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Review

Towards a Revolutionized Agricultural Extension System for the Sustainability of Smallholder Livestock Production in Developing Countries: The Potential Role of ICTs

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Abstract: The creation of commercialization opportunities for smallholder farmers has taken primacy on the development agenda of many developing countries. Invariably, most of the smallholders are less productive than commercial farmers and continue to lag in commercialization. Apart from the various multifaceted challenges which smallholder farmers face, limited access to extension services stands as the underlying constraint to their sustainability. Across Africa and Asia, public extension is envisioned as a fundamental part of the process of transforming smallholder farmers because it is their major source of agricultural information. Extension continues to be deployed using different approaches which are evolving. For many decades, various authors have reported the importance of the approaches that effectively revitalize extension systems and have attempted to fit them into various typologies. However, there is a widespread concern over the inefficiency of these extension approaches in driving the sustainability of smallholder farming agenda. Further, most of the approaches that attempted to revolutionize extension have been developed and brought into the field in rapid succession, but with little or no impact at the farmer level. This paper explores the theory and application of agricultural extension approaches and argues the potential of transforming them using digital technologies. The adoption of information and communication technologies (ICTs) such as mobile phones and the internet which are envisaged to revolutionize existing extension systems and contribute towards the sustainability of smallholder farming systems is recommended.

Keywords: agricultural extension; sustainability; smallholder farmers; ICTs; mobile phone; Africa

Citation: Mapiye, O.; Makombe, G.; Molotsi, A.; Dzama, K.; Mapiye, C. Towards a Revolutionized Agricultural Extension System for the Sustainability of Smallholder Livestock Production in Developing Countries: The Potential Role of ICTs. *Sustainability* **2021**, *13*, 5868. https://doi.org/10.3390/su13115868

Academic Editor: Donato Morea

Received: 4 April 2021
Accepted: 27 April 2021
Published: 24 May 2021

1. Introduction

In the past 25 years, the creation of commercialization opportunities for smallholder livestock producers has taken primacy on the development agenda of many developing countries. However, most of the smallholder producers are invariably less productive than commercial farmers and continue to lag in commercialization [1,2]. Across Africa and Asia, many governments together with the private sector and non-governmental institutions have extended different forms of support to reduce the lag in commercialization by smallholders and to leapfrog their transformation to commercial farming [2,3]. Countries such as South Africa have attempted to support smallholder livestock farming through the provision of inputs, land, production, and marketing infrastructure, unfettering of agricultural markets, and improvement of financial access [4]. While the deployment of such measures might be the necessary conditions for bolstering the sustainability of farmers, it is posited that, unless agricultural extension approaches are radically transformed, the intent of these strategies is most likely not to be realized [3,5,6]. These attempts are generally regarded as costly and ineffective [3] and lacking in extension-based follow-up support. Apart from

that, Anandajayasekeram et al. [7] noted that many governments have decimated their budgetary support towards the agricultural sector, making it even more difficult for it to deliver agricultural extension services. The uneven access to agricultural extension services by smallholder farmers due to limited public extension support is, therefore, one of the key factors hampering their potential to commercialize [8,9]. Inadequate access to extension services and appropriate agricultural information further reduce the ability of farmers to address everyday challenges and optimize the path to commercialization [3,10–12].

The public extension system is the largest and most common source of information for smallholder livestock farmers in developing countries [13,14]. It is one of the major undertakings of the government, with the Ministries of Agriculture having a de facto monopoly over the provision of extension and advisory services [15–17]. However, there is a widespread concern that the public extension system is underperforming and has failed to effectively push the smallholder commercialization agenda [10,18,19]. This has driven the need for research and innovation strategies that promote the development of resilient and farmer-driven extension systems. To improve efficiency, most extension systems across Africa and Asia have attempted to move from being supply-driven to being pluralistic and demand-driven but with minor success [17,20,21].

A review of the literature suggests the potential of linking extension systems with ICT-based strategies to promote and hasten farmer–farmer interactions and the ability of farmers to effectively communicate with extension and researchers (feedbacking) [1,12,18,22,23]. However, as noted by Hazell et al. [24], most developing countries lack innovative institutions to support extension delivery and the development of smallholder farming. The adoption and use of ICTs such as web-based and mobile applications, therefore, present unprecedented opportunities for transforming smallholder farming [9,17,25]. Already, some initiatives have been developed across Africa and Asia to support the delivery of extension services [22,26]. In Africa, most of the initiatives started in East Africa, where over 60% of all registered smallholder farmers currently using digital technologies are based. This shows an enormous gap for the Southern African region. The continued development and implementation of innovative strategies in revolutionizing public extension services is therefore essential [27]. This review discusses the main limitations of improving the sustainability of smallholder livestock production in developing countries and the role of agricultural extension. It identifies and characterizes agricultural extension approaches used in Africa and South and East Asia. The review also explores the theoretical and practical application of the extension approaches in various countries, their respective implementation objectives, and assumptions, as well as their advantages and limitations. The potential for using ICTs in revolutionizing public extension services delivery towards sustainable smallholder farming systems is highlighted.

2. Review Methodology

All eligible academic articles used in the review were identified by systematically searching the major electronic databases such as AGRICOLA, Google scholar, Science Direct, SciELO, SCOPUS, and SpringerLink. Initially, a broad Boolean search string 'smallholder farming' AND 'livestock' AND 'agricultural extension' AND 'developing countries' was used. In this review, developing countries refer to the less developed and emerging economies in Africa and South and East Asia. The search was then narrowed to focus on specific extension approaches used by some countries in these regions. For example, a combination of the terms "Training and Visit", "Extension", and "Approach" was used to search for articles about the Training and Visit extension approach. The main search engines provided links for free to access full text articles and if not found, research websites such as ResearchGate, which offer an option of direct full-text request from authors, were utilized. The Google Search engine was used for the retrieval of research articles and reports that may have been dropped from first search. The first method involved searching reference lists of included study/review articles, and the second method involved performing a citation tracking in which all the articles that cite each one of the

included articles were tracked. We searched literature published between the period 1980 and 2021. The search was conducted in 10-year periods (1980–1990; 1991–2001; 2002–2012; 2013–2021). The proportions of articles obtained for each time period were 5%, 8%, 26%, and 61%, respectively.

3. Limitations of Improving the Sustainability of Smallholder Livestock Production and the Role of Agricultural Extension in Developing Countries

Smallholder livestock farming in many developing countries is challenged by several factors. These can be broadly classified into ecological, economic, social, and institutional challenges. Some major ecological challenges being faced by the farmers include severe incidences of droughts [28,29], water and feed shortages, poor breeding management practices, and limited animal welfare and health skills [30]. Apart from that, lack of access to formal, high-value output markets by smallholders is one challenge limiting their environment for economic growth and development [31,32]. Thus, smallholder farmers are forced to compete for market share with already established commercial producers, where they are often dislodged due to lack of competitive advantage. This is also due to a lack of precise market information and knowledge about how the markets function [32], and market unreliability incidences such as inconsistent pricing, and inappropriate (possibly unfair) grading and classification of produce [31,33]. Furthermore, a large proportion of smallholder farmers have poor management skills due to a lack of training services [10,30,34] and have limited access to working capital [30]. Lack of access to finance is worsened by banks which often associate themselves with large-scale commercial farmers who have collateral, better farming track records, and proof of reliable income streams [35].

Limited access to extension services by smallholder livestock farmers, especially those in remote areas, is a key limitation for their commercialization [16]. Literature is replete with shortfalls associated with the provision of public extension services to smallholder farmers in developing countries [3,10,19,36,37]. Generally, public extension systems in developing countries are heavily under-resourced, over-stretched, lack skilled human resource, and infrastructural support, and are faced with an overall decline in investment [17,18]. Further, systems are characterized by high farmer-to-extension ratios as the number of trained extension agents is limited [4,21]. According to Anandajayasekeram et al. [7], many governments in East and Southern Africa (ESA) have radically reduced budgets in the agricultural sector, making the provision of public extension services more difficult. In addition, Kerr [38] notes that the provision of extension services has been disrupted by the COVID-19 pandemic, while Cook et al. [19] argued the persistent exclusion of social and political factors as a major factor impacting the performance of extension. Therefore, the reduced impact from extension services suggests the importance of characterizing the existing extension approaches and developing measures to revolutionize them [7,35].

