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Review

Important Policy Parameters for the Development of Inclusive Digital Agriculture: Implications for the Redistributive Land Reform Program in South Africa

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Abstract: The creation and deployment of digital technologies throughout the agro-food system contribute to achieving Sustainable Development Goal nine. However, various digitalization studies offer limited insight into the policy issues and solutions around emerging technologies and big data systems in agriculture. There is a need for an additional understanding of how agricultural policymaking should respond to the usage of digital technologies in the agri-food sector. Furthermore, evidence is limited on how existing agricultural government programs such as land reform can be linked with digitalization policy. This systematic review of literature sought to determine the transformation that is needed in the political and economic environment for the digital revolution to take place within South African land reform agriculture. A thematic analysis of data sampled from ProQuest Central, Scopus, Dimensions, and Google Scholar reveals five areas of intervention from agricultural policymaking. The digital revolution in agriculture can be brought about by transforming digital infrastructure, data interoperability and governance, digital markets, the compatibility of government incentives with the private sector, and the digital cultural landscape. This essay contributes to agricultural policy and decision-making dialogues that pay attention to digital technologies and land reform programs in South Africa.

Keywords: digital policy; agricultural economy; redistributive land reform program; South Africa

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1. Introduction

The potential disruptions of the fourth industrial revolution will impact the lives of people around the world, including in Africa. Policy choices on the African continent are likely to vary, but they must embrace digitalization to maximize its benefits and address its challenges [1]. These policies may also largely contribute towards achieving sustainable development goals (SDGs) such as SDG nine. SDG nine focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation [2,3]. Achieving SDG nine through technological innovations is important for African countries. For example, higher technology industries performed better and recovered faster in 2021 from the COVID-19 pandemic [2].

The relevance of the digital economy has increased in the era of the fourth industrial revolution (4IR) for all economic sectors, including agriculture. The 4IR has re-emphasized the role that information plays in addressing market imperfections. The current levels of growth in the digital economy can be attributed to its increased relevancy. For instance, information is known for increasing production and market efficiencies, with a great prospect of eliminating market failures. The digitalization of agriculture has been repeatedly identified as the next agricultural revolution, with policies and industries claiming that digital agriculture holds benefits for the environment and farmers [4]. At the industry level in South Africa, a positive correlation between information communication technology (ICT) growth and output has been found [5].

The relevance of the digital economy has transcended the boundaries of all economic sectors, including agriculture, and this is evident in the exponential growth of digital agricultural solutions. Current agricultural solutions have not only enabled greater data production but also increased its timeliness and applicability. The impact of digital technologies on the economy is expanding rapidly, with rapid diffusion and increasing depth of effect accompanied by ever-stronger affordances [6]. Digital solutions for agriculture not only generate data but also utilize it to improve optimization opportunities. Thus, agricultural digitalization—the production of data and its utilization through digital solutions for agriculture—results in the development of new agricultural business models based on data production and utilization.

Unlike in a classical economy where labor, capital, and land are the only factors of production, data is considered a factor of production in an envisaged agricultural digital economy (i.e., data-driven agriculture). Data is becoming increasingly important as a factor in production as agriculture also attempts to leverage it for critical and timely business decisions. Nonetheless, technology and knowledge have been considered important factors of production under the economics of agricultural research and development. The deployment of resources to produce agricultural digital solutions in Africa is still reliant on donor funding [7]. However, there are emerging high-tech markets in South Africa that aim at providing agricultural digital solutions to commercial farmers. The data produced through the employment of different kinds of agricultural digital solutions can be used to increase competitiveness [8].

There are various applications of agricultural digital solutions in Africa, from the provision of advisory and extension services to services related to input and output market access, allowing for the optimization of important tasks through automation [7,9]. The lowering of costs related to production has increasingly relied on the amount of available farm data. Moreover, businesses can leverage such data to gather important information about the choices of consumers. This enables businesses to align decisions about the prices of their products with consumers' willingness to pay and thereby extract the most benefits from product sales. For example, blockchain technologies can be used to trace the product from the farm to the retailer. Thus, consumers use this data to learn about how the products are produced and marketed. This enables them to have more knowledge about the products and make informed purchasing decisions. The generated production, marketing, and consumer data are used by various value chain stakeholders, including producers and consumers, as well as the general membership of societies to judge the acceptability of value chain operations [9].

