies (satellite and drone imagery), and automated machinery and agricultural robots [15]. In this study, the most commonly used agricultural ICTs by the respondents, either before or after the emergence of the pandemic, were social media (Facebook and/or WhatsApp), online platforms and Internet services, mobile applications, and interactive voice response. In contrast, agricultural ICTs, including wearable and sensor technology and robotic vehicles, were less frequently used. Nevertheless, both were among the major technologies used in developed countries, specifically during the period of the pandemic emergence. These findings are consistent with those reported in similar studies [16][17]. For example, Madushanki et al. [17] indicated that Wi-Fi and mobile technology are the most frequently used technologies by applicants involved in the agriculture and farming industries. Together, these results reflect the importance of the affordability, price, and ease of use of these technologies. Most technologies, which depend on mobile phones and Internet services, are easy to use and available at acceptable prices, thereby making them the common agricultural ICTs used in the agricultural sector. Today, most farmers have mobile phones and thus can easily receive targeted agricultural advice through simple texts or voice messages even without accessing the Internet. The use of such simple technologies has led to real advancements in the agricultural sector in many countries. For example, in Odisha, India, the Precision Agriculture for Development organization has delivered free agricultural advice to almost 800,000 farmers through their phones and to other farmers in Bangladesh, Ethiopia, India, Kenya, Pakistan, Rwanda, Uganda, and Zambia [13]. ICTs play an integrating role in research–extension–farmer linkage. Mobile and Internet-based technologies are not only limited to deliver agricultural extensions but also can help farmers and stakeholders access production inputs and follow consumer demand and product marketing [8].

3. Impact of the COVID-19 Pandemic on the Agro-Livestock Production Systems and Consequences on Agricultural ICT Development

Regarding the role and importance of the agricultural ICTs during the emergence of the COVID-19 pandemic, the spread of this pandemic is widely believed to have strongly impacted the agro-livestock production systems worldwide [15][18][19]. The agricultural key supply chains have been interrupted at different levels due to movement restrictions, lack of production inputs, market closure, shortage of agriculture labor, and constrained currency liquidity [20]. Thus, global supply chains in the agricultural and food industries have struggled to cope with panic buying, followed by forced changes in food consumption patterns and large declines in incomes [21]. Our cross-sectional study confirmed such production obstacles during the pandemic period, specifically social distancing, shortage of labor, and precision farming management. The subgroup analyses of our data revealed the presence of some specific production obstacles; for example, the respondents belonging to developed countries indicated that the shortage of labor was one of the specific production obstacles. It reflects how the pandemic has caused a great shortage of labor, which presents a real problem for developed countries relying on imported workforce and foreign migrated laborers [22]. In addition, the subgroup analyses suggested that product marketing was the main production obstacle that challenged those belonging to developing countries and small-scale agribusiness owners. These findings may reflect the negative impacts of the pandemic on the trade and purchasing empower, affecting the agribusiness sustainability of these vulnerable subcategories.

Interestingly, as inferred from the respondents' answers obtained in this global survey on agricultural ICTs conducted after the onset of the COVID-19 crisis, applying agricultural ICTs during the pandemic period has been found to be effective in solving production obstacles, including precision farm management, product marketing, and social distancing and movement restrictions. Many farmers, specifically those involved in livestock production systems, have imposed the

repopulations of animals in their farms, discarding and killing animals due to weak consumer demands for animal products and surplus animal products [20]. Moreover, dairy farmers have to dump thousands of milk gallons, which conflicts with the food security concept and contributes to global food insecurity crisis [23][24][25].

Finally, the results indicate for the first time after the onset of the COVID-19 crisis that there is an international/global trend toward the digitalization of the agricultural sector, as most respondents belonging to different geographic regions either in developing or developed countries revealed that the agricultural ICTs are financially supported by their authorities and governments. However, more support is still required since a similar percentage of the respondents revealed that they personally support the agricultural ICTs that they use. Governments need to take vigorous steps to facilitate agricultural ICTs use by different stakeholders of the agricultural sector, emphasizing increasing knowledge of the benefits of such technologies and improving stakeholder skills to use all available agricultural ICTs including those of high technology such as robotics and drones. This would consequently contribute to empowering the role of the agricultural sector to cope with increasing food demands and to sustain the resilience of the food chain in face of unexpected crises such that has raised following the emergence of the COVID-19 pandemic [26].

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