The role of agricultural extension and advisory services is pertinent to effecting change and driving the rural development imperative through smallholder agricultural production. Across Africa and Asia, agricultural extension has long been one of the major conduits of agricultural development and transformation leading to rural poverty reduction and increased food security [11,14,15]. Despite extension having been criticized for failing to deliver such results adequately, it is perceived to have remained the bedrock of smallholder livestock production [19]. This is because it brings farming information, inputs, facilitates access to markets and credit facilities, and promotes the organization and training of smallholder farmers and producer groups for improved production, livelihoods, and the ensuing growth in household income and well-being [6,35,36,39]. According to Hanyani-Mlambo [40] and Danso-Abbeam et al. [11], agricultural extension also provides a framework through which challenges constraining smallholder farmers can be identified for further investigation and for the development and modification of solution strategies and policies which guide the farmers.

Given that technical knowledge is generated through research conducted by various research institutions and organizations, the primary role of extension is to customize and facilitate the dissemination of the research findings to farmers [16,41]. Thus, Wesley and

Faminow [27] and Danso-Abbeam et al. [11] described the extension as a bridge between scientists, who strive through technical means to find solutions for farmer challenges, and the farmers who employ the solution measures to support their farming systems. Agricultural extension services are provided to smallholder livestock farmers by multiple players and through numerous approaches. An understanding of the major extension approaches being used to support smallholder farmers in Africa and Asia is, therefore, critical.

4. Agricultural Extension Approaches Used in Africa and Asia

Given the envisaged link between research and farmers' needs in modern agricultural systems, effective mechanisms are essential in the provision of technical expert advice to the farmers. Due to the diversity of farmer needs, production systems, and agricultural policy objectives, all countries virtually have a mix of extension approaches [13,42]. Thus, over the past few decades, the extension has been tested and deployed using different approaches and strategies [23,43,44]. These extension concepts have evolved, and many authors have attempted to fit them into various typologies. Generally, the approaches are not mutually exclusive and can be complementary. The main extension approaches that have been used in Africa and Asia include technology transfer approaches, commodity specialized approach, participatory extension approaches, cost-sharing approaches, and education institution approaches. Drawing on experiences from Africa and South and East Asia, the following section provides a historical and descriptive synopsis of each of these approaches. Therefore, researchers and policy makers can draw on these lessons to replicate, generalize, and scale up the process of developing new extension approaches or improving the existing ones.

4.1. Technology Transfer-Based Extension

Towards the beginning of the nineteenth century, colonialism and imperialism gradually introduced various agricultural innovations, and most of them were farm-based technologies that had a limited impact on farmers [45]. However, the rise in agricultural sciences allowed more technology to be created outside the farms by both public and private research organizations. During that time, the research–extension–farmer linkage in Africa and Asia was weak, presenting a gap in the dissemination of modern research findings (technology). This gave birth to technology transfer-based extension approaches which somewhat involved centralized and top-down planning in the dissemination of innovations to farmers [19,36,46]. As a further matter, Alex et al. [47] noted that technology transfer must not just be restricted to production technologies but should extend to management, administration, and adaptations of the technologies to post-harvest as well as off-farm practices. More importantly, Nagel [46] implored that the use of technology transfer systems and the commitment by governments to modernization should not discredit the farmers' knowledge base, including their indigenous knowledge. The main technology transfer approaches used in Africa and some parts of Asia include Ministry-based or public extension and the training and visit (T&V) extension approach.

4.1.1. Ministry-Based or Public Extension Approach

The Ministry-based, also termed public extension approach, has traditionally been the most dominant extension system worldwide [13,14] and was adopted by many countries in Africa and Asia. Invariably, the key responsibility for agricultural extension activities often rests with central governments, since agriculture is the state subject [17]. The technology transfer approach is largely supply-driven, efficiency-based, and focuses on specific national objectives, such as increasing yield and reducing costs of production on national commodities [39]. Proponents of this model perceive the planning and management of extension as the sole responsibility of the Ministry of Agriculture [16,46]. The flow of information from the ministry to farmers is usually facilitated through a uniform and nationwide organizational pattern [46] as prescribed by the national policy.

The basic assumption of the approach is that there is useful technology and information that is available in the Ministry of Agriculture and is not being used by the farmers [41]. The success of the approach is measured by increases in the production of national commodities by the farmers and the betterment of their families [41].

One of the major advantages of the public extension approach is that the government can use it to implement national agricultural policies and development programs for smallholder farmers [41,48]. Under Ministry-based extension, the services are generally free, and farmers can visit the extension offices anytime to seek information and advice [15]. However, the approach has been constantly under pressure for its poor performance and the lack of two-way flow of information between extension staff and farmers [12,13,18]. The approach is continuously beset by the principal-agent arrangement, is costly, and has, therefore, faced an overall decline in investment across Africa and Asia [15,18]. Furthermore, FAO [18] added that the public extension system has institutional inefficiencies associated with bureaucratic processes, lack of accountability, and poor transdisciplinary arrangements. In addition to these factors, the poor performance of the approach could be attributed to a lack of technological interventions such as the use of ICT-based innovations [12,39,49].

The public extension approach was reported to be used in various African countries such as Ethiopia, Tanzania, Malawi, Botswana, Senegal, and Zimbabwe, as well as Asian countries such as China, Indonesia, and India [39]. In Kenya, the National Agriculture and Livestock Extension Programme (NALEP) which started in 2000 has been implemented through the Ministry of Agriculture and the Ministry of Livestock and Fisheries Development. Based on the NALEP internal assessment reported by Cuellar et al. [48], as many as 80% of the beneficiary farmers agreed that the introduction of the program offered new and good opportunities to them. Over 70% of the farmers claimed that the NALEP approach influenced them to regard farming as a business rather than a way of surviving. Further, in Zimbabwe, the Ministry-based extension approach was successfully used to drive the rapid adoption and use of hybrid maize varieties and fertilizers and the initiative doubled maize production under smallholders in six years, 1980–1986 [50].

4.1.2. The Training and Visit (T&V) Extension Approach

According to Nagel [46], the T&V extension approach is not a separate but one way to organize Ministry-based extension. The approach was introduced, promoted, and sponsored by the World Bank in Africa and Asia, between 1975 and 1998 [17,39,42,47]. The T&V approach was generally introduced for transferring the latest agricultural technologies and practices from research to farmers [20,23]. Proponents of the approach believed that transfer of technology can be achieved by increasing and regularizing farmer visits by extension workers, strengthening the supervision of extension programs and workers, providing extension workers with specialized knowledge and resource support, and increasing the extension agent-farmer ratio by recruiting and training more frontline extension staff [39,46,51,52]. Thus, the T&V approach is more centralized, linear, top-down, and is based on a hierarchical structure and a rigorously planned schedule to be followed by extension officers [41,46,53].

The primary assumption of the T&V approach is that technology is developed and validated by researchers, whereas extension practitioners only focus on transferring the technology and its adoption by farmers [5]. The approach further assumes that, before its implementation, the existing extension staff are poorly trained, not up-to-date, and tend not to regularly visit farmers but rather stay in their offices [41]. Success of the approach is, therefore, tied to the need to increase the yields and total production of targeted national agricultural commodities by individual and small farmer groups in the targeted communities [53].

One of the major advantages of the T&V approach is that through improved training, extension officers can become more knowledgeable and be up to date with information and technology needed by the farmers [14]. Other advantages include more regular farmer

visits and a more professional approach to the provision of extension by the extension staff, which ultimately improves the quality of services. The approach, however, has limitations. It has huge and long-term demands for financial support [23,44]. As it expands to support more farmers, it requires more support staff, their continuous training, and supervision, as well as support infrastructure, and transport facilities [54]. This substantially raises the costs of implementing the approach. Moreover, the withdrawal by World Bank created some long-term recurrent budgetary problems for governments which included payments for many permanent workers created by the system and supporting the continuation of extension activities. Due to the relatively high financial outlay required and the withdrawal of funding by the World Bank, the approach was deemed financially unsustainable and rejected by many countries [39,44].

Most countries that continued using the approach, such as India, Ghana, Mali, Mozambique, Zambia, South Africa, and Zimbabwe, had to initiate various modifications to improve the systems' effectiveness [13]. For instance, in Zimbabwe, the approach was modified to use extension groups instead of targeting only lead farmers, but it was later abandoned [40].

