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Review

The Opportunities and Barriers in Developing Interactive Digital Extension Services for Smallholder Farmers as a Pathway to Sustainable Agriculture: A Systematic Review

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Abstract: Digital extension services (DESs) play a crucial role in transforming the agri-food sector while creating the potential to enhance production towards sustainable development via ensuring resource efficiency, environmental resilience, and economic viability for smallholder farmers. However, there is less research on the availability and quality of digital advisory information to provide the foundation for the ways forward to ensure accessible and timely benefits of science-based extension and innovation for smallholder farmers. This study used a systematic review method to explore the opportunities and barriers to develop interactive DESs in developing countries (2005–2021). Features of 141 articles were summarized resulting in the identification of 13 opportunities and 21 barriers. Opportunities indicate that interactive DESs were the best source for learning and the exchange of information/ideas/experiences, useful for enhancing agricultural productivity and profitability, creating network collaboration among farmers and stakeholders, and making extension service delivery cost-effective. Barriers of interactive DESs include a lack of a two-way interaction information, lack of a centralized information network between farmers and service providers, lack of technical know-how on ICTs, poor internet connection, and lack of effective training on ICTs. However, farmers' awareness, motivation, and readiness to use interactive DESs has increased in several countries. It is therefore a great opportunity to invest in digital platforms as a long-term intervention to boost sustainable agricultural sustainability.

Keywords: digitalization; opportunities; barriers; review; smallholder farmers; sustainable agriculture

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1. Introduction

Smallholder farmers often find themselves ensnared in a recurring cycle of low productivity and grappling with constraints related to agricultural product market issues, including challenges in accessing information services, technologies, and financial services [1]. A pivotal governance question arises regarding the effective alleviation of technology information and market access constraints faced by smallholder farmers. In recent years, the

increase in mobile phone usage has leveraged information and communication technologies (ICTs), such as text messages, training videos, and interactive voice response services, enhancing the delivery of market and weather information to farmers' households [2,3]. Additionally, the high adoption rate of high-speed internet connections and smartphones revolutionized new approaches to digital extension services [4]. The integration of cloud services, affordable open-source software, and big data analytics has enabled emerging economies to invest in innovative agriculture technology platforms that can tailor extension information based on farmers' individual needs and conditions [5]. This is facilitated by the synergy of predictive analytics and machine learning algorithms, consolidating data on weather forecasts, soil conditions, market pricing, and individual farmer characteristics to formulate and dispense site-specific agricultural recommendations [6].

Traditional extension services have faced limitations stemming from a dearth of extension personnel, expertise, outdated market access information, timeliness issues, and inadequate information storage [7]. Consequently, the integration of digitalization becomes imperative to surmount these challenges by leveraging various ICT tools [8]. Within the agricultural sector, the interactive digital extension services (DESs) are assuming an increasingly pivotal role in reshaping the agri-food sector as well as creating the potential to enhance production and mitigate the impacts on national and global food security [4]. There were several studies conducted which showed that understanding advantages and disadvantages of interactive DESs is critical to support farmers' access to agricultural information for sustainable development [9–13]. For example, the main findings of these studies showed that if interactive DES systems satisfied the users' expectations and requirements they would be an effective tool for the institution, extension services unit, and community to make better strategic decisions and extension agents could answer questions with a reduced workload compared to conventional communication channels. Additionally, many disadvantages of interactive DES systems were mentioned in these studies, such as slow internet connectivity, lack of infrastructure in remote areas, lack of trust in the received information, lack of capacity of extension workers, etc. Although there have been many studies on interactive DESs, most of them have mainly focused on case studies and there has been a lack of systematic reviews on this topic. The absence of comprehensive or systematic reviews on the availability and the types and quality of digital advisory information has resulted in a lacuna, impeding the establishment of a solid foundation for ensuring the accessibility and timely benefits of science-based extension and innovation for smallholder farmers. Thus, the systematic review can identify gaps in the literature and provide evidence-based insights to inform future studies and policy-making. In the absence of such an evaluation, the complete extent and consequences of our current knowledge remain ambiguous, and the potential to enhance DESs for smallholder farmers may be overlooked. Therefore, this systematic review undertakes an exploration of the opportunities and barriers in developing interactive DESs for smallholder farmers, aiming to serve as an effective tool in supporting advisory systems, and improving the governance of DESs as a pathway to sustainable agriculture. This systematic review offers policy makers significant insights for developing supportive frameworks and policies that enhance the adoption and scalability of public investment in interactive DESs. Furthermore, this review aims to direct future studies towards addressing the research gaps identified in this extensive collection of literature evaluations. This review seeks to address two main questions: (1) what are the opportunities presented by interactive DESs and (2) what are the barriers of interactive DESs in the agricultural sectors?

The structure of this paper is organized as follows: Section 2 delineates the methodology employed for the systematic literature review, elucidating the distinct steps involved in scrutinizing scientific peer-reviewed articles. Following this, Section 3 provides a pre-

sentation of the key findings, succeeded by a comprehensive discussion in Section 4. This paper culminates with a conclusion in Section 5 that accentuates the implications for future research and practice.

2. Research Methodology

The systematic review has gained prominence across various disciplines, notably in health research, and has witnessed a growing application in environmental studies, encompassing domains such as climate change, water policy, and food security [14,15]. In contrast to conventional review methods, the systematic review affords a comprehensive evaluation of the existing knowledge landscape, employing a rigorous and transparent methodology with the explicit aim of mitigating reviewers' selection and interpretation biases [16]. Consequently, the systematic review methodology necessitates a structured approach in the processes of searching, selection, and analysis [17]. Specifically, the method entails the use of clearly defined key search terms and unambiguous inclusion and exclusion criteria to facilitate the judicious selection of eligible literature.

