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Research Paper

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ABSTRACT

Despite the growing interest in e-agriculture research in South Africa, academic studies have not sufficiently and deeply investigated the current e-agriculture research trends in the South African context. It is unclear how primary e-agriculture research in South Africa will aid both current and future generations to create new and better ways to transform agricultural development using this modern technology. This study sought to determine the current status of e-agriculture research in the South African context. A systematic literature review was used to gather and analyze data. The results indicate that 17 papers (26.5%) were published during the first two years (2010-2011) and 28 papers (43.7%) during the last two years (2014-2015). The results of the study further indicate that the use of satellite enhancing agriculture (14 papers, 21.8%) was the most prominent e-agriculture research area in South Africa (27 papers, 23.6%). The results of this study show that information mapping was the most used research method by researchers in their studies (30 papers, 46.8%). The results of the study helped to understand the importance of enhancing research capability and socio-economic transformation of farmworkers and farmers through enhanced communication of agriculture research knowledge in the area of agricultural informatics.

KEYWORDS

Agriculture, e-agriculture, research, information and communication technology (ICT), South Africa, systematic literature review.

INTRODUCTION

All over the world, people are beginning to adopt electronic agriculture (e-agriculture) for sustainable agriculture and rural development. Sylvester (2011) defines electronic agriculture as a particular emerging branch of study paying attention to improvement of agriculture and rural development by using enhanced information and communication procedures. It is determined by important components such as capacity development, education, support of standards and norms, facilitation, and technical support (Ghogare and Monga, 2015). E-agriculture offers an excellent opportunity to facilitate communication channels and traditional delivery of services to support the agricultural organization's ability to meet the needs of farmers (Namisiko and Aballo, 2013). It improves access to information and resources, empowers farmers to make agricultural decisions, and streamlines organizational processes and transactions.

South Africa is classified as the world's 25th largest country because of its land area and is located at the southern tip of the African continent. It is considered as the 24th most populous nation in the world as the population is close to 53 million people (Arteaga, 2014). South Africa has been classified among African countries as a 'desert' when it comes to the use and adoption of technology. (Maumbe and Okello, 2010). However, South Africa's agriculture has followed the trends toward using and adopting e-agriculture with the purpose of facilitating agricultural information and knowledge exchange, improving agricultural delivery programs, processing and marketing functions, and promoting productivity among farmers (Jones, 2011; Mpofu, 2011). This is observed by many e-agriculture initiatives across the country and through websites in order to improve the agricultural sector and encourage rural development (Maumbe, 2010). The growth of e-agriculture is considered an important and practical means to facilitate rural development and develop the agricultural sector, as well as to promote food security and reduce rural poverty in South Africa (Tembo and Maumbe, 2011).

In general, E-agriculture research is focused on efforts to harness the potential of information and communication technology professionals (ICTs) in agriculture with various stakeholders, such as private, public as civil society, and international government and non-government organizations in various parts of the world willing contribute to the sustainability and productivity of agricultural industries (Chisenga, 2008). The growing attention in e-agriculture research in recent years has shown e-agriculture to be an emerging trend in information and communication technology (ICT) use of agriculture in the rural development domain (Patrikakis and Maumbe, 2012). Therefore, the importance of e-agriculture research has been recognized by industries and academic researchers as a crucial tool to enhance the competitiveness of the agricultural business in South Africa (Simpson and Calitz, 2014).

Understanding early e-agriculture research in South Africa will assist both current and future generations with creating new and better ways to develop the agricultural sector when using this modern technology (Tembo and Maumbe, 2011). Previous studies on e-agriculture in South Africa concentrated on specific sectors, and were limited to certain geographical locations in South Africa, but the country as a whole was not considered in terms of how e-agriculture research can contribute to agricultural development in South Africa (Hooper, Kew and Herrington, 2010). This study is intended to cover studies published during the years 2010 to 2015. The objective of this research was to determine the current status of e-agriculture research in South Africa. A summary of systematic literature reviews in the e-agriculture research in South Africa was represented. All related research in response to the research questions was illustrated and classified in this systematic literature review. Therefore, this study seeks to respond to the following research questions:

1. What has been the focus of research on e-agriculture in South Africa?

2. What types of research methods, approaches and theoretical lenses have been used in e-agriculture research in South Africa?
3. What are the units of analysis and observation and levels of analysis that have been used in e-agriculture research in South Africa?