Based on its implementation, the T&V approach has proved effective in Asia, and this was largely attributed to the high homogeneity of farming systems and advanced capacity among extension agents and the farmers [55]. In this region, the T&V approach was very instrumental in disseminating Green Revolution technologies, especially to farmers in the high-potential, irrigated areas [13]. However, it failed to reach farmers located in rain-fed areas. In Africa, deployment experiences in Kenya and Burkina Faso as reported by Bindlish and Evenson [56] proved the approach effective in improving farmers' management and raising productivity. In Nigeria, the T&V approach was reported to have boosted the production of cereals as it positively influenced the adoption of improved technologies by farmers [52]. However, experiences in Cote d'Ivoire and Rwanda suggest the model failed to improve farmer productivity and to motivate extension workers [55]. According to GFRAS [51], poor incentives often discourage extension workers from requesting feedback engagements with farmers.

4.2. The Commodity Specialized Extension Approach

The commodity specialized extension approach dates to colonial times [42] and is currently being used across Africa and Asia [13,44]. Implementation of the approach follows a planned and coherent set of extension procedures designed to promote the production of high-income livestock projects such as domestic-oriented dairying [42] and predominant export or cash crops [17,40]. It is also used to promote the utilization of strategic agricultural inputs such as cattle dipping acaricides, crop fertilizers, and herbicides. Commodity specialized extension is centralized [17,53] and planned based on a self-financed model with coordination from the government [39,40,44] or private organizations working with contracted farmers [46]. Its primary assumption is that the production of commodity increases by exclusively concentrating on that commodity or utilization of a certain input [41]. It also assumes that overall farming development is realized when modern farming technologies, traditional farming practices, research, input supplies, and marketing are fused and placed under one administration [44,46].

The main strength of the commodity specialized approach is that it has much impact and is more efficient as it can be tailored to specific agro-ecological zones and used to target a fragmented series of farmers [39,42]. The major weakness of the approach is its inability to support some staple food crops or indigenous livestock species other than those of concern (high-value commodities) [42]. Furthermore, [41] previously noted that farmers' interests are less likely to take priority as compared to those of the leading organizations when using this approach. Consequently, these issues lead to unsustainable utilization of some local resources, poor understanding of whole farm system challenges, and opportunities for farmers which ultimately lead to food shortages [46].

An example of a successful application of the commodity specialized extension approach is the Gujarat Cooperative Milk Marketing Federation in India. It reached over 35 years of existence in 2010, with approximately 2.8 million producers supplying milk from village societies across the country. In Africa, the approach has been successfully used to support the exporting of cotton and palm oil in Mali [44]. Thus, smallholder cotton farmers were served by a self-financed cotton research and extension system with government extension services targeting farmers outside the cotton zone [13]. In Zimbabwe, the commodity-based extension was generally organized and supported by private firms or parastatals. It was successfully used to establish out-grower schemes for commodities such as vegetables, tobacco, sugar cane, and dairy cattle [40,44,57]. In countries such as South Africa, the commodity-based extension approach with support from government extension, research universities, and the Industrial Development Corporation (IDC) is being used to promote the re-introduction of Nguni cattle through emerging smallholder farmers [10,12].

4.3. Participatory Agricultural Extension Approaches

Following the decline of investments in government extension services in the 1980s–1990s, community-based and participatory extension approaches became increasingly prominent [16,20,51]. Participatory extension approaches use farmers to deliver extension services to fellow farmers in group setups with frontline extension agents serving as facilitators, not teachers. Program planning for the approaches is usually controlled locally by farmer groups or farmer associations [58]. These approaches recognize that farmers are already key sources of information for other farmers, as argued by Mapiye et al. [12]. By using the existing farmers' social networks and group learning arrangements, participatory approaches promote a reinforcing effect which is essential in mobilizing farmers to embrace local agricultural programs and adopt new technologies [27,41]. Such actions include information sharing, peer consultations, collective problem diagnosis, and decision making [47]. Implementing these approaches features many regular meetings and demonstrations with small, large, general community groups, or one-commodity specialized groups [41].

The primary assumption of the participatory approaches is that there are existing indigenous knowledge systems [59] that differ from the scientific knowledge systems, and because of the differences, interacting the two can benefit the farmers [41]. Thus, farmers can be more productive through learning more about what is outside their farming systems. The positive impact of the participatory approaches is measured by the number of farmers actively participating, the continuity of local extension organizations and their systems, and the ultimate benefits that accrue to the community [41,53].

One of the main advantages of participatory approaches is that by allowing farmers to participate in determining what program goals and what methods can be used to achieve the goals [51], they increase the relevance of the programs to the farmers [58]. Another major benefit associated with the approaches is the growth of a mutually supportive relationship between the farmers. Alex et al. [47] assert that the approaches tap into indigenous farmer knowledge and allow the development of farmer-centric information content that easily applies to other farmers. However, some concerns usually come from the governments indicating that there is a lack of control of extension programs from the center especially where the ministry of agriculture is not controlling the approaches [41]. Moreover, it becomes more difficult to manage central reporting and accounting for such approaches as programs are subject to change from time to time due to changes in conditions.

Most African countries including Benin, Malawi, Nigeria, Uganda, and Zambia have adopted, and some, such as South Africa, are developing suitable participatory extension systems to suit local conditions [20,36,39]. However, effective participation by farmers in these countries seems elusive due to lack of time, uneven political will, and budgetary constraints [47,55]. This often leads to extension projects that are just nominally participatory but lacking effective empowerment to the farmers and stakeholders. The main participatory extension approaches used in Africa and some parts of Asia include Farmer Field Schools, the project approach, and farming systems research–extension approach.

4.3.1. The Farmer Field School Approach

The Farmers Field School (FFS) came to Africa from Asia, where it was successfully used to educate farmers about integrated pest management through farmer group learning [39,60]. The approach is widely accepted in these regions because it is participatory and uses a nonformal education approach where extension officers are more of facilitators than instructors [23,27]. The approach is group-based and uses iterative and interactive adult learning practices involving periodic meetings (e.g., weekly, or monthly) following a planned schedule, observations, and experiential learning to enhance the development and transfer of innovation [7,44]. During the meetings, farmers are assisted to carry out their research, analyze and test farm problems, and develop appropriate solutions for the problems [43,58]. The fundamental assumption of the FFS approach is that all the initial facilitators have high expertise and are believed to be well capacitated in implementing farmer group learning for farmer capacity building. It also assumes that farmers already have a wealth of knowledge [7].

One of the FFS approach's advantages is that it is based more on farmers' discovery and reflections and not on extension workers who normally use blanket recommendations. Further, it is useful in teaching farmers about specialized and knowledge-intensive subjects such as sustainable natural resource management [39]. Central limitations of the FFS approach include that it has a relatively very high implementation cost, it is labor-intensive, and reaches a few interested farmers [60,61]. According to Abadu-raheem and Worth [61], the participatory FFS approach, if not carefully guided, can negatively affect community benefits. This is because exclusive reliance on farmers' demands may result in the provision of exclusive technology or services that are often of short-term importance to the farming community as they could be suggested without considering the longer-term externalities such as environmental degradation.

The FFS approach has been implemented in many countries in Africa including the Democratic Republic of Congo, Gambia, Niger, Cameron, Togo, Uganda, Namibia, Tanzania, Nigeria, and Zimbabwe. Evidence from the five case studies in ESA countries [7] shows that FFS has contributed to changes in attitudes and perceptions of participants and facilitated the development of new relationships between farmers, researchers, extension workers, and community development personnel. However, its implementation in most of the ESA countries was largely hampered by the inadequate exposure of research and extension staff to the concepts and procedures of the approach. A study by Wandji et al. [62], in Cameroon, showed that FFS participating farmers had significantly more knowledge about crop husbandry practices than the non-participating ones. In addition to having significantly impacted farmer productivity and income in studies conducted in Kenya, Tanzania, and Uganda, FFS was reported to have also significantly impacted younger farmers, female-headed households, and people with low literacy [63]. In a study by Ali and Haider [43] in Faisalabad, Pakistan, more than 90% of the respondents received the latest package of agricultural technologies from agricultural experts through the FFS extension approach. In Nepal, a participatory FFS for a seed selection and multiplication project using new crop varieties led to a 45% increase in yields and improved food access by many households [27]. However, even given the positive impacts, studies by Bodnar et al. [64] and Feder et al. [60] in India and Indonesia respectively observed incidents of poor knowledge diffusion from FFS-trained farmers to other farmers in the village have an effect on the improvement of farmer practices.