2.1. Selection of Search Keywords and Databases

The identification of key search terms commenced with an initial exploration for publications referencing DESs or digitalization in the agricultural sector. The objective was to comprehensively capture all relevant keywords associated with the topic. Subsequently, the identified keywords were systematically organized into three distinct blocks: the first block for media devices; the second block for service contents; and the third block for farming components (see Table S1). A comprehensive search was conducted across combined databases, including Scopus, Thomas Reuter Web of Science (WoS), and CABI, to encompass a broad spectrum of related literature. This approach aimed to prevent any geographical bias by covering diverse subjects, thereby avoiding a selection bias towards exclusively European (Scopus) or American (WoS) articles [16]. The configuration of the search was tailored to the specific characteristics of each database (see Table S2).

2.2. Inclusion and Exclusion Criteria

Several inclusion and exclusion criteria were applied to refine the scope of the search. First, the inclusion of eligible papers was limited to the period between 2005 and 2021. The starting year, 2005, was chosen because of the following: (1) a large number of people had access to the internet with a 1 billion virtual population while 3 billion people worldwide used cell phones by the end of the decade and (2) devices for Web 2.0, social media, smartphones, and digital TV have strongly developed. Second, subject areas were focused on environmental, social, and agricultural sciences. Last, only peer-reviewed journal publications published in English and available electronically were selected. Publications in other languages, as well as books, book chapters, and gray literature, were excluded. After removing duplicate records, the final database comprised 4935 articles (Figure 1) from an initial 6199 retrieved articles.

The next step covered the manual scanning of titles, abstracts, and keywords which allowed a more progressive focus. Articles related to interactive DESs in the agricultural sector were included while those unrelated were excluded; for example, articles on formal education, health, and traditional extension services, etc. (see Table S3). As a result, 1022 articles were selected for full-text reading while 3913 articles were excluded. The full-text reading of selected articles was classified into 6 groups: (i) articles focused on roles of DESs; (ii) articles focused on barriers of DESs; (iii) articles focused on opportunities of DESs; (iv) articles focused on households' characteristics; (v) articles with interactive DESs; and (vi) other articles. The group with interactive DESs also included articles with roles, and/or

barriers, and/or opportunities, and other research issues but focuses on interactive DESs. According to the definition provided by the Food and Agriculture Organization, interactive DESs entail the delivery of advisory services through various means, including context-specific text messages, interactive voice responses, smartphone applications facilitating access to multimedia advisory content, farm inputs, and potential buyers. Furthermore, this approach incorporates the utilization of satellite systems and drones for the analysis and enhancement of farmer activities. Using this definition of DESs, the sample size of the systematic research was further reduced by selecting only articles in the interactive DES group. The articles with only one-way communication DESs were not selected, except for the combined conventional services and interactive ones. These criteria resulted in 141 relevant articles discussing opportunities and barriers of farmers using interactive DESs. The identification of indicators for analyzing the information collected from the 141 selected articles depended largely on the research questions and research objectives. The main indicators included regional focus, year, thematic scope, type of DESs, opportunities of DESs, and barriers of DESs. Based on the research objectives, the analysis of indicators was identified in detail and interpreted in Table S4.

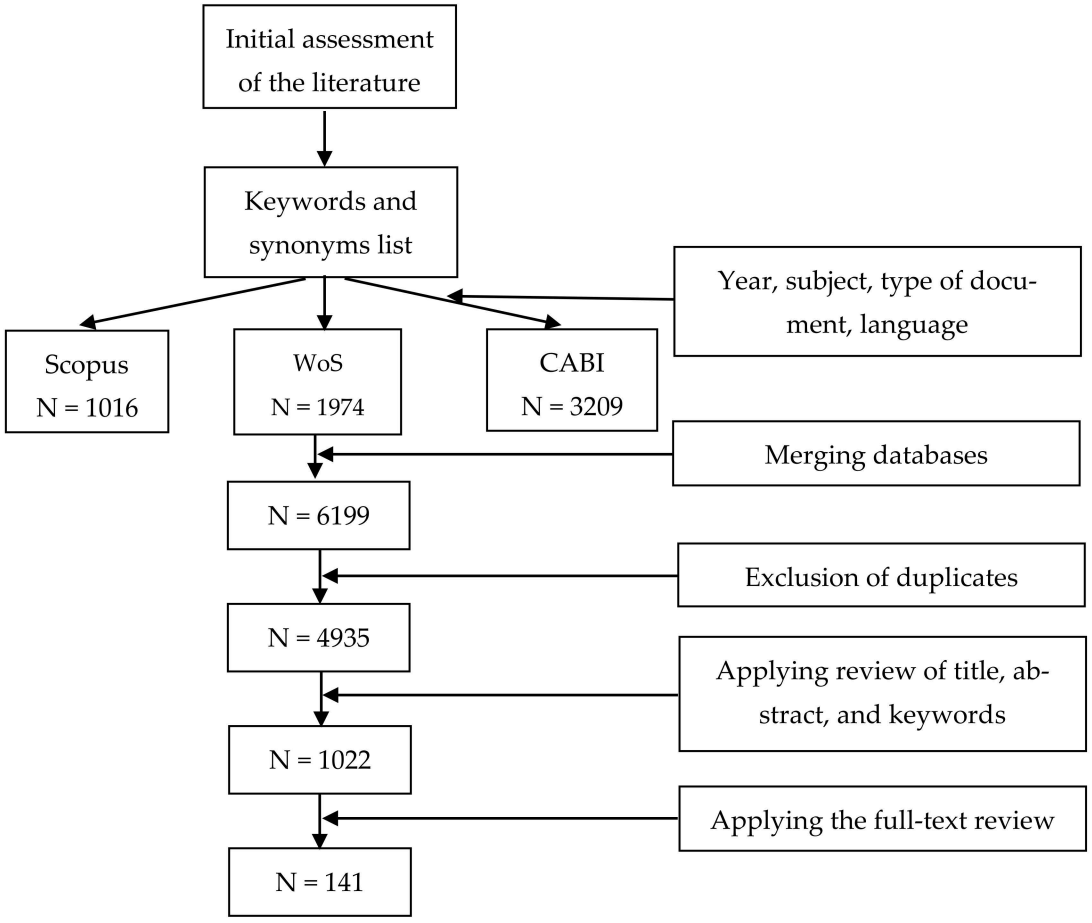

Figure 1. Data collection for systematic review process.