This study is organized as follows: firstly, the introduction is presented; secondly, the review method is addressed; thirdly, the paper presents the results of the study, which includes a summary of the research finding;. fourthly, the paper addresses the discussions of the findings; fifthly the paper presents the limitations of the study; finally, conclusions are addressed and recommendations for future study are presented.

RESEARCH METHODOLOGY

REVIEW METHOD

The review method was used by categorizing the research questions, search strategy, study selection criteria, selection procedure and data extraction according to guidelines. The guidelines of Unterkalmsteiner et al. (2010) have been adopted for a complete review. These guidelines have been used in several papers in information systems and software engineering.

Search Strategy

For the paper to conduct the review and answer this systematic literature review research questions efficiently and scientifically, pertinent papers from the following web search engines and digital databases were covered: EBSCOhost, Google, Google Scholar, IEEE Xplore Digital Library, ProQuest, SA Theses, SA ePublications, ScienceDirect, and Scopus.. The quality of search strategy adopted by the researcher to avoid overlooking pertinent publications was high. Different keywords were created regarding the research questions to find the pertinent papers. Firstly, keywords were used in Google and Google Scholar. Secondly, the researcher extended the search results by using many keywords combined with the AND operator. Thirdly, the researcher used keywords and combined search keywords in digital databases. This process yielded 142 published papers on e-agriculture in South Africa. The papers included books, conference papers, Master's theses, Doctoral theses, and journal articles.

STUDY SELECTION CRITERIA

The researcher conducted the abstract reading step to exclude the papers not pertinent to this systematic literature review. Publications that were not written in English, that were not full papers, and that were not within the related fields (i.e. ICT adoption and use in agriculture companies, e-government direct services, mobile in agriculture, computerized back-end developed systems, use of networking in agriculture, use of geographic information systems improving agriculture, use of global positioning systems improving agriculture, use of satellite enhancing agriculture, e-commerce, ICT in agricultural supply chains, empowering local agricultural communities through information and ICTs and providing broader information on agriculture), have been excluded.

SELECTION PROCEDURE

Papers were reviewed for the second time by means of keywords and abstracts to be more focused on the research questions and the objective of the study. The paper reviewed publications on e-agriculture

in the South African context based on titles, abstracts and by date. Only literature published within the years 2010-2015 was analyzed for the objective of this study. A total of 64 papers on e-agriculture in South Africa were yielded in this process. These papers included books, conference papers, Master's theses, Doctoral theses, and journal articles.

DATA EXTRACTION

The extraction of data was created based on the research questions of this study. A pilot review was conducted to assess the form. The focus of e-agriculture research in South Africa was the principal perspective of the first version of the data extraction after reading the abstract of each paper. Next, different empirical research methods used in these papers were determined. Then different research approaches used in the papers of the study were ascertained. Next, different theoretical lenses used in the papers of this study were identified. Thereafter, the unit of analysis used in the papers was determined. The unit of observation used in the papers was also determined.

RESULTS OF LITERATURE REVIEW

FOCUS OF E-AGRICULTURE RESEARCH IN SOUTH AFRICA

The investigation into various types of research papers for this study was designed with the focus on e-agriculture research in the South African context to identify the focus of e-agriculture research investigated by researchers in their studies. It was therefore anticipated that different topics on e-agriculture research would be found in the research papers. The results of this study show that a large number of e-agriculture research studies in South Africa have been focused on the use of satellite enhancing agriculture (14 papers, 21.8%), followed by the use of geographic information systems (GISs) improving agriculture with a contribution of 12 papers (18.7%). Empowering local agricultural communities through information and ICTs contributed with nine papers (14%). The results of this study furthermore indicate that ICT adoption and use in agriculture companies contributed six papers (9.3%), followed by computerized back-end developed systems with a contribution of five papers (7.8%). The use of global positioning systems (GPSs) improving agriculture, and providing broader information on agriculture were discussed in four papers (6.2%), respectively; followed by e-commerce that was discussed in three papers (4.6%). The least focus was on mobile agriculture with a contribution of one paper (1.5%); followed by e-government direct services, ICT in agricultural supply chains and networking in agriculture with a contribution of two papers (3.1%), each.