4.3.2. The Project (Integrated) Extension Approach

The project-based extension approach focuses on a defined location (community), for a given period (usually, some few years) [47,58], and emphasizes work with disadvantaged farming groups to alleviate poverty [46]. Invariably, the approach focuses on what is needed by both the beneficiaries and donors [53] and involves substantial infusions of outside sourced funds and resources to achieve that common goal [41]. Even though substantial financial and technical input support comes from international development

agencies, project-based approaches may be controlled at central government levels. The aim is largely to demonstrate the potential of certain new technologies and methods that could be extended and sustained after the project period [58].

The philosophical assumption of the approach is that high-impact farming projects and activities conducted under controlled conditions can continue even after the withdrawal of external support [41]. Thus, measures to boost production under this approach are inextricably linked with a strong emphasis on self-help [46]. In this approach, short-term change at the project site is often used as a measure of success [58].

The main advantages of the project approach are that it enables evaluation of effectiveness and can produce quick results within that small location where it is being implemented, which particularly suits foreign donors [41]. It also allows novel techniques and methods to be experimented with and assessed within the confines of the project [41]. The main drawbacks of this approach are that it has a short time frame, restricts the flow of ideas and innovations outside the project area, and that when the money ends, so do the extension programs [41]. Additionally, since the program is implemented based on a consensus, it must always meet the immediate needs of both parties for success to be realized [53].

In Nepal, the project approach coordinated through the Ministry of Agriculture and financed by the Asian Development Bank was successfully used to support extension work by fishery officers working on the national aquaculture project in many different locations across the country [58]. In Indonesia, the Australian Centre for International Agricultural Research (ACIAR) project was used to improve the productivity and profitability of smallholder shrimp aquaculture and related agribusiness [15]. However, it was noted that there was not much support from the district extension office to enable more training on the best management practices to other farmers not participating in the project. In African countries such as South Africa and Zimbabwe, commercialization attempts towards smallholder farmers are also being spearheaded through project extension approaches. The Nguni cattle development program in South Africa [12] and out-grower schemes on fruit and vegetable export produce in Zimbabwe [57] are supported with project-based extension services. These programs are also receiving much support from the public extension system.

4.3.3. The Farming Systems Research–Extension Approach

The farming systems research–extension (FSR-E) approach is centered on solving farmer problems through holistic, systems-based, localized, and iterative technology development and delivery processes [53,58]. Early forms of this approach driven by economists and social scientists began with experiences in Africa, Asia, and Latin America [65]. This was after prescriptive agricultural growth models failed [40,51]. Thus, too often, agricultural extension strategies failed because they could not match the objectives and socioeconomic situations of smallholder farmers, and their agro-ecological conditions [41]. The FSR-E approach aims to develop practices that are tailored to fully meet the heterogeneous demands of the farmers [54,65].

The primary assumption of the FSRE approach is that technology that fits the needs of the farmers, particularly smallholders, is not available and can be created locally [41]. Therefore, the agricultural extension content must be developed off-research station but through on-farm research processes involving local farmers and their farms [53,65]. The success of the approach is measured based on the extent to which farmers adopt the technologies created by the program and continue using them with time [53].

The main advantage of the FSR-E approach is that first, it provides a model for understanding challenges and constraints faced by the farmers and how they deal with them [66]. Thus, research and extension programs are developed through an understanding of farmers' needs [51] and not from prescriptions by research scientists and extensionists [17]. This also involves farmers' cogent concerns over off-farm activities, issues of food and nutrition security, sustainability, risk reduction, income, and employment opportunities, which form the multiple needs and objectives of the farmers [58]. Based on Alex et al. [47] and

Franzel et al. [67], these activities are a sustainable way of facilitating links between smallholder farmers, researchers, and extension workers. However, according to GFRAS [51], the main superficial limitation of the FSR-E approach is that it relatively targets crop systems and less livestock-based systems. Additionally, the approach is costly to implement, and results are obtained slowly as it takes more time to study and understand the farm system and its elements in their natural ecosystems [41].

The FSR-E was well established in Zimbabwe, where it was championed through the Farming Systems Research Unit under the Department of Research and Specialist Services (DR and SS) [40,67]. The Department of Agricultural Technical and Extension Services (AGRITEX) through its extension workers was the one more visible and active at the grassroots level identifying farmers and monitoring on-farm trials [51]. In a study conducted by Alonge [66] in Nigeria, a higher proportion of farmers participating in the FSR-E had adopted insecticides, improved rice varieties, and water control techniques than nonparticipants. In the same study, it was recommended that the approach not be discarded but rather re-evaluated and improved because of its importance in improving the farmer–extension–research linkage. The approach has also been well established in countries such as Senegal and Zambia. However, its introduction in Zambia was associated with high operational costs especially due to transport and payment of daily subsistence allowances [65]. The Southern and Eastern African Association of Farming Systems Research-Extension (SEAAFSR-E) is the biggest regional networking association, which accelerates agricultural and rural development in Southern and Eastern Africa by promoting FSR-E [68]. It links its members through conferences, seminars, and workshops for building capacity. Some member states of this association where FSR-E is practiced include Namibia, Tanzania, South Africa, Kenya, and Uganda.

4.4. The Cost-Sharing Extension Approach

Cost sharing is an emerging extension approach in developing countries [51]. The approach requires that users pay a fee for accessing agricultural extension services that benefit them [47]. The approach targets those farmers who do not have the means to pay the full amount for accessing the extension services [58]. Its primary purpose is, therefore, to promote the use of agricultural programs that are likely to meet local situations, contribute to farm improvements, and make frontline extension agents more accountable to the interests of the farmers [53,58].

The approach assumes that non-formal extension educational programs are more likely to achieve the intended goals if beneficiaries (farmers) share the costs of bringing them [41]. It further assumes that rural farmers are too poor to pay the total cost of accessing extension services, so central and regional governments should cover part of the cost. Farmers' willingness and ability to contribute a share towards the cost individually or through their local government units are often used as a measure of success in this approach [51].

The main advantage of this approach is that some degree of local control (farmer-centric) in program planning increases the relevance of the program's extension content and activities to the needs and interests of targeted farmers [41]. Generally, this positively influences adoption. Cost sharing especially involving government–farmer partnerships at national and local levels is considered one of the most sustainable reforms in delivering extension services because of its ability to generate funding that can support its effective deployment [51]. Further, it lowers costs incurred by the central government as the costs will be shared by lower levels of the government and local farmers [41]. However, this approach could be a disadvantage as it does not allow the government to control either the program or personnel running the program. This becomes worse in situations where the government does not contribute at all towards the costs.

This cost-sharing approach is flexible and can be incorporated into other extension models, including Ministry-based, FFS, and FSR-E [47]. Anandajayasekeram et al. [7] recommended the use of a cost-sharing approach to ensure the sustainability of FFS ap-

proaches especially where programs such as the provision of inputs or farmer refreshments are donor-funded for a given period. In Uganda, some Farmer-Field-Schools and National Agricultural Advisory Services (NAADS) programs encouraged the use of cost-sharing approaches [55]. Ethiopia started following the cost-sharing model in the late 2000s where, for instance, a Farmer Training Centre (FTC) was established at the local government level serving five villages and serving between 750 and 1500 smallholders. The farmers donated 1–2.5 ha of community land to establish the FTC, including a demonstration farm, and the government paid for the construction of the center. The farmers also contributed by providing free labor during the construction of these facilities [63]. In a study conducted to examine the perceptions of farmers and extension professionals about cost sharing of agricultural technology transfer in Nigeria, more than 80% of the farmers and extension professionals had favorable perceptions. However, in a few developing countries where the approach has been tried, it was not well adopted [55]. Thus, Eicher [13] has argued that there is insufficient evidence to whether smallholder farmers, by being able to pay for such costs, can ever "buy their way out of poverty".

4.5. The Education Institution Extension Approach

The education institution approach was developed through the United States Land Grant university experiences. The approach was introduced to Africa and Asia by donor agencies such as USAID [39]. An education institution extension is a decentralized approach that is often implemented by well-established educational institutions (Agricultural schools, colleges, and universities) with the technical knowledge and research capacity to conduct the extension activities especially to poorly resourced farmers [41,53]. The approach, therefore, forms part of the institution's outreach activities [53]. These remarkable features of the approach extend to user-centric research, quality pre-service and in-service training for extension field staff personnel, and a sturdy linkage between academic teaching and field practices [39,46]. The educational institution extension approach is facilitation for empowerment approach which builds practical knowledge in the classroom and technical skills in the farming field. Program planning for the approach tends to be controlled by those who determine the curriculum of educational institutions. Generally, in this model, industry (research), as well as intermediary players, become part of the extension system [46].