1.1. Widespread Inequality within the South African Agricultural Sector

While the modernization of farms through the development of innovative digital technologies is taking place in agricultural sectors of developed economies [8], widespread inequality in the South African agricultural sector has the potential to impede the full realization of the benefits associated with the digitalization of agriculture. The widely documented dual nature of South African agriculture is linked to historical land dispossessions of the apartheid era [10]. Attempts to reduce inequalities in South Africa's agrarian sector through redistributive land reform and smallholder support programs have achieved little success [10,11]. This persistent inequality means that there is a potential for uneven adoption of digital technologies within the South African agricultural sector. There are significant differences in proprietary investments in Information and Communication Technology (ICT) aimed at improving the productivity of large-scale commercial agriculture by the private sector and public agricultural research investment, as well as research targeting the well-being of poor, smallholder farm households in the developing world [12]. However, the redistributive land reform program offers scope to deal with the potential digital divide in the South African agricultural sector.

1.2. Suitability of the Redistributive Land Reform Program for Digital Transformation in South African Agriculture

While the South African land reform program is used as a tool to deal with agrarian inequality, it is currently not envisaged as a tool for the digital transformation of the South African agricultural sector. We argue that the incorporation of digital transformation objectives in the redistributive land reform policy has the prospect of simultaneously addressing the sector's inequality while also improving efficiency and resuscitating failing redistributed farms. Agricultural transformation across the continent can be accelerated by incorporating digital technology into the management of an agricultural business, most often a farm [13]. The challenges faced by the land reform beneficiaries are not unique but common to African smallholder agriculture. Smallholder farmers are faced with institutional constraints such as poor infrastructure and telecommunications, poor human health, and thin markets for agricultural inputs, outputs, insurance, and finance as key challenges to African agricultural transformation [14]. While noting that land reform is one of the programs at the forefront of agricultural interventions in South Africa, there are lessons to be learned from other countries that have implemented the land reform program. The success of South African agriculture is heavily dependent on the success of the land reform program, which has the potential to affect not only the transferred farms but also foreign direct investments.

Land redistribution in South Africa is also constrained by the available budget and institutional capacity [15]. However, digitalization in South Africa has received considerable attention from policymakers. Although quantifiable commitments are still lacking, the South African government has demonstrated its support for the development of the digital economy through the enactment of various national policies and strategies. The Science, Technology, and Innovation (STI) policy, the Towards Digital Industrial Policy, the Digital and Future Skills Strategy Policy, and the Commission on Fourth Industrial Revolution are some of the key national efforts through which the South African Government aims to resolve existing challenges for successful development of the digital economy. The land reform program can take advantage of the opportunities provided by digitalization to improve the state of productivity on redistributed farms. Digitalization stands a chance because it allows farmers to access both input and output markets and optimize the production process by saving on inputs while increasing outputs.

The literature contains evidence of studies that examined factors affecting the adoption of digital technologies in agriculture within Europe, Central and South America, and Asia [9,16–18]. Factors affecting the digitalization level of agri-food cooperatives have been extensively examined in Europe [19]. Particular attention has been given to Spanish agri-food cooperatives [20,21]. There is also evidence of the impact of digitalization at the firm level in Indonesia and China [22,23]. Evidence of the impact of digitalization in the African context is still scanty, but some evidence of the impact of mobile applications among Kenyan farmers has been reported [24] and the effect of ICT within agro-processing industries [5]. Smidt and Jokonya [25] highlighted economic, social, and political factors influencing digital technology adoption by small-scale agriculture within South African agricultural value chains. Moreover, recent studies on Proactive Land Acquisition Strategy (PLAS) farms are limited to socioeconomic-related success factors [26], land size determination [27], and beneficiary selection criteria [28]. There are no studies that have examined the policy parameters that are important for the digitalization of PLAS farms. Thus, a question that remains to be answered is, "what are the important policy parameters for digitalization intervention?"

The literature on the digitalization of agricultural food systems is growing, but it is dispersed. In addition, there has not been a clear direction for the government to act. This is because of the restricted overview of established, evolving, and new themes and the lack of organized suggestions for policy. This is where this study intends to make a contribution by providing a summary of the digitalization literature and suggesting key social, economic, and institutional policy factors for improved government action. Ehlers et al. [29] stated that there is a need for additional understanding of how agricultural policymaking should respond to the usage of digital technologies in the agri-food sector. The potential relevance of the redistributive land reform initiative for addressing the digital divide in South Africa's dual agriculture sector is highlighted. The position of the redistributive land reform program within the agricultural policy makes it ideally suited for use as a two-pronged development instrument—to combat land inequality and address digital development. Without the identification of policy parameters, the government cannot identify the role that it has to play and delineate its approach. This could limit the derivation of the benefits associated with digitalization. The evidence generated in the aforementioned studies is insufficient because the approach is individualistic and only identifies the behavioral characteristics associated with the adoption of specific digital solutions. Thus, identifying these policy parameters is crucial for ensuring inclusive digital agriculture development in South Africa. The systematic review method is chosen because of its ability to provide an up-to-date summary of digitalization literature from a large amount of data and its relevance for policy decisions [30]. The implications for the land reform program are highlighted because of the position of the redistributive land reform program in the South African agricultural policy and how this gives it the advantage to be used as a two-pronged development tool to address land inequality and deal with digital development. The structure of the research is as follows: First, the materials and methods for data sampling and analysis are presented, followed by the results, which are provided in five themes. The discussion section follows. Then the study concludes.