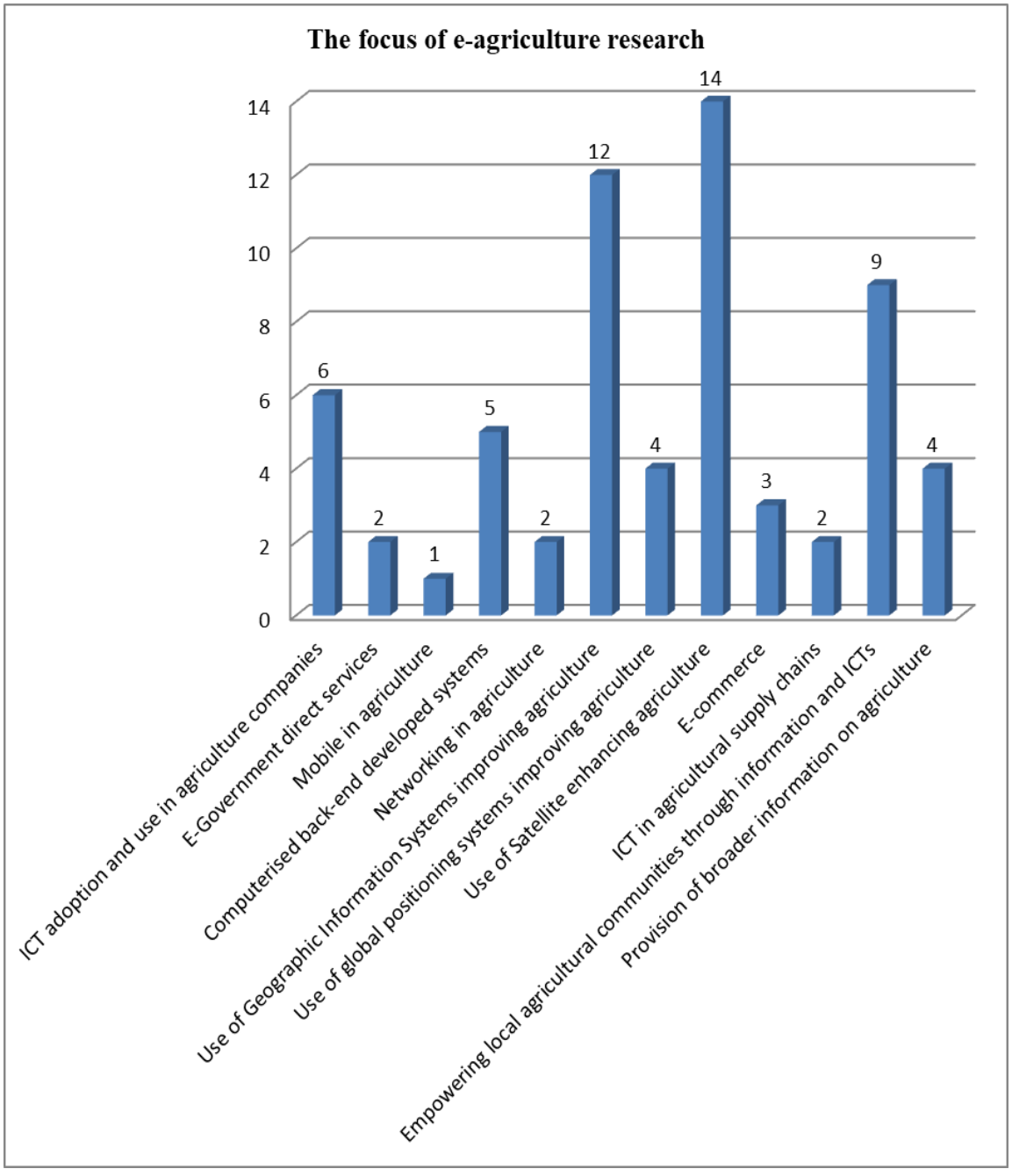

Figure 1: The focus of e-agriculture research in South Africa

ICT Adoption and Use in Agriculture Companies

ID	Topics
[70]	Explored the Internet access profile of farmers and sought to examine which devices are employed for Internet access by commercial farmers. Sought to determine the objective for which mobile technology is employed in the South African farming community. 70% of farmers use their mobile devices to access the Internet. No brand of tablet computer or mobile phone was found to dominate the agricultural community.
[32], [33]	In North West Province, South Africa, the level of awareness of ICTs among agricultural extension officers was examined. There are several ICT tools used by extension officers to share agricultural messages and information such as CD-ROM, radio, organization website, fixed telephone, fax machine, video, computer, personal e-mail, overhead projector, television, mobile phone, World Wide Web, DVD, Internet, newspaper, and organization email.
[73]	Investigated factors helpful in the development of commercial agriculture in South Africa that affect ICT use by farm employees. ICT training, race, age, current occupation on farm, educational level, and ICT literacy are elements affecting the use of ICT by farm employees.
[43]	Reviewed several irrigation technologies in agriculture enhancing socio-economic conditions in both Kenya and South Africa. Sought to determine farmers' constraints on modern technology adoption for irrigation and the role played by both government and nongovernmental organizations to encourage modern technology adoption for irrigation. The total cultivated areas in South Africa and Kenya with modern technologies for irrigation are only 9% and 3%, respectively.
[31]	Sought to understand how farmers and agribusiness are utilizing Instagram to raise the profile of farming in South Africa. The author revealed that with Instagram, farmers have started sharing snaps from the farm. This raised the profile of their product and generated positive sentiment in the process.

Table 1: Focus and findings of research papers on ICT adoption and use in agriculture companies

E-government Direct Services

ID	Topics
[41]	Proposed an e-agriculture and e-government marketing framework and used the Cape Gateway Project (CGP) experience to determine communication and marketing strategies for e-agriculture and e-government in the South African context.
[40]	The existing and potential use of ICT in agriculture and rural development were determined in Sub-Saharan Africa (Kenya and South Africa). Sought to determine e-government developments as a medium that helps to support the deployment of ICT in the agricultural sectors of South Africa and Kenya. ICT use can be considered a useful instrument to support agriculture and to enhance rural development and the living standard of South Africans and Kenyans.

Table 2: Focus and findings of research papers on e-government direct services

Mobile in Agriculture

ID	Topics