The approach's primary assumption is that faculties of agricultural institutions create technical knowledge that is relevant and useful to farmers, and their service staff (teachers) can constantly interact with farmers to transfer knowledge and improve their agricultural teaching skills [39,41]. Furthermore, the approach is based on the notion that some farmers who tend to be reluctant to undertake formal or long-term educational courses may in the future change and be willing to acquire some informal theoretical and practical learning. Success in this approach is measured by farmer turnout and the extent of participation by farmers in the institution's extension activities.

The approach's main advantage is that of reducing costs to the national government. Generally, the approach encourages academic institutions to develop policy briefs from their research, and the research outputs contribute to the national extension system. Further, the relationships that exist between specialized scientists and field-based extension workers become good practical training for both [41]. This is because some research can be carried out on farms just like in farming systems research, depending on rapport with farmers. However, one limitation associated with having academic personnel to teach in the field is that they sometimes become too academic, which makes their demonstrations less practical and useful to the farmers. Moreover, some of the research from academics may be scientific curiosity and not addressing immediate farmer problems.

In some countries, such as South Africa, Zimbabwe, Malawi, and Nigeria, education institution approaches have been designed to be one of the principal mechanisms for disseminating research findings to farmers and linking research with farmers' needs [47,53]. However, the institution does not assume the full responsibility for extension work [46]

but supports other dominant extension systems [41,46]. In countries such as India, the education institution approach through a vast network of State Agricultural Universities (SAUs) supports the general extension approach by taking over extension functions inadequately implemented by the ministry-based extension [17,46]. Thus, the SAUs are integrating teaching, research, and extension at all levels of university administration and in various districts across the country [17]. For example, the Punjab Agricultural University (PAU) developed its multidisciplinary extension team stationed in each district to engage in adaptive research, training, extension, and consultancy with farmers [46].

5. Towards a Revolutionized Extension System in Developing Countries

Failure by the public extension system to effectively support the ever-expanding smallholder livestock sector calls for innovative strategies to revolutionize the system [49]. This suggests the need for the extension system to be reformed and become more cost-effective, smallholder farmer-centered, and pluralistic [5,36]. The revitalized extension system should embrace the contemporary application of ICTs in extension processes, emphasize the participation of resource-constrained smallholder farmers, rural women's empowerment, as well as the involvement of both farmers and extension agents in adaptive research [17,25,26]. Figure 1 illustrates the potential of infusing extension systems with ICTs for sustainable growth of the smallholder farming systems. However, the use of innovative strategies in developing countries is being hampered by the gaping lack of innovative institutions, especially those supporting smallholder farmers [24]. Further, there is arguably little research that is being conducted to revitalize the public extension system through innovation. Abadu-raheem and Worth [61] argued that integrating the country's agricultural policy agendas and innovation with a clear understanding of the needs of the smallholder agricultural sector is a prerequisite for revolutionizing the country's extension. To this end, this paper presents a practical expression on the potential role of ICTs such as mobile phones and the internet in revolutionizing public extension and its support towards smallholder farmers.

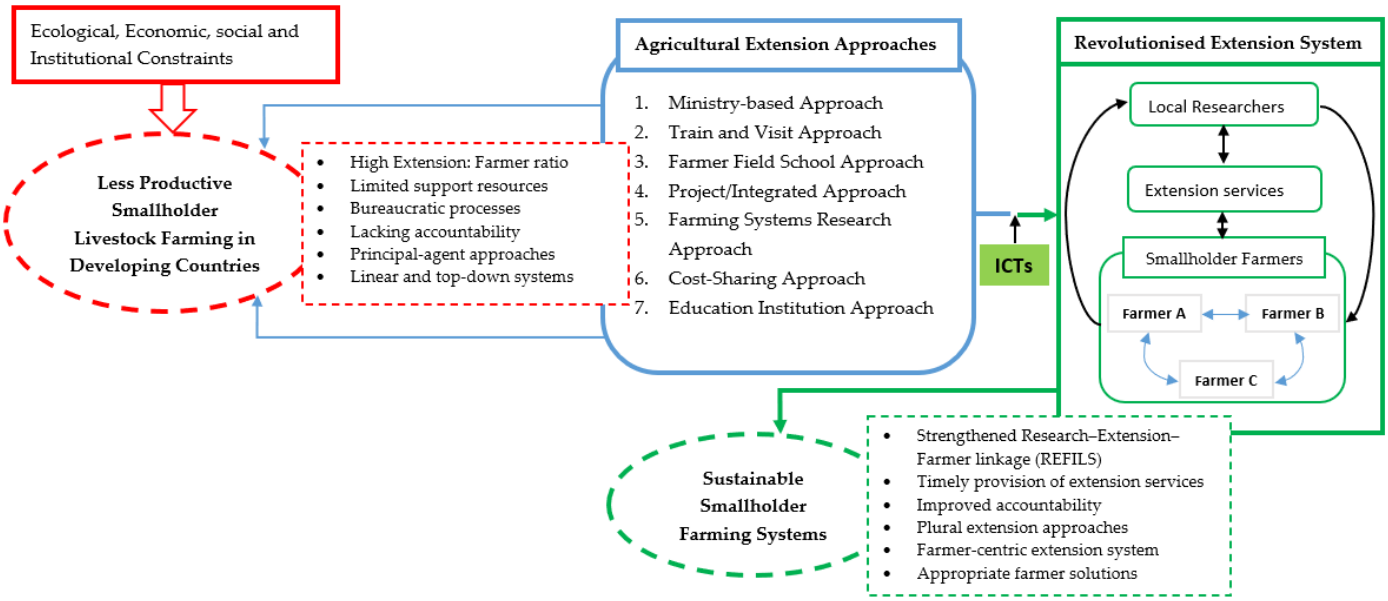

Figure 1. The schematic presentation on the prospects of revolutionizing agricultural extension using ICTs.

Potential for the Application of ICTs in Revolutionizing Agricultural Extension

The provision of extension services has continued to evolve with efforts pointing to the application of ICTs [17,23]. Already, the research discourse in this area underscores the potential for ICTs in improving the provision of information and agricultural services towards

smallholder farmers [1,22,23]. In agricultural innovation, the fast-evolving ICTs and the use of mobile phones have assumed a prominence that has progressively moved beyond mere communications [8]. Such innovation presents a tremendous potential to drive sustainable and inclusive agricultural growth and development among marginalized groups such as subsistence farmers, youths, and female agricultural producers in Africa [26,69,70]. The capacity of ICTs to bring this new momentum to smallholders seems even more compelling due to the current increased investments in research and development and the upsurge of organizations promoting their use in rural farming communities especially in East Africa [71]. Additionally, the ever-increasing availability and uptake of mobile phones (Figure 2) present a huge potential for the proliferation of all-inclusive ICT-based innovations among smallholder farmers [1,26]. According to FAO [72], many countries within SSA have population sizes that are smaller than their total number of mobile-cellular subscriptions. Currently, the SSA region has a mobile subscriber penetration rate of 45% and a mobile internet adoption rate of 24% [73]. Global Systems for Mobile Connections (GSMA) [73], reported that the mobile-cellular market for SSA reached 446 million unique subscribers (9% of global mobile subscriptions) in 2018 and is expected to reach 690 million by 2025. Smartphones account for a third of these total mobile subscriptions. Smartphones are expected to take over basic phones as their penetration rate is rising sharply [9], with countries like South Africa expected to exceed 60% penetration rate by the year 2025 [73].