2. Materials and Methods

2.1. Sampling and Data

Appropriate keywords were determined and defined to construct a search string. Each keyword's synonyms were also found. In addition, alternative spellings were monitored using appropriate truncations. Relevant papers were found in the databases Scopus, Dimensions, ProQuest Central, Google Scholar, and EconLit. After customizing the final syntax of the search phrase, these databases were queried to obtain relevant articles, policy documents, and prominent media outlets. The "explode" option was initially chosen, and then the search was narrowed for retrieval of data that was consistent with the objective of the study. Only studies that recommended areas of policy intervention were targeted. Finally, the final search string was produced using the necessary Boolean operators. The time period from 2000 to 2022, as well as English language options, were used to refine the search even further. Thus, the concentrated search returned 26 articles from Scopus, 77 articles from ProQuest Central, 19 documents from Google Scholar, three documents from EconLit, and no documents from Dimensions. Other documents (about 7) were identified through reviewer suggestions and reference checks. The data were loaded into the EndNote reference management system. Only 11, 35, 15, and 3 full document searches from Scopus, ProQuest Central, Google Scholar, and EconLit were successful using the endnote reference manager.

Moreover, documents from all the databases were combined, and duplicates were removed, leaving a total of 50. Every reference was exported in XML format and integrated into the ATLAS.ti 22 software package (developed by Scientific Software Development GmbH of Berlin, Germany) for qualitative data analysis. Based on the research question, the article titles and abstracts were evaluated and divided into two groups: relevant and irrelevant. Figure 1 represents the steps followed to arrive at the final sample size of 57. The final step was to analyze and develop the themes for the synthesis and summary of findings. Figure 1 below depicts the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework for the current study.

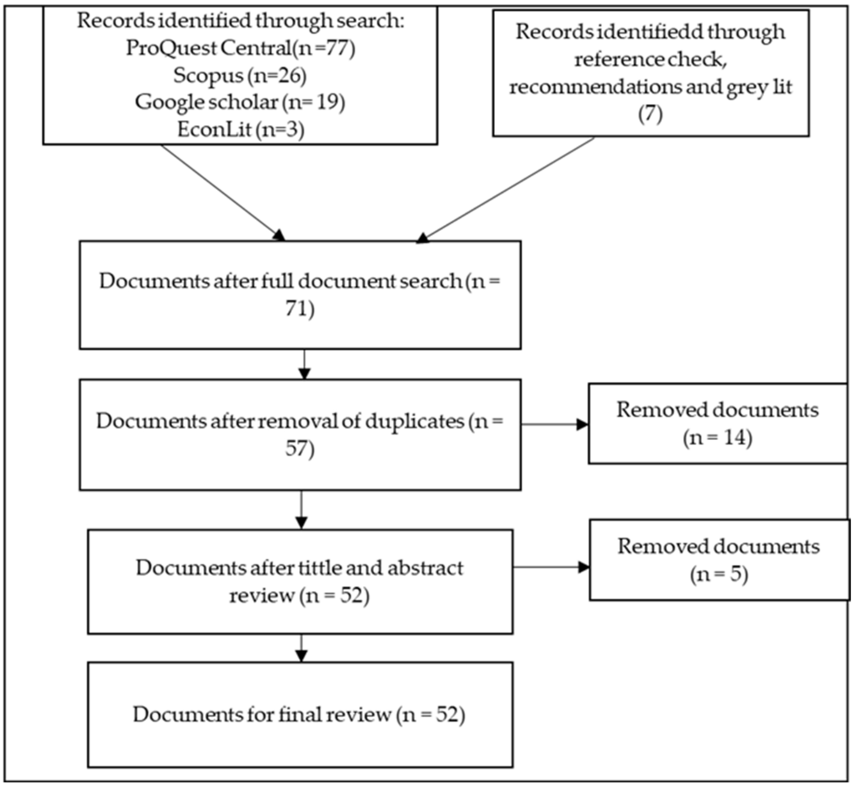

Figure 1. Literature search method using PRISMA framework.

2.2. Data Analysis

The main objective of the study was to classify and synthesize agricultural digitalization literature to develop themes and identify parameters for policy. Since systematic reviews are another form of qualitative literature review, there is no specific method for data analysis [30,31]. Given the nature of the research objective for the current study, thematic analysis (TA) was employed to analyze the data. The thematic analysis encompasses various methods, from quantifying qualitative data (content analysis) to more interpretive forms of data analyses based on recognizing themes and patterns in the data [32]. It differs from other forms of analyzing qualitative data, such as a grounded theory which is suitable for developing a theory from data that has been gathered systematically and analyzed [33].