2.3. Research Limitations

While systematic reviews are meticulously designed to achieve comprehensiveness and transparency, it is essential to acknowledge and address certain limitations inherent in this research for future considerations. Firstly, the focus was exclusively on published peer-reviewed articles in the English language, thus excluding valuable insights from gray literature, books, and book chapters. Secondly, despite the incorporation of precautionary measures in the research design to encompass all pertinent keywords and search queries, it

is conceivable that some articles within the searched databases might have been inadvertently excluded due to variations in terminology or keyword usage. Thirdly, the review's scope was confined to three specific databases, potentially limiting the scope of the analysis, as other databases could have yielded additional relevant articles. Lastly, this study built a search query and timetable for searching the articles in 2021. Reviewing and analyzing articles took quite a lot of time. In addition, reviewing articles when sending the manuscript to journals also requires a certain amount of time, so the final number of reviewed articles was determined in 2021. Future studies should be mindful of these limitations and may consider broadening the inclusion criteria to enhance the comprehensiveness of the review.

3. Results

3.1. Descriptive Results

Figure 2a–d present a descriptive overview of our systematic review results for the 141 articles. The years in which documents were published show an upward trend from 2015 onwards (Figure 2a). The number of studies on interactive DESs has increased rapidly. More than 79% (n = 111) of the analyzed papers were published after 2015. Although the systematic review started from 2005, none of the papers were published before 2007. While there were no published papers before 2007, they increased to six and eight in 2014 and 2015, respectively, and thirteen and twenty-two in 2016 and 2017, respectively. This observation confirms the notion that the digital transformation provided the impetus for increased research on interactive DESs in general [18]. Figure 2b shows that a large proportion of the included articles focus on the African countries (42%, n = 59) and Asia (37%, n = 52), providing a total of 111 articles. A relatively small proportion of the literature covered other regions, including Europe, America, and Australia with 5%, 6%, and 1%, respectively. Nine articles did not mention any particular country or region.

In terms of thematic scope, the majority of reviewed articles focused on five categories: information services (n = 104), methods for applying digital technologies (n = 16), farming education (n = 10), digital technologies (n = 9), and payment for ICTs (n = 1). Studies on services for digitizing agricultural products or applying digital technologies in predicting the tendency of agricultural production or markets were rarely mentioned in the reviewed papers [8,19,20]. The majority of studies (n = 103) implicitly referred to barriers and opportunities when farmers access information through digital devices (e.g., [15,21–26]).

Regarding the thematic focus of information service provision (Figure 2c), this study analyzed the types of information provided in the reviewed articles more in depth. According to the synthesized analysis of 104 reviewed articles, we divided the information into three main groups: input information for agricultural production (e.g., [25]), output information for products (e.g., [21]), and general farming information (e.g., [27]). The results showed that 88 reviewed articles mentioned input information for integrated farming (n = 40) (e.g., [28,29]), crop production (n = 19), agricultural extension services (n = 9), livestock production (n = 6), aquaculture (n = 6), agro-weather information/climate services (n = 5) (e.g., [30]), and irrigation systems (n = 3) [31–33]). Regarding output information for products, there were 10 reviewed articles that mentioned digital platforms/e-commerce (n = 3) [23,34,35] and agricultural marketing (n = 7) (e.g., [20,36–39]). Only 6 reviewed articles were about general information provision, such as rural development (n = 2) [28,29] or agricultural development (n = 6) [2,27,32,40–42] (see Figure 2d), while only 11 out of 141 reviewed articles mentioned gender issues. This indicates that gender issues in DESs are less prioritized as an issue in interactive DES studies from 2005 to 2021.