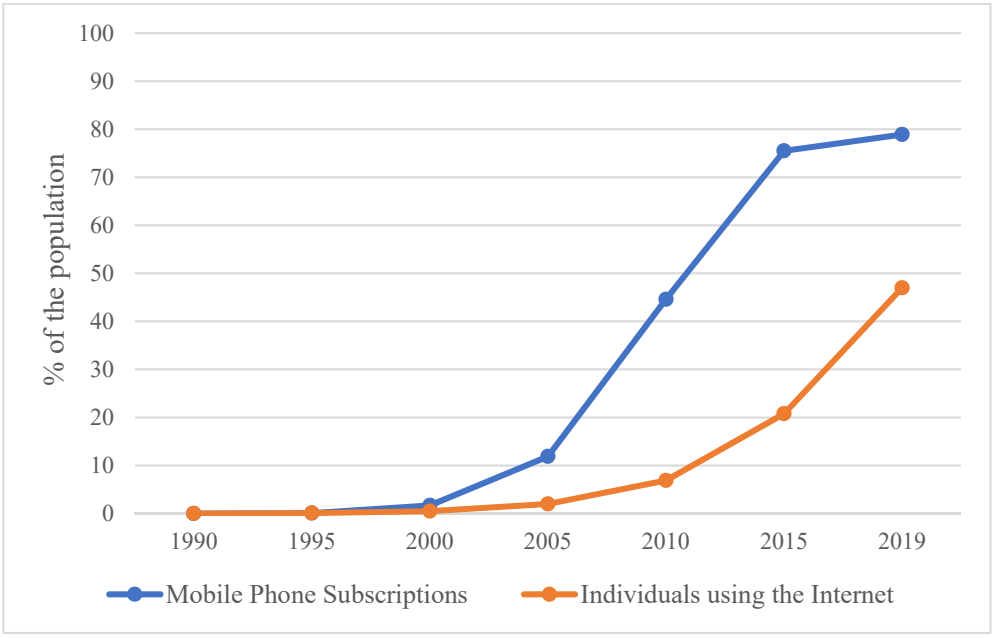

Figure 2. The spread of digital technologies in the SSA region (Source: World Bank Data [74]).

Internet is also an important component of digitization, and its access by smallholder producers further unlocks the prospects of driving smallholder agricultural production through digital-based strategies. As shown in Figure 2, internet use is also projected to continue growing in developing countries and specifically within smallholder agricultural systems [69]. Since most online or internet-based activities take place on mobile phones [75], the proliferation of mobiles, especially smartphones, could be key in leapfrogging internet use and provision of mobile broadband to smallholder farmers [25]. The current mobile internet adoption for SSA is 24% and is expected to continue growing [73]. Chair et al. [70] reported a significant increase in internet usage and mobile uptake by youth between 2008 and 2012 in countries such as Nigeria, Kenya, South Africa, Uganda, Ghana, Cameroon, Mozambique, Ethiopia, Botswana, and Rwanda.

Apart from that, there are dozens of various agricultural mobile applications (Apps) and web-based platforms being developed and implemented to support agricultural exten-

sion delivery and, hence, transformation of smallholder farmers [22,25,71]. Given the need to address heterogeneous and complex farm management issues within the smallholder sector [22], these initiatives are constantly evolving (growth of the "App economy") [76]. Esoko, established in 2005 in Ghana, which offers marketing, livestock, and crop production advice and weather forecasting to smallholder farmers, has since been replicated and currently operates in 16 African countries including Nigeria, Sudan, Malawi, Kenya, Uganda, Rwanda, and Zimbabwe [69]. This indicates the importance and potential gains of using ICTs such as mobile phone-based innovations in supporting smallholder farmers.

One of the greatest potentials for revitalizing extension is the fact that smallholder farmers are inherently agricultural innovators, and that they actively engage in sharing innovations among themselves and with extension agents [12,59]. Thus, Deichmann [6] notes that people have sought advice from one another ever since they started growing crops, raising livestock, and catching fish. However, Anandajayasekeram, et al. [7] observed that most farmers in the ESA region were willing to share information with fellow farmers, but an internal mechanism was not put in place to compensate for their time. The evolution of digital technologies, therefore, presents new and efficient channels for farmers to exchange innovations and experiences (networking). This existing knowledge and skills sharing can help in expediting the introduction and use of digital technologies by the farmers. Further, ICTs are perceived to foster back-to-back and timely sharing of extension information between farmers, extension agents, and researchers [16,18]. Furthermore, the increasing number of mobile phones and broadband connectivity could assist in bringing high-end services closer to the smallholder farmers [71]. Additionally, such technologies offer opportunities for farmer-centered documentation of local information and innovations which define traditional knowledge [59,71].

According to Ogbeide and Ele et al. [1], ICTs can also improve access to and the provision of financial services to smallholder farmers. Expansion of the mobile money ecosystem to reach previously unbanked resource-constrained and remote farming populations will be enhanced through increased access to mobile phones and the internet [8,73]. Moreover, the provision of tailored financial services further presents valuable opportunities such as the improvement in women and youth engagement in agriculture [18,69]. Since most smallholder farmers are women (>50%), and they perform more than 60% of all agricultural activities in the smallholder sector [26], improved access to management information and financial services through digitalization is perceived to increase overall productivity and poverty reduction in rural areas.

According to Costopoulou et al. [22], efforts to promote the adoption and use of ICTs in agriculture require the active involvement of government agencies and various other agricultural institutions. In addition, the development, adoption, and use of these technologies to support agricultural extension delivery in smallholder farming systems should be supported by effective policy agendas and implementation frameworks. South Africa's NPEAS policy draft has already flagged the introduction of ICTs into extension as one of the government's main objectives [77]. Thus, extension agents can use the ICT-based tools to gather, retrieve, adapt. and disseminate a broad range of agricultural information and services required by smallholder farmers.

Policies should also focus on developing infrastructure in the rural farming communities which include expansion of electrification programs, as well as widening access to internet service and mobile network coverage to facilitate efficient extension services delivery [23].

6. Conclusions

Smallholder livestock production is an important component of the agricultural economy. However, smallholder farmers continue to lag in commercialization, and this is caused by many challenges and constraints. Some of the major challenges include the shortage of inputs, low formal market participation, land degradation, poor access to financial resources, lack of skills, and limited access to extension services. Agricultural extension

invariably helps to bring agricultural information, inputs, and improved technologies and facilitates access to markets and credit facilities by smallholder farmers for improved productivity and livelihoods. Sustainable agricultural development among smallholder livestock farmers can be achieved by adopting and applying extension approaches that fit into the condition of the farmers. They are various extension approaches that are being used to support the smallholder agricultural development agenda in developing countries. Some of these approaches include technology transfer approaches (Ministry-based and T&V), the commodity specialized approach, participatory extension approaches (FFS and project (integrated) approach, farming systems research and extension approach), cost-sharing approach, and education institution approach. Public extension is the chief source of extension services for smallholder farmers in developing countries; however, it has remained deficient due to various systemic challenges, which are complex and multi-faceted. It is deemed to be heavily under-resourced, costly, overstretched, unaccountable, and often beset by bureaucratic processes. The inefficiency of the extension system often restrains farmers from addressing their everyday challenges and seizing various developmental opportunities. Failure by the public extension system to effectively support the ever-expanding smallholder livestock sector calls for innovative strategies to revolutionize the system. To this end, this paper discusses a practical expression on the potential role of ICTs such as mobile phones and the internet in revolutionizing public extension and its support towards smallholder farmers. The proliferation of mobile phones and the internet is envisaged to present an opportunity for the development of innovations that improve timely access to localized information and close the farmer–extension–research gap.

Author Contributions: Conceptualization, O.M., G.M., C.M., and A.M.; original draft writing, O.M.; review and editorial inputs, O.M., G.M., C.M., A.M., and K.D. All authors have read and agreed to the published version of the manuscript.

Funding: O.M. acknowledges the Seed Initiatives Funding from the Division of Social Impact and the Animal Sciences Departmental Bursary both from Stellenbosch University.

Data Availability Statement: The data used to develop Figure 2 in this article are openly available in [World Bank Open Data] at [https//data.worldbank.org], reference number [API_IT.CEL.SETS_DS2_en_excel_v2_2256600].