TA provides more flexibility as it can be used in various ways, guided by various theoretical frameworks, and analyzing different forms of qualitative data (interviews, focus groups, diaries, etc.) [32]. More specifically, inductive, descriptive, and interpretative approaches to coding and analysis were employed. This means that while the analysis was grounded in data, it went beyond describing the patterns and themes to deciphering their meanings and interpreting their importance. Following Braun and Clarke [34], the six steps of thematic analysis were undertaken: familiarization with the data, coding, searching for themes, theme review, theme definition and naming, and report writing.

The data was coded in ATLAS.ti 2022. There is no specific coding scheme that was adopted. However, a word document search was employed to identify common terms across the data (see the word diagram in Appendices A and B). The coding scheme was then developed from the common terms. The data was disaggregated into text units that were then classified into sub-categories and parent categories. A descriptive thematic classification was then followed.

3. Results

The results section provides a summary of the data's findings. Coding was used to separate the data collected from various databases into text units. For the development of themes, textual data units were sorted into subcategories and then parent categories. The results revealed five significant descriptive themes about policy. Among these are infrastructure development; interoperability and data governance; market development; and the compatibility of government incentives and cultural transformation. The market development theme highlights both supply- and demand-side policy concerns. In this section, a statistical summary of the included publications and reports is offered first, followed by the previously specified themes. The infrastructural development subject is covered first, followed by the interoperability and governance of the data theme. The concept of market development is discussed next. Before the last topic, which is about cultural change, the theme concerning the compatibility of government incentives is presented.

The articles were categorized into five types of publications: unpublished theses (8%), conference proceedings (8%), journal articles (62%), newspaper pieces (12%), book sections (10%), and magazine articles (2%). As the majority of publications are published in scholarly journals, the proportion of unpublished articles is similarly high (about 38%). This could potentially lessen publication bias. In addition, the publication year runs from 2000 to 2022. About two-thirds (65%) of the articles were published between the years 2012 and 2022. The percentage of articles published in 2020 and 2019 was 10% and 10%, respectively. The majority of publications (15%) were for the year 2021, followed by the year 2016. (12%). Academic institutions and other interested parties, such as the government, have recently published on digitalization, as seen by the timeliness of these publications. This is consistent with Kamilaris et al. [35].

3.1. Infrastructure Development

The last-mile problem is persistent across farms, making it difficult to reach farmers and develop their digital infrastructure. Farmers cannot be reached easily because of their non-proximity to digital centers. Nevertheless, digital infrastructure is fundamental for the development of the digital agriculture revolution. Investments in "ICT Infrastructure" are seen as necessary starting points to develop the digital characteristics of a sustainable knowledge society [36]. Moreover, mobile broadband and Web 2.0 technologies and platforms, especially social media, have pushed the consumption of ICT infrastructure and applications in most societies, revolutionizing economic activities.

To deal with the last-mile problem, various programs that have been rolled out are focusing on fast broadband technologies. According to Kruger and Gilroy [37], the following strategy has been enacted at the federal level in the USA:

"The Rural Broadband Access Loan and Loan Guarantee Program and the Community Connect Broadband Grants, both at the Rural Utilities Service of the U.S. Department of Agriculture, are currently the only ongoing federal funding programs exclusively dedicated to deploying broadband infrastructure."

Rolling out fast broadband technologies (cable, telephone wire, fiber, satellite, wireless) seems to be at the forefront of government infrastructure development programs. While firms in other economic sectors can leapfrog and benefit from the current digital revolution, agriculture is unique because the location of farms requires that the government become heavily involved in rolling out the needed infrastructure. However, agriculture is similar to other economic sectors when it comes to digitalization because current digital agricultural solutions still require similar infrastructure.

The literature puts more emphasis on technology-specific infrastructure when it comes to digital agriculture solutions. Blockchain, big data and AI, the Internet of things, and machine learning infrastructure are required to make significant advances in agriculture digitalization [35,38–44]. Thus, policies that guarantee high-performance digital connectivity need to be promoted in all regions of the world [19]. The digitalization infrastructure is regionally skewed, with the European and North American regions leading the world. The macro-economic indicators of digitalization, such as the ICT Development Index, the Network Readiness Index, the Digital Innovation Index, and high-tech exports, reveal significant strides made by these regions in digitalization development [39]. As a result, the

South African government can either build the necessary infrastructure or allow the private sector, such as the mobile network operators, to provide the required digital solutions by creating a conducive environment for deriving returns on their investments.