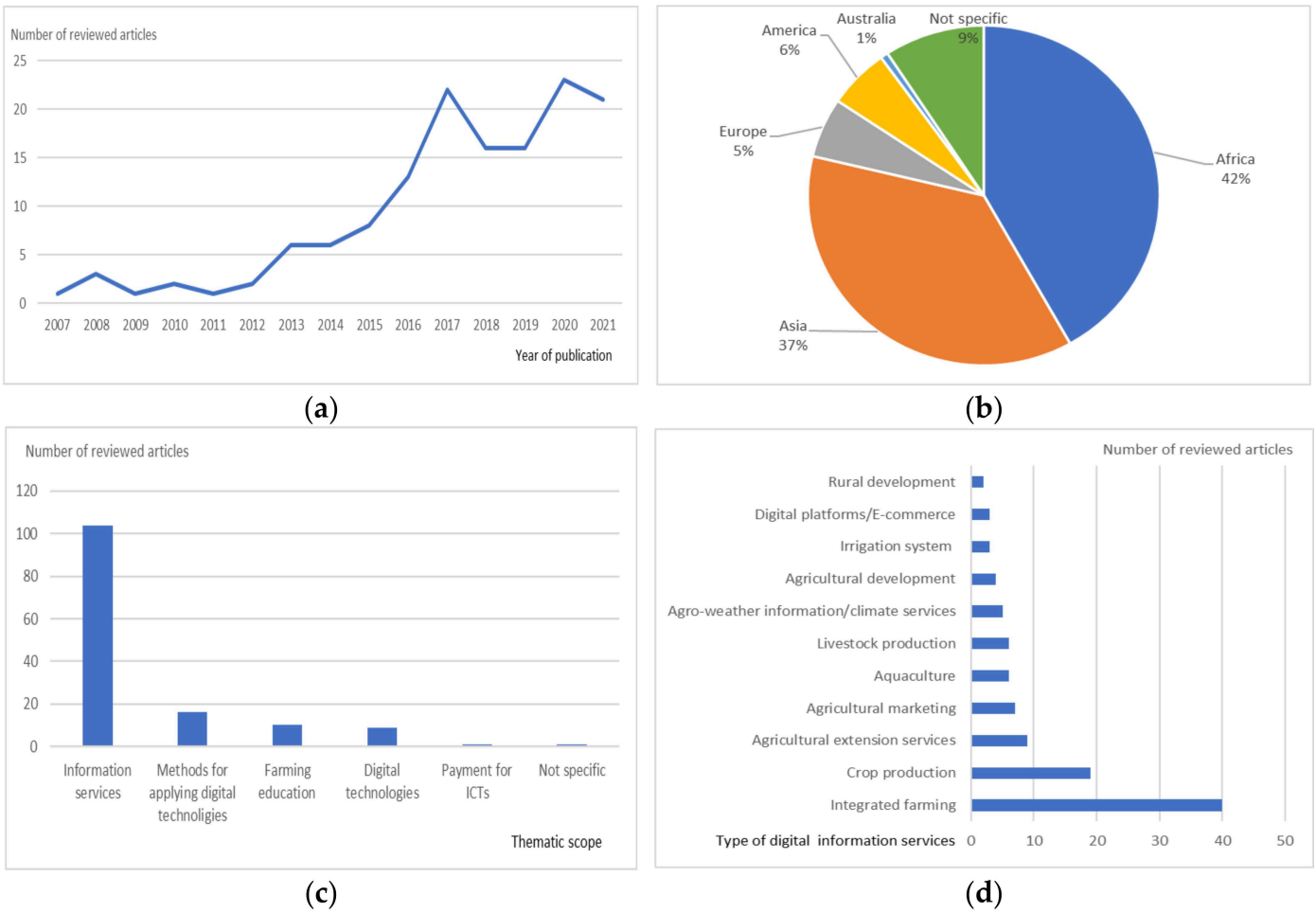

Figure 2. (**a**) Number of publications by year; (**b**) regional focus; (**c**) thematic scope of articles; and (**d**) types of digital information services.

3.2. Types of Digital Extension Services

In the analysis of the 141 scrutinized articles, to ascertain the types of DESs, priority was accorded to discerning the digital devices utilized by farmers for receiving and exchanging information. The identification of digital devices was conducted through statistical methods, relying on the frequency of occurrences within the reviewed articles. This approach facilitated a quantitative assessment, enabling the characterization of prevalent digital devices employed through digital extension services. The result of the meta-analysis in Figure 3 shows that smart mobile phone devices were mentioned the most in reviewed articles with n = 138, accounting for 97.9% (e.g., [43–50]); followed by computers with internet connection mentioned in 54 articles, accounting for 38.4% (e.g., [33,51–54]). Farmers used other devices to receive information such as mobile phones without internet connection (e.g., [55,56]), radio (e.g., [57–59]), television (e.g., [60–62]), ICT in general (e.g., [63–69]), and DVDs (e.g., [70–72]), which appear in 21, 16, and 5 of the reviewed articles, respectively.

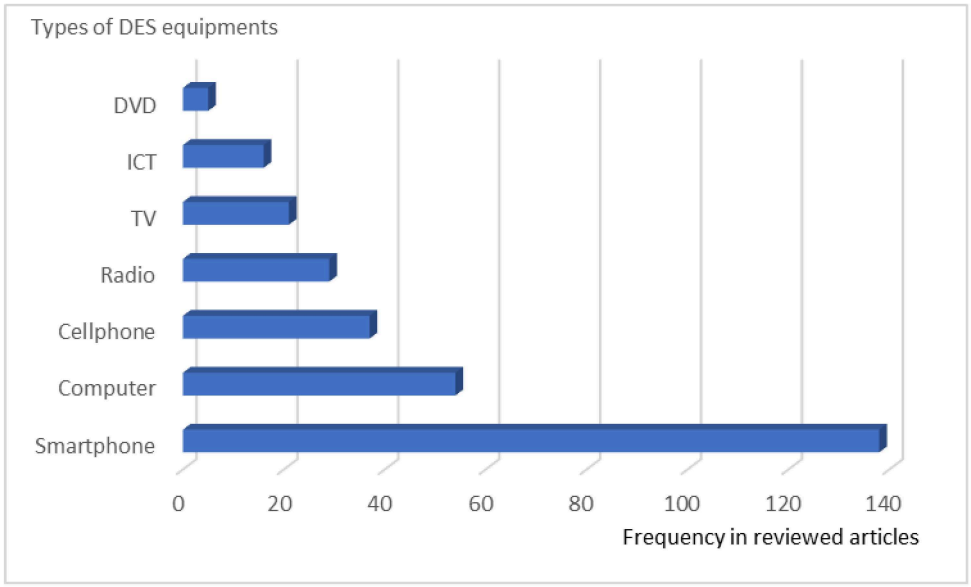

Figure 3. Types of digital extension service devices.

The analysis of the reviewed articles showed that the smartphone was the most convenient device used to receive and communicate agricultural extension services due to its ease of use in combination with low costs for equipment and sim cards (3G or 4G services), including the low cost for electrical charging (n = 111) (e.g., [21,32,46,73–75]). According to several authors (n = 87) (e.g., [30,71,76]), computers have become more common among farmers to receive and exchange information, through sending emails or participating in forums and other communication platforms, or store information for production planning. However, the analysis from different studies showed that the use of computers is only suitable for the target group of young farmers with relevant knowledge and skills and those with economical and regulatory conditions as well as large-scale production [10,77,78]. Other types were not disseminated for reasons such as being inconvenient (like radio, e.g., [79–81]), depending on the source providing the information (as with television, e.g., [82–85]), or not being suitable for information that needs to be fast and timely (as with DVDs, e.g., [2,40,41,86–88]).