[27]	Sought to understand how applications that farmers can download from their smart phones and tablets can be used for their benefit. A variety of weather apps are available that can serve as an information source and early storm warning system for farmers.

Table 3: Focus and findings of research papers on mobile in agriculture

Computerized Back-end Developed Systems

ID	Topics
[69]	Developed a cloud-computing model to enhance agricultural enterprises in marginalized rural areas in South Africa. The model includes a cloud architecture described as mobile information system with the purpose of helping farmers to download, share, and upload agricultural information such as weather, markets, seeds, and farming techniques.
[49]	Used virtual engineering tools for functional visualization, evaluation, and decision-making of intended infrastructure outcomes without physical modeling improve development of agricultural post harvesting and farm produce handling technologies. The introduction of Virtual Reality (VR) facilitates design interpretations during the preliminary stages through elaborative visualization.
[35]	A seasonal time-step computerized integrated model with prediction capability was developed and applied to facilitate decision-making under Integrated Water Resources Management (IWRM).
[38]	Sought to examine the irrigation scheduling schemes for water management and effective utilization in the Piesanghoek Macadamia cropland in Limpopo Province of South Africa. Several farmers are still using conventional irrigation techniques, leading to low irrigation productivities and poor water utilization, but only a few have adopted new computerized technologies to manage the irrigation.
[50]	The experience of integrating different low-cost VR tools to help instructional delivery and junior researchers' visualization of a cattle handling system prototype.

Table 4: Focus and findings of research papers on computerized back-end developed systems

Networking in Agriculture

ID	Topics
[59]	A model facilitating wireless node deployment that is focused on experimental outcomes was proposed to disperse the impact of surrounding foliage on the wireless signal.
[52]	Signal strength for three different types of agricultural crops (density vegetation, medium height, and ground foliage) and the impact of near vegetation on the wireless signal with regard to link accuracy were examined; showed how current radio propagation foliage loss models are not developed for use in satellite farming or site-specific crop management.

Table 5: Focus and findings of research papers on networking in agriculture

Use of Geographic Information Systems (GISs) Improving Agriculture

ID	Topics
[56]	Delineated small-scale irrigation farms by using GIS technology to assess the possible risk management and the importance of farmers to be close to buyers of fresh products. The scope of the distance between consumers and farmers was from 60 km to 265 km and a large number of farmers were situated far from the main roads. In addition, the authors found that cash crop was the most preferred technique to alleviate poverty among poor farmers.