3.2. Data Interoperability and Governance

Governance issues related to data ownership, data access rights, and potential lock-in need to be addressed. A crucial problem for policymakers is to strike a balance between maintaining the privacy and confidentiality of agricultural data and farmers' economic interests in those data while also enabling the sector's growth and innovation to capitalize on their potential [45]. Service providers tend to want to lock customers into exclusive use of their services to maximize revenue per user [38]. Various providers of digital agricultural solutions have also been observed to engage in such activities. Typically, intellectual property rights are conferred on club goods such as software, allowing a service provider to profit from advancements by charging customers a license fee. However, these intellectual property rights have enabled suppliers to make more money by developing software that works solely with data from certain agricultural machines [40]. Thus, interoperability needs to be addressed. An excerpt from Shibusawa [46] notes that,

"ICT strategy was issued by the government for precision agriculture to enhance the interoperability and portability of data . . . focused on standardization of data/information protocol, common terminology to share the information and knowledge." The standardization of databases enhances the digitalization effort by allowing data collected by different digital tools to be transferred between databases. Industry self-regulation has also benefited. For instance, the introduction of ISOBUS (ISO 11783) standards for tractors is one of the tactics used by machinery and equipment manufacturers to address compatibility concerns [40]. Moreover, potential lock-in may be addressed by enforcing competition. This is supported by findings from Rotz et al. [47] that, while Lely and DeLaval milking systems operate in a similar manner, it is difficult to access and pool data from these systems. Furthermore, farmers may be able to save money on digitalization for configurations developed for specific digital tools that can be exported to hardware/software from a different manufacturer. The specificity of farm management systems that makes technology bundles expensive can be reduced through cooperative adoption approaches. Although access may be a necessary condition, resources that increase operational capabilities and the development of open-source technology are also important.

There are additional privacy concerns around data ownership and monetization [35]. Data gathering and usage rules for various nations have been revised to provide guidance for resolving personally identifiable data. However, there is a lack of knowledge regarding the question of other data that is not personal, specifically when it comes to the question of who can monetize such data. E.g., does the data that is acquired using software and hardware and then used to support farm decisions still belong to the owner of the farm unit, or does it belong to the service provider? A Clear policy directive is essential so that farmers can establish their rights regarding data that is acquired from their farming units. According to Lezoche et al. [48], a lack of transparency regarding the ownership and control of data poses significant problems. Transparency is one of the six internal factors identified by Wolfert et al. [49] in the big data governance framework. Thus, the establishment of a data ownership policy framework is essential [35].

3.3. Market Development

There are few firms upstream that enjoy some level of market power. Downstream, there are many farmers who demand these digital agricultural solutions. This has implications for the distribution of benefits associated with digitalization. Oligopolistic firms may seek to capture a large portion of the benefits that influence pricing and the development process of these digital agricultural solutions.

3.3.1. The Supply Side of Agricultural Digital Solutions

Technology production and data development are important and depend on the functioning of markets. The oligopolistic firms for technology production and data development upstream are important for the development of the digital agricultural economy. According to Rotz et al. [47],

> "the Big Six: Bayer, Monsanto, Dow, Dupont, ChemChina, and Syngenta ... captured over 75 percent of the global agricultural input market ... have been central to the development and expansion of digital agriculture."

The concentration of these firms means that they have the human and financial capital to develop digital agriculture solutions. However, their corporate orientation means that the technologies developed may be suitable for a particular group of farmers. In South Africa, commercial farmers may be well positioned to adopt and use these agricultural digital solutions because of how they are priced. The prices for digital agricultural solutions may be a bit higher and, therefore, not affordable to medium- and small-scale farmers. Moreover, digital agricultural solutions are mostly developed to solve a specific problem and for production systems [35]. This may make the adoption of a bundle of these technologies very expensive. Another concern is the top-down development process of these technologies, which may make farmers unable to adapt them to their specific farm context. The creation of a conducive business environment for investments to start flowing into digital solutions from the government is necessary. Digital Infrastructure development, protection of intellectual property rights, regulation of markets, etc., are some of the services that are required from the government.

3.3.2. Demand Side of Agricultural Digital Solutions

The evolving context for the expansion of digital solutions is influenced by both top-down and bottom-up ICT policies and collaborative initiatives [46,47]. Digital Farmers also face numerous obstacles. Farmers must continue to use fertilizer, insecticides, and other vital inputs [7]. Therefore, even though digitalization may increase production and marketing efficiencies, the benefits may not be readily apparent to farmers, and evidence of the benefits is required to justify adoption. Farmers still require education about the advantages of agricultural digital technologies. A selection from Farkas et al. [50] points out that,

> "government interventions and campaigns to support the positive processes that have been set in motion could help digital solutions to spread."