With DESs, the results of the reviewed articles identified six types of services, which included input information services for agricultural production (n = 94) (e.g., [89–91]), output information services for agricultural products (n = 9) (e.g., [92,93]), ICTs using technical consulting services (n = 16) (e.g., [21,76,92–94]), training services (n = 10) (e.g., [95,96], technical provision services in agricultural production (n = 9) (e.g., [97–99]), and only one article mentioned the service of the commercialization of products (putting agricultural products on the floor and digitizing agricultural products) [100].

The types of services used is determined by the farmers' behavior and the convenience and effectiveness of a particular service [28,101]. Findings from the review show that farmers mainly used voice-based, short message services and messages from social networks (including text, voice-based, video calling, or video sending) to receive and give feedback on information [28,34,92,93,101–103]. In addition, farmers' preferences were to use voice- or text-based services in order to obtain farm information [104,105]. The reasons put forward are that information providing services in the form of voice-based short message services or messages from social networks are convenient and less demanding in terms of literacy and mobile phone operating skills [19,106,107].

3.3. Opportunities in Developing Interactive Digital Extension Services in Agricultural Sector

Table 1 indicates the perceived opportunities of interactive DESs in the agricultural sector for smallholder farmers. The results from the reviewed 141 articles indicated that interactive DESs were considered the best source for learning and exchanging information, ideas, or experiences (71.6%, n = 101) for farmers compared to traditional extension services (e.g., [108–112]). A total of 54.6% (n = 77) of reviewed articles agreed that interactive DESs can be useful for enhancing overall agricultural productivity as well as profit and income for farmers (e.g., [72,113–116]). A total of 51.1% (n = 72) of reviewed articles mentioned that interactive DESs enabled the creation of networks and collaboration among farmers and different stakeholders, such as extension workers, agricultural policy makers, or service providers (e.g., [8,15,117–119]).

Table 1. The opportunities of interactive DESs in the agricultural sector (percentage of articles (number of articles)).

#	Opportunities in Developing Interactive DESs in the Agricultural Sector	% (n)
1	Best source for learning and exchanging information/ideas/experiences	71.6 (101)
2	Useful for enhancing overall agricultural productivity/profit/income	54.6 (71)
3	Creating networks and collaboration among farmers and different stakeholders	51.1 (72)
4	Make extension service delivery more cost-effective	40.4 (57)
5	Facilitate the process of farm input procurement (information, financial, fertilizers, pesticides, weather, climate, making plan, and input supplier)	39.7 (56)
6	Facilitate the marketing of products (supply chains and prices)	36.9 (52)
7	Improve price negotiation capacities, find alternative markets, and enable them to timely sell or buy at better prices	33.3 (47)
8	Faster and easy access to information (saving time)	33.3 (47)
9	Contacts between farmers and extension workers	32.6 (46)
10	Saving or reducing cost for searching quality information	35.5 (50)
11	Useful for adoption and diffusion of latest agricultural technologies	24.8 (35)
12	Further reduce the operational costs and raise revenue from information services	22.0 (31)
13	Inspiring and attracting rural youths into agribusiness activities as it makes market information accessible	6.4 (09)

One of the opportunities, according to 57 reviewed articles (40.4%) (e.g., [55,73,120,121]), that interactive DESs bring to the agricultural sector is making extension service delivery more cost-effective. Based on the analysis of the 141 reviewed articles, it is evident that interactive DESs present substantial opportunities for farmers, particularly in streamlining the process of procuring farm inputs (information, financial, fertilizers, pesticides, weather, climate, making plan, and input supplier) (e.g., [20,71,122,123]) as well as facilitating the marketing of products (supply chains and prices) (e.g., [31,49,124,125]). The integration of social media and mobile devices offers farmers several opportunities to improve their price negotiation abilities, investigate new markets, and conduct timely transactions at more advantageous prices for their agricultural goods. Additionally, these digital tools enable farmers to access information swiftly, thereby contributing to informed decision-making in their agricultural endeavors (e.g., [57,126–128]). Therefore, the cost of transactions or accessing information is greatly reduced.

3.4. Barriers of Interactive Digital Extension Services in Agricultural Sector

The results from the reviewed articles in Table 2 show various barriers to effective perception on the use of the interactive DESs in agricultural sectors. The primary barrier, identified in over 50% of the reviewed articles, is the absence of two-way interaction information. This pervasive limitation underscores critical challenges in achieving effective communication and engagement within DESs (n = 94, 66.7%) (e.g., [29,75,76,129–131]),

such as the lack of a centralized information network for the farmers and service providers (n = 84, 59.5%) (e.g., [70,72,132–134]); lack of technical know-how on the use of ICTs (n = 83, 58.9%) (e.g., [26,37,135,136]); poor internet connection (n = 75, 53,2%) (e.g., [31,44,135,137,138]); and lack of effective training on ICTs (n = 74, 52.5%) (e.g., [59,66,85,117]).

Table 2. Barriers of interactive DESs in the agricultural sector (percentage of articles (number of articles)).

#	Barriers of Interactive Digital Extension Services in the Agricultural Sector	% (n)
1	Lack of two-way interaction information	66.7 (94)
2	Lack of a centralized information network for the farmers and service providers	59.6 (84)
3	Lack of technical know-how on the use of ICTs (users)	58.9 (83)
4	Poor internet connection	53.2 (75)
5	Lack of effective training on using ICTs	52.5 (74)
6	Information services providing poor-quality information	48.2 (68)
7	Electricity problems	46.1 (65)
8	Poor extension services	45.4 (64)
9	Poor infrastructural facilities	45.4 (64)
10	High illiteracy level among farmers	44.0 (62)
11	Untimely information inputs provision	43.3 (61)
12	Lack of capacity of extension staff	43.3 (61)
13	High cost for investment and use	42.6 (60)
14	Lack of ICT facilities for service providers	39.0 (55)
15	Lack of trust in information from social networks	34.8 (49)
16	Lack of human resources to support farmers to access digital extension services	33.3 (47)
17	Lack of applicable software	32.6 (46)
18	Lack of understanding or low awareness of how to obtain benefit from the various ICT options	27.0 (38)
19	Local language not used in social media	26.2 (37)
20	Lack of interest in using ICTs	17.0 (24)
21	Social and culture barriers	14.2 (20)

One of the main barriers listed is the deficiency in the two-way interaction between farmers and service providers [54,132,135]. This has serious implications for the success and effectiveness of interactive DESs for farmers. For example, Etwire et al., [43] highlighted that the lack of interaction of weather forecasting services through text messages affected farmers' decision-making process in agricultural production. The provision of information services to farmers and the lack of feedback interaction between farmers and service providers leads to a large amount of information provided to farmers that is not applicable or is still very vague when applied [109].