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ogbeide, O.A.; Ele, I. Smallholder Farmers and Mobile Phone Technology in Sub-Sahara Agriculture. *Mayfair J. Inf. Technol. Manag. Agric.* **2015**, *1*, 1–19.
2. Hemming, D.J.; Centre for Agriculture and Bioscience International (CABI); Chirwa, E.W.; Ruffhead, H.J.; Hill, R.; Osborn, J.; Langer, L.; Harman, L.; Coffey, C.; Dorward, A.; et al. Agricultural Input Subsidies for Improving Productivity, Farm Income, Consumer Welfare and Wider Growth in Low- and Middle-Income Countries A Systematic Review. *Agriculture* **2018**, 1–139. [CrossRef]
3. Aliber, M.; Hall, R. Support for Smallholder Farmers in South Africa: Challenges of Scale and Strategy. *Dev. S. Afr.* **2012**, *29*, 548–562. [CrossRef]
4. Liebenberg, F. *Agricultural Advisory Services in South Africa*; A Discussion Paper; Department of Agricultural Economics, Extension and Rural Development, University of Pretoria: Pretoria, South Africa, 2015.
5. Terblanche, S.E. Towards an Improved Agricultural Extension Service as a Key Role Player in the Settlement of New Farmers in South Africa. *S. Afr. J. Agric. Ext.* **2008**, *37*, 58–84.
6. Deichmann, U.; Goyal, A.; Mishra, D. *Will Digital Technologies Transform Agriculture in Developing Countries?* Policy Research Working Paper; World Bank: Washington, DC, USA, 2016; Volume 47.
7. Anandajayasekeram, P.; Davis, K.; Workneh, S. Farmer Field Schools: An Alternative to Existing Extension Systems? Experience from Eastern and Southern Africa. *J. Int. Agric. Ext. Educ.* **2007**, *14*, 81–93. [CrossRef]
8. Henze, J.; Ulrichs, C. The potential and limitations of mobile-learning and other services in the agriculture sector of Kenya using phone applications. In Proceedings of the 12th European International Farming Systems Association (IFSA) Symposium, Social and Technological Trans, Newport, UK, 12–15 July 2016; International Farming Systems Association (IFSA): Shropshire, UK, 2016; pp. 1–11.

9. Nikola, T.; Samuel, V.; Meng, Z. *Digital Technologies in Agriculture and Rural Areas*; Food and Agriculture Organisation: Rome, Italy, 2019; Volume 21.
10. Gwala, L.; Monde, N.; Muchenje, V. Effect of Agricultural Extension Services on Beneficiaries of the Nguni Cattle Project: The Case Study of two Villages. *Appl. Anim. Husb. Rural Dev.* **2016**, *9*, 31–40.
11. Danso-Abbeam, G.; Ehiakpor, D.S.; Aidoo, R. Agricultural Extension and its Effects on Farm Productivity and Income: Insight from Northern Ghana. *Agric. Food Secur.* **2018**, *7*, 1–10. [CrossRef]
12. Mapiye, O.; Makombe, G.; Mapiye, C.; Dzama, K. Management information sources and communication strategies for commercially oriented smallholder beef cattle producers in Limpopo province, South Africa. *Outlook Agric.* **2019**, *49*, 50–56. [CrossRef]
13. Eicher, C.K. *Agricultural Extension in Africa and Asia*; Department of Agricultrural Economics, Michigan State University: East Lansing, MI, USA, 2007.
14. Raidimi, E.M.; Kabiti, H.M. A Review of The Role of Agricultural Extension and Training in Achieving Sustainable Food Security: A Case of South Africa. *S. Afr. J. Agric. Ext.* **2013**, *47*, 120–130. [CrossRef]
15. Millar, J. Adapting Extension Approaches to Cultural Environments in South East Asia: Experiences from Laos and Indonesia. *Ext. Farming Syst. J.* **2009**, *5*, 143–148.
16. Baig, M.B.; Aldosari, F. Agricultural Extension in Asia: Constraints and Options for Improvement. *J. Anim. Plant Sci.* **2013**, *23*, 619–632.
17. Meena, M.S.; Singh, K.M. *Pluralistic Agricultural Extension System in India: Innovations and Constraints*; Munich Personal RePEc Archive: Munich, Germany, 2013.
18. FAO. *Information and Communication Technology (ICT) in Agriculture: A Report to the G20 Agricultural Deputies*; Food and Agriculture Organisation: Rome, Italy, 2017.
19. Cook, B.R.; Satizábal, P.; Curnow, J. Humanising Agricultural Extension: A review. *World Dev.* **2021**, *140*, 105337. [CrossRef]
20. Duvel, G.H. Towards an Appropriate Extension Approach for Agricultural and Rural Development in South Africa. *S. Afr. J. Agric. Ext.* **2000**, *29*, 10–23.
21. Davis, K.E.; Terblanche, S.E. Challenges Facing the Agricultural Extension Landscape in South Africa, Quo Vadis? *S. Afr. J. Agric. Ext.* **2016**, *44*, 231–247. [CrossRef]
22. Costopoulou, C.; Ntaliani, M.; Karetsos, S. Studying Mobile Apps for Agriculture. *IOSR J. Mob. Comput. Appl.* **2016**, *3*, 1–6.
23. Marwa, M.E.; Mburu, J.; Oburu, R.E.J.; Mwai, O.; Kahumbu, S. Impact of ICT Based Extension Services on Dairy Production and Household Welfare: The Case of iCow Service in Kenya. *J. Agric. Sci.* **2020**, *12*, 141. [CrossRef]
24. Hazell, P.; Poulton, C.; Wiggins, S.; Dorward, A. *The Future of Small Farms for Poverty Reduction and Growth*; International Food Policy Research Institute: Washington, DC, USA, 2007.
25. Qiang, C.Z.; Kuek, S.C.; Dymond, A.; Esselaar, S. *Mobile Applications for Agriculture and Rural Development*; World Bank: Washington, DC, USA, 2012.
26. Tsan, M.; Totapally, S.; Hailu, M.; Addon, B. *The Digitalisation of African Agriculture: Report 218-219*; The Technical Centre for Agriculture and Rural Cooperation (CTA): Wageningen, The Netherland, 2019; ISBN 9789290816577.
27. Wesley, A.; Faminow, M. *Background Paper: Research and Development and Extension Services in Agriculture and Food Security*; Asian Development Bank: Mandaluyong, Philippines, 2014.
28. Udmale, P.; Ichikawa, Y.; Manandhar, S.; Ishidaira, H.; Kiem, A.S. Farmers' Perception of Drought Impacts, Local Adaptation and Administrative Mitigation Measures in Maharashtra State, India. *Int. J. Disaster Risk Reduct.* **2014**, *10*, 250–269. [CrossRef]
29. Kohler, M. Confronting South Africa's Water Challenge: A Decomposition Analysis of Water Intensity. *S. Afr. J. Econ. Manag. Sci.* **2016**, *19*, 831–847. [CrossRef]
30. Oduniyi, O.S.; Rubhara, T.T.; Antwi, M.A. Sustainability of Livestock Farming in South Africa. Outlook on Production Constraints, Climate-related Events, and Upshot on Adaptive Adapacity. *Sustainability* **2020**, *12*, 2582. [CrossRef]
31. Mcdermott, J.J.; Staal, S.J.; Freeman, H.A.; Herrero, M.; Van de Steeg, J.A. Sustaining Intensification of Smallholder Livestock Systems in the Tropics. *Livest. Sci.* **2010**, *130*, 95–109. [CrossRef]
32. Thamaga-Chitja, J.M.; Morojele, P. The Context of Smallholder Farming in South Africa: Towards a Livelihood Asset Building Framework. *J. Hum. Ecol.* **2014**, *45*, 147–155. [CrossRef]
33. Chingala, G.; Raffrenato, E.; Dzama, K.; Hoffman, L.C.; Mapiye, C. Towards a Regional Beef Carcass Classification System for Southern Africa. *S. Afr. J. Anim. Sci.* **2017**, *47*, 408–423. [CrossRef]
34. Bester, J.; Matjuda, L.E.; Rust, J.M.; Fourie, H.J. The Nguni: A Case Study. *J. Afr. Econ.* **2001**, *12*, 127–155.
35. Myeni, L.; Moeletsi, M.; Thavhana, M.; Randela, M.; Mokoena, L. Barriers Affecting Sustainable Agricultural Productivity of Smallholder Farmers in the Eastern Free State of South Africa. *Sustainability* **2019**, *11*, 3003. [CrossRef]
36. Akpalu, D.A. Agriculture Extension Services Delivery in a Semi-Arid Rural area in South Africa: The Case Study of Thorndale in the Limpopo Province. *Afr. J. Food Agric. Nutr. Dev.* **2013**, *13*, 8058–8076.
37. Mapiye, O.; Makombe, G.; Mapiye, C.; Dzama, K. Limitations and prospects of improving beef cattle production in the smallholder sector: A case of Limpopo Province, South Africa. *Trop. Anim. Health Prod.* **2018**, *50*, 1711–1725. [CrossRef]
38. Kerr, W.A. The COVID-19 Pandemic and Agriculture: Short- and Long-run Implications for International Trade Relations. *Can. J. Agric. Econ.* **2020**, *68*, 225–229. [CrossRef]
39. Swanson, B.E.; Rajalahti, R. *Strengthening Agricultural Extension and Advisory Systems: Procedures for Assessing, Transforming, and Evaluating Extension Systems*; World Bank: Washington, DC, USA, 2010.