While this demonstrates the necessity for initiatives to educate farmers about the advantages of digitalizing agriculture, attention must also be paid to other issues that have plagued farmers for the past century. For instance, farm revenue has not increased considerably due to persistently low prices for various agricultural products. The adoption of high-value crops and high-yielding cultivars has continued. Thus, although efforts to increase demand for digital agricultural solutions necessitate government education and awareness programs, prior efforts to increase farm revenue through price support and subsidy programs may continue to be significant. Farmers in Delhi have voiced their concerns about the minimum support price through protests [51].

Some digital agricultural solutions are very cheap or almost free, whereas others are very costly or almost unaffordable. For example, data costs are also high in South Africa [52]. The high cost of digital services and prevalent illiteracy hinder the electronic platform development of agriculture [51]. Economic growth is also important for boosting the demand for agricultural digital solutions. The growth and development between and among countries have led to digital inequality [53]. Moreover, the levels of digitization of agri-food cooperatives in European nations with varying incomes differed considerably [19].

3.4. Compatibility of Government Incentives with Private Sector Investment

Government intervention is essential, but it must not impede private-sector investment. It establishes order and reduces market uncertainty. An excerpt from Kruger and Gilroy [37] points out that,

> "a key issue is how to strike a balance between providing federal assistance for unserved and underserved areas where the private sector may not be providing acceptable levels of broadband service while at the same time minimizing any deleterious effects that government intervention in the marketplace may have on competition and private sector investment."

In order to secure the growth of the market for agricultural digital solutions, private sector investment is essential and must be incentivized. Public-private partnerships will also help with the development of those digital services that resemble public goods [40].

3.5. Cultural Change

While all other aspects of developing a digital agricultural economy are important, they need to be matched with the context of the people involved. The most important thing about changing people's culture is digital literacy.

> "Lower educated or lower skilled workers who are not able to adapt to the new technologies are left behind, while those that manage to adjust may capture immense opportunities." [44]

Farmers need to adapt to digital culture through digital literacy. An excerpt from Sharma et al. [36] suggests that "instead of a one-size-fits-all solution to the digital divide and digital literacy programs, a context-specific approach may be more effective." Braun and Clarke [34] also emphasize the role of adapting to digital technology. People's digital culture can be altered through several effective means. For example, while the impact of COVID-19 disruptions on supply chain digitalization has been acknowledged in [50], Kushnir et al. [54] advocated for youth and adult collaboration. Thus, digital culture should be regarded as an element of cultural diversity [55].

4. Discussion

The world's digitalization development is regionally skewed, with the leading countries in Europe and North America [39]. South Africa is among the leading countries on the African continent in digitalization development in terms of the ICT Development Index, Network Readiness Index, and exports of high technologies. It has also paid great attention to digitalization in its policymaking. The South African government's support for the growth of the digital economy has been proven through the adoption of numerous national policies and strategies. Agriculture is one of the primary targeted areas that these national programs attempt to benefit from. Part and the main reason for this is that the digital economy creates prospects for data-driven solutions to several agricultural development problems, which can help the country to meet its agricultural goals more effectively [25]. The dual South African agricultural sector could lead to a digital divide as adoption is likely to be skewed towards commercial farmers. Thus, the main concern is the integration of existing government programs, such as the land reform program and planned digitalization techniques for enhanced government intervention. Although academics are still investigating ways to provide evidence-based suggestions for combining existing government programs with planned ones, these ideas are currently in the works.

Digitalization has numerous ramifications for the land reform program, particularly if it can be included in the implementation of the program. The land reform initiative has several implementation difficulties [56]. The budget limits not only the amount of land that can be acquired for distribution but also the post-settlement assistance that is crucial to the success of the transferred land [11]. Therefore, the adoption and utilization of digital agriculture solutions can be advantageous for PLAS land reform farmers. Agricultural digital solutions enable value chain optimization, automation, and improved precision in data gathering, processing, and dissemination. However, the digital agricultural revolution has several implications for agricultural policy, and the literature points to how South African agricultural policymaking should respond to and facilitate the usage of digital technologies in the agri-food sector.

To allow value chain digitalization and, ultimately, improvement of efficiencies, the development of blockchain, big data, AI, the Internet of Things, and machine learning infrastructure is necessary. Specific government programs that focus on rolling out specific internet infrastructure, such as broadband, are more appropriate for farmers [37]. This is because the last-mile problem persists across farms, necessitating strenuous efforts to connect farmers and enhance their digital infrastructure. Farmers are difficult to approach because of their non-proximity to digital centers. Land-reform farmers are hindered in their access to input and product markets by several obstacles [26]. Appropriate infrastructure will increase agricultural digital innovations from high-tech and input suppliers. Adoption and use of agricultural digital solutions would therefore enable farmers to lower the transaction costs associated with getting market information and the information asymmetry that frequently prevents them from participating in input marketplaces.