Particularly, in developing countries in Asia (e.g., [110]) and Africa (e.g., [39]) the analysis of the reviewed articles showed that the absence of a centralized information network for farmers and service providers has been appraised as a critical factor impeding the effective receipt of information and the proliferation of diverse types of DESs in the agricultural sector. The majority of service centers were situated in urban areas, distant from rural regions. Furthermore, impediments arising from poor communication infrastructure hindered the optimal utilization of ICTs, particularly mobile phones or smartphones (e.g., [94,116,139,140]). As the people in the villages have less technological advancement, they easily face complications in using mobile phones (e.g., [132,141,142]). Numerous reviewed articles (e.g., [81,128,135,137,138]) underscored the lack of centralized DES providers coupled with challenges in securing finances and establishing connections with private DES providers as major barriers. Addressing these issues necessitates the implementation of a flexible mechanism to effectively overcome these barriers.

A lack of technical know-how on the use of ICTs, particularly among farmers in rural areas, is also a barrier which needs to be tackled [39,43,74,137]. For example, Lu et al. [15] stressed that in order to increase the capacity of farmers in accessing and receiving services from DES providers, farmers need to understand how to use and operate ICTs, especially social networks and other supporting apps in smart phones. However, research results in India (n = 26) (e.g., [37,38,143]) and Bangladesh (n = 3) [55,110,116] reveal that farmers in these countries, particularly those in ethnic minority and disadvantaged areas, have faced limitations in understanding how to effectively utilize ICTs. Additionally, in these regions, there is a deficiency in robust networks, resulting in poor internet connectivity [102]. Verdouw et al., [137] highlighted that the absence of access to a reliable internet connection contributes to an increased cost associated with using phone services (where the service charges are higher than internet usage costs). This limitation significantly hampers the process of accessing information from service providers delivering DESs, particularly those involving image services (e.g., [21]) or video calling services [49]. Hence, the absence of supporting infrastructure for DESs in utilizing ICT was explicitly referenced in more than 52.5% (n = 74) of the reviewed articles (e.g., [1,59,99]).

Table 2 shows a list of barriers that both service providers and farmers of digital agricultural extension services have faced. For farmers, when social networks develop, information services are provided more abundantly, but it also means that the quality of information might not be high enough (48.2%, n = 68), and the quantity is too much. Information through social networks has not been quality tested (e.g., [22,38,144,145]), so farmers also lack trust in information from social networks and lack confidence in the information they receive (34.8%, n = 49) (e.g., [22,79,87]). The illiteracy level among farmers is quite high (44.0%, n = 66) in many rural areas in Asia (e.g., [15,50,110]) and Africa (e.g., [21,45,47]). Therefore, they are not interested in the use of ICTs and do not understand the value and benefits of DESs through ICT equipment.

For service providers, there is a poor quality and lack of interactive DESs provided to farmers (45.5%, n = 64) (e.g., [36]) due to the limited capacity of extension staff to use ICTs (43.3%, n = 61) (e.g., [3]; limited ICT types of equipment (39.0%, n = 55) (e.g., [65]); lack of human resources to support farmers in accessing DESs (33.3%, n = 47) (e.g., [77]); and lack of applicable software (32.6%, n = 46) (e.g., [46]. Thus, interactive DESs provide untimely information inputs (43.3%, n = 61), especially in developing countries (e.g., [19,46,83,141]).

In connection to technical factors related to ICTs, electricity emerged as a predominant issue, being explicitly cited in 65 of the reviewed articles (e.g., [1,24,58]). ICTs in general, and mobile phones or smartphones in particular, rely on electricity for charging. Especially when using the internet, electricity is a very important issue [3]. However, an inadequate electricity supply may hinder the use of ICTs for farmers. Hence, the utilization of electronic devices poses significant challenges for farmers, particularly those in ethnic minority and disadvantaged areas. At the same time, 64 reviewed articles (45.4%) mentioned that infrastructure supports for digital extension services, such as internet lines (e.g., [116]) and centers or broadcasting stations (e.g., [119]), were also very poor and limited for the development of digital extension services. Furthermore, for farmers in low-earning areas, the cost of ICT equipment, as well as the cost to use and maintain the service, is quite expensive for them (42.6%, n = 60) (e.g., [90,125]). Within the cost categories mentioned in 60 reviewed articles, 31 articles highlighted that the purchase of a mobile phone was perceived as a significant financial burden for farmers. Furthermore, the high cost associated with paying for internet services is also underscored (n = 27) (e.g., [135,146]), as well as paying for telephone services (n = 20) (e.g., [67,71]). Other high costs that farmers have to pay when using digital extension services include the high cost of an alternative power supply (n = 14) (e.g., [23]); high cost of data subscription (n = 12) (e.g., [112]); high cost of mainte-

nance of ICTs (n = 12) (e.g., [81]); and high cost for digital technologies (n = 2) ([127,147]). In addition, some (n = 20) articles mentioned social and cultural barriers, including farmers' belief in their own culture, respect for tradition, pride and dignity, and relative values (e.g., [67,71]).