[12]	In the Western Cape, a GIS based pesticide risk indicator composed of toxicity endpoints (using species sensitivity distributions) and exposure variables (physicochemical, pesticide application, crop data, and geographic) was created to evaluate the Predicted Relative Risk (PRRI) and the Predicted Relative Exposure (PREX) of applied pertinent pesticides to aquatic ecosystem health in the Lourens River catchment. International databases provide physicochemical data that are reliable for pesticide behavior and crop data in the Western Cape.
[68]	Compared the perspectives of former and current farmers by using GISSs to understand why farmers have abandoned farming. Sought to understand the composition of land areas abandoned by farmers at different periods, as well as the uses and woody plant cover. Farmers continued to abandon their farms over many decades with a decrease from 12.5% area of land cover in 1961 to 2.7% in 2009.
[16]	Sought to analyze the effects of rainfall variability on crop acreage in Mafikeng municipal area in North West Province by using GIS techniques and remote sensing applications. The size of cropland in Mafikeng municipal area is not negatively affected by the periodic variation and irregularity of rainfall.
[65]	In southern Gauteng, stonewalled structures were determined by using GIS software and Google Earth satellite imagery to support different cultures sharing a cattle-centered worldview as well as a rural and a mixed agricultural economic base.
[77]	Sought to determine the extent of fragmentation of the natural vegetation to indicate regions vulnerable to invasion and to delineate densities and the current extent of Prosopis in the Northern Cape province by using GIS techniques and remote sensing. There is a high degree of accuracy (72%) for densities and extent in the Northern Cape.
[20]	Used GISs that produce Digital Elevation Models (DEM) to illustrate data acquired for the wetlands in South Africa. Sought to understand how virtual globe systems such as Google Earth can help to obtain high-resolution elevation data acquisition instead of using geographic information systems. High-resolution DEMs can be obtained by using virtual globe systems such as Google Earth, particularly for areas of flat topography where it was very difficult to have access to suitable relief information.
[29]	Used GIS techniques and remote sensing data to characterize and identify the vineyards based on texture in the Helderberg basin in South Africa to solve the current problems and give direction for further studies on viticultural terroir. Pertinent information on vineyard areas can be obtained through remote sensing data.
[61]	Utilized a remote sensing and GIS to evaluate the agricultural development capacity in a particular area of Limpopo province, with the aim of creating a strategy for agricultural development. Remote sensing and GIS technology provide a possibility for integrated analysis of resource development capacity within a particular period of time and scale.
[26]	In a communal land use area in Barberspan in North West Province, land capability of the redistributed land was evaluated by using remote sensing and a GIS in spatial planning for arable farming. 48.7% of the area is covered by woodland, 29.7% by cropland, 15.1% by bare land, and 6.5% by water body.
[47]	A Spatial Decision Support System (SDSS) was developed by using Multi-Criteria Decision Making (MCDM), earth observation (EO) data, and GISs to determine strategically located land for land reform. The authors found that GISs and earth observation are important tools that help with facilitating evidence-based decisions for land reform.

[36]	Sought to understand the complexity of introducing centralized GIS decision support ICT applications in GDARD after 2003, with the focus on a specific GIS information and communication technology application for GDARD known as the Gauteng Integrated Decision Support (GIDS) system in agriculture. The needs of stakeholders for e-service delivery have not been fully met.

Table 6: Focus and findings of research papers on use of geographic information systems improving agriculture

Use of Global Positioning Systems (GPSs) Improving Agriculture

ID	Topics
[53]	Used global positioning wireless nodes to understand cow behavior and determine the position of a cow and the presence of the thieves. The value of the threshold to identify the agitation of an animal was 2.5 km/h. A cow has less chance when standing still at the outer limits of the farm. The predictive model enables preventing stock theft on South African farms and other farms in the word.
[18]	Tried to explain how GPSs are guiding the commercial agriculture sector in South Africa. GPS technology is important to manage the campaign against the invasive fruit fly and Bactrocerus dorsalis. Farmers are increasingly making use of GPS technology to monitor the movements of tractors and activities such as spraying herbicides or insecticides.
[67]	Used GPSs to analyze streamflow records, current land use, and long-term rainfall in the Incomati River basin in South Africa. The more important factors of temporary changes in streamflow are flow regulation and land use. Areas under irrigated agriculture and commercial forestry have increased more than 400%.
[19]	Re-evaluated and expanded on a previous study in the Swartland in Western Cape of South Africa that examined land use change and its environmental implications during the period 1960 to 2010 to determine a clear description of land use change and to investigate significant implications and problems of the observed changes by using GPSs.