Transaction costs are significantly higher for farmers in Africa compared to those in other regions of the world [14]. Thus, with the reduction in transaction costs, farmers' participation in input markets such as fertilizer and improved seed markets is likely to rise. Similarly, farmers will promptly participate in markets that offer necessary services, such as loan markets and markets for renting machinery. This is consistent with the findings of Bahn et al. [9], who show that digitalization has made a significant contribution to the Mena region's agri-food by facilitating access to land and machinery and services; resilient production and risk mitigation; access to finance; market access and information; transparency and traceability; and improved input use efficiency; farm management and decision-making; and extension services.

Land-reform farmers are also dependent on the gathering, processing, and dissemination of data. The results are consistent with some of the literature [29,35,40] that suggests transparency in data governance will be key to the development of efficient data collection, processing, and dissemination solutions. The digital agricultural technologies within this dimension or cluster offer three functions. First, they give farmers real-time information that is essential for planting, weeding, irrigation, and harvesting decisions. Most of the actions involved in automating farm processes rely largely on the data collected, processed, and disseminated by the digital tools in this cluster. Hence, agricultural digital solutions assist or enable the automation of these processes. Policy needs to pay attention to issues of data ownership and interoperability [45,46]. This is very crucial since it provides insights into the types of data that can be monetized and the processes thereof. Moreover, it also ensures transparency, which is important for farmers as they are able to see the value of digitalization [49]. Through the services supplied by these instruments, farmers can also gain access to consulting services.

Sustainable development of markets for digital agricultural solutions is still a challenge in Africa, and the development of a number of digital agriculture solutions is still donor-funded [57]. As a result, the development of digital agricultural solutions has favored digital solutions that provide advisory services. South Africa's scenario is different. A small market for digital tools has developed, although it is aimed at large-scale commercial farmers [58]. Although market development for agricultural digital solutions is beneficial to the South African agricultural industry, there are fears that it will facilitate digital inequality since it will exclude small and medium-sized farmers. There are calls to make agricultural digital technology research and development in the public sector more accessible [40]. The Agricultural Research Council's mobile application is one example of such efforts in South Africa. Regardless of how successful such efforts are, their adequacy and effectiveness in meeting the needs of farmers remain a source of controversy [40].

The willingness to pay for advisory services remains low because most of them provide information that is not context-specific. Thus, these services often assume a merit-good status [40]. For farmers to be prepared to pay for services, the government must invest in educational programs that raise farmers' understanding of digitalization's benefits. If these educational awareness programs are accompanied by the development of patents that protect intellectual property rights, the increase in demand for these services will also create good profits for suppliers. Strategies for sustained economic growth are required. Although the income elasticity of agricultural products is lower, economic growth is required to increase farmers' incomes. This could lead to increased adoption of digital agricultural solutions. For example, high-income European countries have a higher number of internet-mature agri-food cooperatives [19].

For PLAS land reform farmers to optimize input utilization, automation is crucial. The battle for cash amongst land reform programs has enormous ramifications for the post-settlement support project, which has been heavily criticized in the past [15]. Thus, optimal use of inputs means that farmers save on inputs and incur lower production costs. The provision of machinery through government support should also continue because some of the digital solutions are embodied in the machinery. If farmers do not have machinery, the adoption of certain digital solutions will be impossible [40]. There are digital solutions for agriculture that are not embedded in machinery, such as mobile applications; farmers should first be encouraged to embrace these solutions. However, these must be modified to deliver context-specific information for farmers to recognize the benefits.

The benefits of digitalization and communication thereof in developing countries seem crucial for the successful adoption of agricultural digital solutions. The communication of the benefits is also, in part, incorporated into digital solutions. This is supported by Antle et al. [12], who, in the introduction to the next-generation agricultural systems data, models, and knowledge products, noted that significantly improved data and models can contribute to the development of advanced farm-management systems and that making better information available about new systems could accelerate the adoption and efficient use of more productive and more sustainable technologies. Such data and models are also indispensable for evaluating the landscape-scale impacts of technology, evaluating policies to improve resource management, and estimating the performance of technologies under changing climatic and other environmental conditions.

Thus, the findings of this review are consistent with those of Ehlers et al. [29], who developed different scenarios by adjusting the levels of the drivers of digitalization which include describing data and infrastructure, degrees of acceptance, knowledge and learning and policy issues and emphasized the dependence of future digitalization on such drivers.