40. Hanyani-Mlambo, B. *Strengthening the Pluralistic Agricultural Extension System: A Zimbabwean Case Study*; Food and Agriculture Organisation: Rome, Italy, 2002.
41. Axinn, G.H. *A Guide on Alternative Extension Approaches*; Food and Agriculture Organisation of the United Nations: Rome, Italy, 1988; pp. 1–31.
42. Baxter, M.; Slade, R.; Howell, J. *Aid and Agricultural Extension: Evidence from the World Bank and Other Donors*; The World Bank: Washington, DC, USA, 1989.
43. Ali, M.; Haider, M.S. An Analysis of Farmer Field School (FfS) as a Potential Source of Advanced Technology Dissemination Among the Farmers of District Faisalabad, Pakistan. *Int. J. Suistanble Dev.* **2012**, *3*, 65–70.
44. Kidane, T.T.; Worth, S.H. Different Agricultural Extension Systems Implemented in Africa: A Review. *J. Hum. Ecol.* **2016**, *55*, 183–195. [CrossRef]
45. Batchelor, S.; Scott, N.; Manfre, C.; Lopez, A.V.; Edwards, D. Is There a Role for Mobiles to Support Sustainable Agriculture in Africa? In Proceedings of the ICT Sustainability Conference, Stockholm, Sweden, 24–27 August 2014; pp. 272–280.
46. Nagel, U.J. Alternative approaches to organizing extension. In *Improving Agricultural Extension: A Reference Manual*; Swanson, B.E., Bentz, R.P., Sofranko, A.J., Eds.; Food and Agriculture Organisation: Rome, Italy, 1997.
47. Gary, A.; Willem, Z.D.B. *Rural Extension and Advisory Services: New Directions*; World Bank: Washington, DC, USA, 2002.
48. Cuellar, M.; Hedlund, H.; Mbai, J.; Mwangi, J. *The National Agriculture and Livestock Extension Programme (NALEP) Phase I. Impact Assessment*; Swedish International Development Agency: Stockholm, Sweden, 2006.
49. David, M.M.; Samuel, H.S. The Role of Agricultural Extension in the 21 Century: Reflections from Africa. *Int. J. Agric. Ext.* **2014**, *2*, 89–93.
50. Eicher, C.K. Zimbabwe's Maize-Based Green Revolution: Preconditions for Replication. *World Dev.* **1995**, *23*, 805–818. [CrossRef]
51. GFRAS. *Module 3: Agricultural Extension Programme Management*; GFRAS: Lindau, Germany, 2016.
52. Ogebe, F.O.; Adanu, D.O. Impact of Training and Visit (T&V) Extension System on Outputs and Income of Cereals Farmers in Zangon Kataf Local Government Area of Kaduna State, Nigeria. *J. Res. Bus. Manag.* **2018**, *6*, 42–49.
53. Kromah, A.T. *Extension Approaches for Agricultural Extension: Modernizing Agricultural Extension Systems*; IL, USA, 2016. Available online: https://meas.illinois.edu/wp-content/uploads/2016/03/Kromah-Abibatu-2016-Extension-Approaches-in-Agricultural-Extension.pdf (accessed on 3 April 2021).
54. Nagel, R. *Agricultural Extension in Africa*; World Bank: Washington, DC, USA, 1989.
55. Davis, K.E. Extension in Sub-Saharan Africa: Overview and Assessment of Past and Current Models, and Future Prospects. *J. Int. Agric. Ext. Educ.* **2008**, *15*, 15–28.
56. Bindlish, V.; Evenson, R.E. The Impact of T & V Extension in Africa: The Experience of Kenya and Burkina Faso. *Oxf. J.* **1997**, *12*, 183–201.
57. SNV. *Rural Agriculture Revitalisation Program: Horticulture Sub-Sector Study Report*; SNV: Harare, Zimbabwe, 2014.
58. Kaur, K.; Kaur, P. Agricultural Extension Approaches to Enhance the Knowledge of Farmers. *Int. J. Curr. Microbiol. Appl. Sci.* **2018**, *7*, 2367–2376. [CrossRef]
59. Burch, S. *Knowledge Sharing for Rural Development: Challenges, Experiences and Methods*, 1st ed.; Latin American Information Agency: Quito, Ecuador, 2007; ISBN 9789942010001.
60. Feder, G.; Murgai, R.; Quizon, J.B. The Acquisition and Diffusion of Knowledge: The Case of Pest Management Training in Farmer Field Schools, Indonesia. *J. Agric. Econ.* **2004**, *55*, 221–243. [CrossRef]
61. Abdu-Raheem, K.A.; Worth, S.H. Suggesting a New Paradigm for Agricultural Extension Policy: The case of West African Cuntries. *S. Afr. J. Agric. Ext.* **2016**, *44*, 216–230. [CrossRef]
62. Wandji, N.; Binam, N.; David, S.; Mva, J.M.; Gockowski, J. Assessing Potential Impact of a Farmer Field School Training on Perennial Crop in Cameroon. In Proceedings of the AAAE Conference Proceedings, Accra, Ghana, 20–22 August 2007; pp. 253–257.
63. Davis, K.; Nkonya, E.; Kato, E.; Mekonnen, D.A.; Odendo, M.; Miiro, R.; Nkuba, J. *Impact of Farmer Field Schools on Agricultural Productivity and Poverty in East Africa*; IFPRI Discussion Paper; International Food Policy Reseach Institute: Washington, DC, USA, 2010; Volume 40.
64. Bodnár, F.; de Steenhuijsen Piters, B.; Kranen, J. *Improving Food Security: A Systematic Review of the Impact of Interventions in Agricultural Production, Value Chains, Market Regulation and Land Security*; Policy and Operations Evaluation Department (IOB) Ministry of Foreign Affairs: The Hague, The Netherlands, 2011; Volume 188.
65. Bingen, J.; Gibbon, D. Early Farming Systems Research and Extension Experience in Africa and Possible Relevance for FSR in Europe. In *Farming Systems Research in the 21st Century*; Donhofer, I., Gibbon, D., Dedieu, B., Eds.; Springer: New York, NY, USA, 2012; pp. 49–71. ISBN 9789400745032.
66. Alonge, A.J. An assessment of the Impact of Farming Systems Research/Extension on the Adoption of Agricultural Technologies in the Middle-Belt Region of Nigeria. Ph.D. Thesis, Iowa State University, Ames, IW, USA, 1993.
67. Franzel, S.; Degrande, A.; Kiptot, E.; Kirui, J.; Kugonza, J.; Preissing, J.; Simpson, B. *Farmer-to-Farmer Extension*; Global Forum for Rural and Advsory services (GFRS): Lindau, Switzerland, 2015.
68. Mudhara, M.; Mutamba, J.; Masangano, C.; Anandajayasekeram, P. *Highlights of the Southern and Eastern African Association for Farming Systems Research-Extension (SEAAFSRE)*; International Farming Systems Association: Vienna, Austria, 2011.
69. AGRA. *Africa Agriculture Status Report 2015. Youth in Agriculture in Sub-Saharan Africa*; AGRA: Nairobi, Kenya, 2015.

70. Chair, C.; Deen-Swarray, M.; Khan, S. *Taking the Microscope to ICT Gender Gaps in Africa*; Communication Policy Research South Conference: Zanzibar, Tanzania, 2016; pp. 1–22.
71. World Bank. *ICT in Agriculture: Connecting Smallholders to Knowledge, Networks, and Institutions*; Updated Ed.; The World Bank: Washington, DC, USA, 2017; Volume 53; ISBN 9788578110796.
72. FAO. *Gender and ICTs: Mainstreaming Gender in the Use of Information and Communication Technologies (ICTs) for Agriculture and Rural Development*; FAO: Rome, Italy, 2018.
73. GSMA. *Mobile Internet Connectivity 2019: Sub-Saharan Africa Factsheet*; GSMA Intelligence: Nairobi, Kenya, 2019.
74. World Bank. *World Development Report 2016: Digital Dividends*; The World Bank: Washington, DC, USA, 2016.
75. GIZ. *Harnessing the Chances of Digitalisation for Rural Development: Lessons Learnt from German-Funded Rural Development Projects*; GIZ: Bonn, Germany, 2018.
76. ITU. *Digital Opportunities: Innovative ICT Solutions for Youth Employment*; ITU: Geneva, Switzerland, 2014.
77. DAFF. *National Policy on Eextension and Advisory Services*; DAFF: Pretoria, South Africa, 2014.