Table 7: Focus and findings of research papers on use of global positioning systems improving agriculture

Use of Satellite Enhancing Agriculture

ID	Topics
[28]	Sought to locate new settlement developments in an automated manner for the agricultural sector by using coarse resolution satellite data.
[30]	Sought to investigate the impact of the South African land cover change on a land restitution project and land reform policy on land use by using the Landsat satellite (remote sensing) in Makotopong in Limpopo Province. Social and environmental condition of the land reform project can be supported by quantifying the changes in land cover and land use.
[25]	Seek to compare ground-based measurements by evaluating the reliability of SPOT Vegetation Normalized Difference Water Index (NDWI) and Land Surface Analyses Satellite Applications Facility (LandSAF) evapotranspiration.
[42]	In two highly invaded provinces of South Africa, native vegetation and alien plant species ((IAPs) were evaluated through satellite-based annual evaporation. Sought to determine the impact of the clearing of alien plant species on the availability of water resources through a diminution of evaporation by the Working for Water (WFW) program.

[1], [2]	In the Cathedral Peak region of the Drakensberg Mountain range in South Africa, mapping and estimating the variability in canopy concentration of C4 grasslands across C3 and nitrogen (N) was determined by using WorldView-2 (WV2) multispectral data. The mapping or estimation of N concentration can also be determined by using WorldView-2.
[11]	Employed SPOT-5 imagery using spatial variance of NDVI to evaluate existing MODIS LAI product accuracy for biomes and important land cover classes in South Africa. Used the inversion of PROSAIL radiative transfer model to evaluate LAI retrieved accuracy. The estimation of the MODIS LAI was specifically poor for Karoo biomes and grassland from November 2012 to February 2013.
[55]	Sought to understand the benefit of WorldView-2 data to map endangered tree species in the Dukuduku Forest of South Africa by employing an Artificial Neural Network (ANN) and Support Vector Machines (SVM) classification algorithms. The accuracy of using ANN was 75% and the accuracy of using support vector machines was 77%. This demonstrates that both machine-learning algorithms are very strong.
[74]	In the upper Molopo river catchment in South Africa, Landsat images were used to evaluate long-term impacts of land use influences that disturb the vegetation. There is statistical significance of the correlation between medium density vegetation and human population ($P < 0.01$, $r = -0.960$).
[46]	Sought to observe woody cover in the Kruger National Park in South Africa by employing SPOT-5 HRG panchromatic band and SPOT-4 HRVIR grey scale band images from 1998 to 2012 in association with panchromatic aerial photographs. There was a high classification accuracy of woody cover on the appropriate multi-temporal texture images.
[57]	Used satellite imagery and digital elevation models to determine the soil information requirements in South Africa, and to summarize a way forward in terms of data interpretation, capture, and storage. The current state of soil information of the country was presented through a historical background.
[37]	In a catchment in Ngqushwa district in the Eastern Cape province, temporal and spatial patterns of encroachment, soil erosion, Pteronia incana, and woody shrub species were investigated between 1998 and 2008 by using SPOT data and remote sensing. There is an increase of soil erosion with concentrated woody shrub encroachment on the hill slopes.
[60]	In KwaZulu-Natal, South Africa, the discrimination of forest species was investigated by using a few strategically placed WorldView-2 multispectral bands. The range of individual forest species accuracy generated by the WorldView-2 imagery was between 63% and 100%. The value of a kappa statistic was 0.83 and the general accuracies were 85.42%.
[76]	Used bootstrapped regression trees and 20-m SPOT satellite images on distinct combinations of morphometric data (wetness index, slope, elevation, and aspect) in order to survey viticultural terroirs on four dates in the Stellenbosch viticultural area. The results indicated that some promise to map viticultural terroirs, capturing expert knowledge on grape harvest quality at many places on a regional scale.

Table 8: Focus and findings of research papers on use of satellite enhancing agriculture

E-commerce

ID	Topics
[48]	Evaluated ICTs allowing agricultural commodity market exchange and sought to understand how small-scale farmers could participate more actively in the market. Even though South Africa has a world-class ICT infrastructure, this has not made it easier for small-scale farmers to enter the agricultural market and value chain.
[72]	Described ICT applications that allow enhancing online marketing to access lucrative global wine markets, electronic packaging, and quality regarding farm management decisions, as well as agricultural market information and product traceability.
[9]	Sought to understand how an e-commerce platform can support the agriculture industries in South Africa. The author found that e-commerce is good for consumers' safety and for facilitating farmers to run their business online.