4. Discussion

This paper aims to systematically review the prevalence of opportunities and barriers in interactive DESs targeting smallholder farmers as a way to ensure sustainable agricultural development. In total, we identified 141 reviewed papers worldwide. Findings identified 13 main opportunities and 21 main barriers related to interactive DESs. According to findings from the reviewed papers, farmers' awareness, motivation, readiness to use the interactive DESs, and the available ICT tools have increased. Therefore, interactive DESs are evaluated as the best source of learning and information exchange platforms in the agricultural sector. In domestic and global markets, growing demands for agricultural products are opportunities in agriculture and rural development for developing countries [148]; for example, changing agricultural policies and creating an open business environment are timely mechanisms to cope with global changes and emerging needs to include access to agricultural inputs and technologies that assist farmers in boosting production [149]. Several ways to enhance the capacity of farmers to access and utilize agricultural information are increasing, which includes the promotion of the availability, quality, and timely delivery of agricultural information services, raising farmers' awareness and applying alternative approaches to disseminate information of existing information channels to different groups of farmers, particularly the marginalized isolated and ethnic minority groups.

Interactive DESs and the enhancement of access to services that include roads, communication, and media services represent additional opportunities for connecting smallholders to markets and market information. In Ethiopia, agricultural extension service agents, along with various partner organizations including telecommunications, set up a hotline advisory service system. Farmers can now use mobile phones to call and receive free guidance on production technology or agronomic practices [21]. Development agents suggest that embracing DESs and establishing farmer groups could enhance technology transfer at the grassroots level, facilitated by the contributions of model farmers [53]. It creates an effective working environment through networks and collaboration among farmers and different stakeholders. From that, DESs have lessened the challenges that development agents encountered when attempting to connect with numerous farmers [150].

In developing countries, the government is dedicated to enhancing the livelihoods of farmers by putting resources into agricultural extension services [151]. For example, in Ethiopia [151] and Vietnam [152] the state has created many mechanisms–policies with the aim of calling for investment from many stakeholders, including different public–private organizations, to support farmers to improve their livelihoods through investment services. As a result, the current policies and strategies for agricultural development are viewed as beneficial to agricultural extension. Access to agricultural information and capacity building for farmers and extension service providers are foundational requisites for promoting interactive DESs and fostering agricultural development [153,154]. Shifts in eating habits and increasing consumer expectations represent new opportunities for agricultural growth. DESs have clearly supported farmers in enhancing the value of agricultural products, reducing production costs and access time, and checking information that relates to the agricultural sector. Therefore, there is a great opportunity for interactive DESs to contribute to assisting farmers in accessing information and activities related to agricultural development and improving farmers' livelihoods [155–157].

The results of this systematic review indicated 13 opportunities, and many previous research results [76,79,82,86,108] have shown that these opportunities hold the potential for advocating and developing policies related to interactive DESs as well as overcome barriers in this systematic review. These opportunities have created many advantages and utilities for DES users, especially farmers, in the context of technological development and market integration. One highly significant and promising opportunity presented by interactive DESs is their role as the optimal information channel for farmers to access and utilize agricultural services. This is attributed to their ease of access at any time and location, ensuring convenience, efficiency, and overall usefulness when farmers have specific needs [18,27,52,53,71,158]. Interactive DESs are perceived as discussion forums where farmers exhibit less hesitancy and greater confidence when accessing, using, and engaging in discussions related to their agricultural production towards sustainability [60,77]. Addressing income, particularly for impoverished households, stands out as one of the primary concerns. Interactive DESs have been identified as a potential solution, as evidenced by several previous research studies.

Nevertheless, this research also demonstrates that the potential of DESs is not completely achieved, as they encounter significant obstacles. In developing nations, smallholder farmers face several major limitations to interactive DESs, including socio-economic issues, resource shortages, social hierarchies, and psychological factors [159–161]. The findings of this systematic review indicate that the most notable barriers include (i) institutional characteristics of the policy and governance system, such as the lack of two-way interaction information and lack of a centralized information network for the farmers and service providers; (ii) governing resources, such as a lack of financial resources for using and applying interactive DESs and investing in infrastructures and facilities (i.e., internet, electricity, road systems, etc.); and (iii) the policy analytical capacity of civil servants (i.e., extension workers) and farmers' capacities, such as skills, attitudes, knowledge, and financial resources. According to Audu, B.S [162], for interactive DESs to be effective and efficient, these barriers should be addressed.

In most developing countries, the government has a national strategy or long-term strategic vision for an agricultural extension system. In recent years, several policies and institutions that are related to interactive DESs were issued. However, those policies are in the form of documents and have not been implemented in practice. In the current context, digital agricultural extension services require a two-way interaction between stakeholders in the service delivery process. However, a critical barrier mentioned in most of the reviewed papers is that the digital agricultural extension services only provide one-way services from the service provider without any interaction or feedback from service users. Technology transfer is another area that the agricultural extension system focuses on. Brhane et al. and Kari et al. claim that agricultural extension has not focused much on developing problem-solving skills and the organizational bodies need to assist farmers in helping themselves [163,164]. The system is highly structured in a top-down technology-transfer fashion. Farmers may be encouraged to "take and use" new technologies using interactive DESs, which have limited communication and exchange, to obtain user input and encourage users to create and modify information from services to fit their own needs.

In Vietnam, the State and the units managing and implementing agricultural activities, specifically the Ministry of Agriculture and Rural Development and the National Agricultural Extension Center, do not yet have a center for the management, coordination, and provision of agricultural extension services for farmers, particularly interactive DESs [152]. Although, there have been several organizations that have worked on interactive DESs, such as agricultural enterprises, telecommunication, NGOs, etc. This greatly affects the control of information sources and the quality of information when provided to farmers.