5. Conclusions

This systematic literature review was meant to identify political and economic challenges as well as methods for addressing them in the development of digital agriculture. The dual nature of South African agriculture is expected to influence the spread of digitalization in the agricultural sector. The position of the redistributive land reform initiative in South African agriculture policy allows for the possibility of bridging the digital divide in South African agriculture. For the development of digital agriculture within the land reform program, the following elements must be addressed: infrastructure development, data interoperability and governance, market development, digital culture, and government and private sector agent compatibility. The infrastructure of the Internet of Things, big data, blockchain, machine learning, and artificial intelligence encourages investments in digital agriculture solutions. Protection of intellectual property rights is also required to alleviate some of the supply constraints. Demand-side market development also relies heavily on educational awareness programs. System stability is ensured through the evolution of digital culture, digital literacy, and the compatibility of government incentives with the private sector. These variables necessitate the collaboration of various parties (businesses, consumers, and the government) because they span digital markets, technologies, platforms, and institutions. While the elements and issues provide salient policy imperatives, there is a need to explore empirical evidence for implementing policy options.

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Appendix A

Table A1. Synonyms for keywords.

Impact	Effect *, affect *, consequence *, repercussion *, ramification *, role, significance
“Digital technolog * poli *”	“Information communication technolog * poli *”
digitalization	“Fourth industrial revolution”
Agricultur *	Farm *, cultivat *, horticultur *, culture, husbandry, agronom *, agronomy, till *, “grow * food” “food grow *” “farm * econom *” agribusiness *
Technolog *	Telecommunicat *, automat *, robot *, “hi * tech *”
Poli *	Act *, approach *, arrange *, behave *, code, guideline *, method, plan *, program *, protocol, rul *, schem *, strateg *, channel *, course, design *, lin *, order *, polity, stratagem, tenet, red tape, dimension *
Digitalization	Digital *, 4.0, 4IR, Fourth industrial revolut *

Appendix B. Final Search String

(TITLE-ABS-KEY (“digital technolog poli*” OR “information communication technolog* poli*” OR “fourth industrial technolog* poli*” OR “ICT* poli*” OR “government* interven*”) AND PUBYEAR > 1999 AND PUBYEAR > 1999) AND (TITLE-ABS-KEY (agricultur* OR farm* OR cultivat* OR horticultur* OR culture OR husbandry OR agronom* OR agronomy OR till* OR “grow* food” OR “food grow*” OR “farm* econom*” OR agribusiness*) AND PUBYEAR > 1999 AND PUBYEAR > 1999) AND (TITLE-ABS-KEY (digital* OR 4.0 OR 4ir OR “Fourth industrial revolut* “) AND PUBYEAR > 1999 AND PUBYEAR > 1999).*

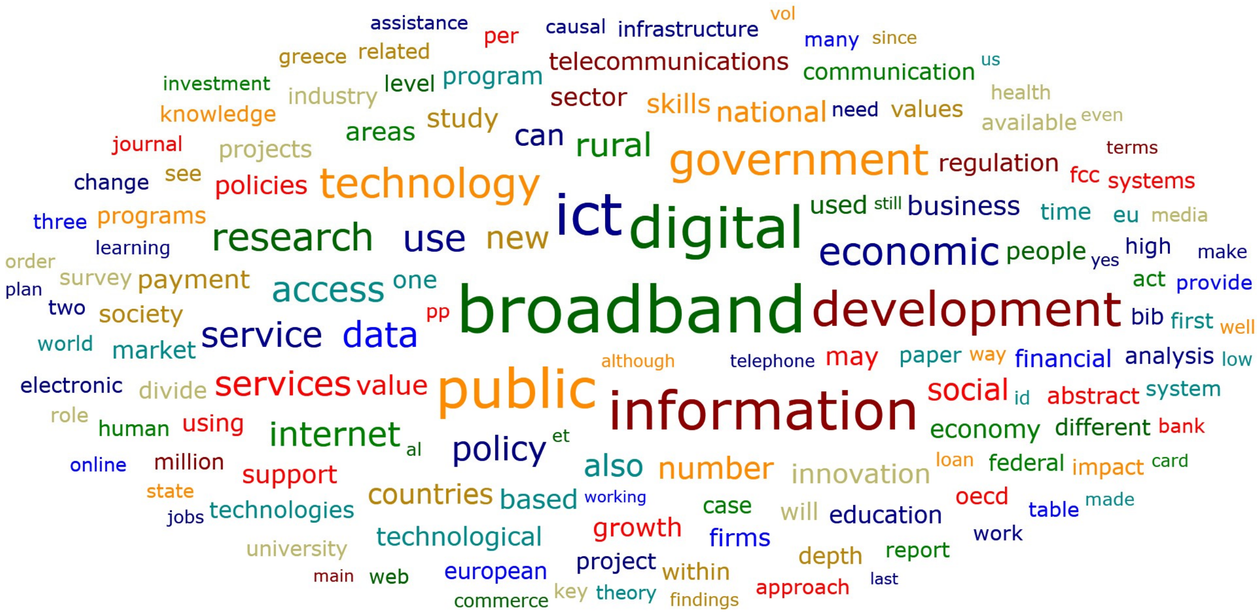

Figure A1. Word document search. Source: Author's computation.

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