Although regulations on the management of digital agricultural extension services have started to be issued in developing countries like Vietnam [152], Bangladesh [55], these regulations lack clarity regarding coercive power and a clear division of tasks and responsibilities. Digital agricultural extension services require strict and multi-dimensional management, following a bottom-up approach, putting the needs of users first. However, in most of the developing countries the governance of DESs follow a top-down approach.

Therefore, we contend that in order to handle the complex contextual variables and integrate both top-down and bottom-up approaches, a flexible institutional arrangement and organizational structure are required. Interactive DESs are a key part of the government's current, vigorous digital transformation efforts in agriculture. Additionally, funding for these initiatives has been found and allocated. However, we discover that the method by which funds are distributed for the creation and deployment of interactive DESs at various governmental levels is more of a barrier than the actual quantity of funding. Burch [165] argues that assisting in the efficient use of current resources is more crucial than locating additional financial resources.

In addition, the analytical capacity of extension workers and farmers plays decisive roles in performing key functions in accessing and using interactive DESs. Therefore, the imperative nature of policies aimed at augmenting the proficiency of agricultural extension personnel cannot be overstated. However, the capacity was found to be limited at the local levels due to the lack of effective training on using ICTs for extension workers or lack of technical know-how on the use of ICTs among the farmers. Existing training programs have not adequately facilitated learning, transferring, and co-learning knowledge about digital extension services for both extension workers and farmers. Interactive DESs, such as social networks, exhibit a low awareness of how to obtain a benefit from the various ICT options [160,166]. Sudden changes in approaches and implementation strategies in interactive DESs contribute to increasing the number of farmers who do not trust the state extension and planning system.

Understanding the interaction of the three main barriers of interactive DESs at different levels of government is important for policy makers and practitioners to support farmers overcoming some of these barriers. It requires comprehensive assessment that is aimed at understanding the intricacies of different causes that create barriers in DESs. In particular, further research needs to pay attention to gender issues in DESs. Previous studies have shown that women are more involved in agricultural activities and need to access and use DESs. However, the review results show that women are still facing a number of barriers, such as a lack of financial resources to access smart devices and knowledge and the lack of skills to access and use interactive DESs.

As mentioned above, the number of barriers is quite large compared to the opportunities for developing interactive DESs. However, the opportunities were found to have potential, especially in creating many advantages and utilities for DES users. Therefore, to adequately address and enhance the realization of these opportunities and mitigate barriers, several recommendations should be raised. A key recommendation for policy development in agricultural advisory services is to enhance interactive DESs in developing countries by establishing a clear legal mandate for DESs that make it a primary concern instead of a criterion to be considered in the annual plan of the agricultural sector. State agencies need to cooperate together to build a digital platform, emphasizing the importance of unifying management units and establishing digital extension centers to provide quality, informative, attractive, and truthful DESs. Addressing this main cause would concurrently tackle numerous related barriers, including those related to financial aspects, accountability, coordination, and modalities of usage. Improving the understanding of DES providers and farmers on how to effectively use these services is essential. Additionally,

education and skill enhancement for extension workers at the local levels and for farmers will be crucial to further advance the access and use of interactive DESs. During COVID-19, smartphones and internet technologies have been widely used by smallholder farmers, presenting a significant opportunity to integrate or develop user-friendly digital extension services. Particularly, establishing linkages among departments managing and operating interactive DESs in both private and public sectors, especially between digital extension service providers and farmers, is critical to narrowing the gap in addressing issues and applying techniques and information related to agricultural production. Implementing communication strategies to raise the awareness about digital transformation for farmers and agricultural extension staff is also important to contribute to the development of interactive DESs.

5. Conclusions

Interactive DESs remain an unexplored study area in the agriculture literature, which offers significant opportunities for smallholder farmers and agricultural development. The reviewed 141 papers point to a number of opportunities to bring smallholder farmers to adopt DESs for developing agriculture towards a digitalized future. In total, 13 opportunities were identified indicating that interactive DESs are considered as the best source for learning and exchanging information/ideas among stakeholders, specifically between smallholder farmers and extension workers as well as agricultural entrepreneurs. Interactive DESs are also useful for improving the overall income of smallholder farmers through increased agricultural productivity and cost-effectiveness. Overall opportunities for interactive DESs access increased as the internet developed and expanded in developing countries. Market information access, in both farm input procurement and marketing agricultural products, has been facilitated by DESs offering several options for smallholder farmers in this digital age.

Findings show that discussions surrounding opportunities and barriers in interactive DESs remain new yet are accelerating and progressing. Fundamental study and exploration on barriers in interactive DESs developed an extensive list of possible barriers in interactive DESs. The results affirm the notion that interactive DESs are non-linear undertakings; situational conditions and particular factors are paths to understanding barriers and their analyses. The primary problem for interactive DESs is the absence of interaction between providers and receivers (smallholder farmers) and the lack of a centralized information network for farmers and service providers. It requires that we shift from the inventory questions of "if" and "which" barriers to interactive DESs toward more analytical questions of "why" and "how" these barriers emerge, then how to address them. The literature holds promise in this direction. Accepting that interactive DESs are a process involving multi-dimensional, variable-rich, and even chaotic conditions implies that our understanding of barriers to interactive DESs must evolve, providing more scientific legitimacy and institutional support that entails emerging questions on the real limiting factors requiring innovative solutions. Moving past exploratory and inductive assumptions about barriers and addressing the analytical difficulties that contextuality presents are essential to developing scientific discussions and understanding the characteristics of barriers to interactive DESs. This advancement is not only crucial for scientific progress but is also a vital step in supporting institutions, policy makers, and implementers who are key facilitators in the timely and effective development of interactive DESs, particularly in developing countries.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17073007/s1, Table S1: The keywords for searching strategies; Table S2: Creating search query for each database and applying exclusion and inclusion criteria;

Table S3: Inclusion criteria used for screening titles, abstract, and keywords; Table S4: The indicators for analysis of reviewed articles; Table S5: Analyzing selected articles.

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