Table 9: Focus and findings of research papers on e-commerce

ICT in Agricultural Supply Chains

ID	Topics
[5]	Investigated the effect of ICTs on agricultural development in the Alice rural community. Several factors such age, language barriers of ICTs adoption amongst farmers, and low levels of literacy are limiting the rural Alice community with access to ICTs.
[8]	Tried to explain how ICTs such as smart phones and mobile technology can play a crucial role in agricultural businesses in South Africa. Smart mobile devices with applications or software programs downloaded and installed have the capacity to boost productivity and revenue.

Table 10: Focus and findings of research papers on ICT in agricultural supply chains

Empowering Local Agricultural Communities through Information and ICTs

ID	Topics
[39]	In order to support agriculture service delivery in South Africa, an implementation framework for e-agriculture composed by a Multi-functional National Agro-portal (MWT) was proposed for agriculture development. Examined the capacity of wireless and mobile applications in agriculture and rural development in South Africa.
[15]	Investigated how IoT technologies can contribute to reduce agricultural needs and reduce poverty in rural environments in South Africa and Zambia. IoT technologies can support the communities to reduce agricultural needs in domains such as livestock farming, rural financing, wildlife management, crop farming, market identification, forestry, and weather forecasting.
[44]	Presented different aspects to use community radio as an important tool to diffuse a diversity of developmental and educational content for farming communities in South Africa. Community radio was presented as an instrument to help disadvantaged communities around the country with important issues. South African community radio stations contribute only little to farming diffusion. Therefore, individual stations need to be trained on hosting radio programs on farming.
[14]	Explored the benefits that South African agriculture can receive from the introduction of ICTs. There are practical issues to be resolved, including communication and knowledge transfer where ICTs can potentially have the biggest positive influence.

[66]	In South Africa, a digital form of aerial photographs was used to investigate the farming history of Okhombe from 1818 to 2009 to support the agricultural sector. Sought to investigate the changes in cattle population through time and rainfall data.
[13]	Explained how big data can improve the agricultural development in South Africa and the entire continent of Africa.
[4]	Sought to understand the existing challenges hampering the transformation of South Africa's emerging farmers into market-oriented farming. Evaluated how ICT could be implemented to provide the needed agricultural knowledge support infrastructure for farmers' transformation. ICT can help black farmers receive agricultural knowledge support infrastructure that could improve direct interaction and collaborative effort of farming stakeholders and that could help in providing solutions to farmers' diverse issues and forming farming educational foundations, which currently lacks.
[23]	Sought to examine different obstacles caused by e-society to the people of Hlabisa in KwaZulu-Natal in South Africa involved in the health, education, and agriculture sectors.
[34]	Sought to investigate e-readiness as an important tool among other ICT tools for extension officers in Mmabatho, South Africa. The age, number of farmers covered, working experience, educational level, and means of mobility and living in the job area are important determinants of e-readiness.

Table 11: Focus and findings of research papers on empowering local agricultural communities through information and ICTs

Providing Broader Information on Agriculture

ID	Topics
[54]	Sought to determine the role of ICTs supporting agricultural information access among extension officers in North West Province of South Africa. Electronic readiness (t=-3.01, p=.003), limitations of ICT tools (t=2.60, p=.010), use of ICT tools (t=4.67, p=.000), and education (t=2.61, p=0.11) are important determinants on the impact of ICT on information access.
[3]	Sought to utilize Internet resources in creating a shared knowledge space to increase natural and casual contact among individuals in the agricultural domain, especially those without formal agricultural education. Sought to understand problems hampering their transformation into market-oriented farming when using traditional agricultural knowledge diffusion approaches.
[22]	Sought to develop a system with limited resources and limited access to traditional technologies such as telephones and computers to facilitate and allow rural farmers access to their information sources or advertising their products. The system assists farmers with increasing their profit margins and ensuring their viability.
[64]	Tested an operational service with the possibility of enhancing water usage efficiency and the production of table wine in the Western Cape. The operational service had to provide online (via a website) information relating to the nitrogen status, crop growth, and water from 1 September 2010 to 30 April 2011 to all Western Cape producers of grape. Information was provided through parameter maps and vineyard blocks of the participating farmers.

Table 12: Focus and findings of research papers on providing broader information on agriculture

RESEARCH METHODS

The investigation of the types of research papers was built into the research questions in the field of e-agriculture research in the South African context to identify the methods used by researchers in conducting their studies. Since this study was related to ICT adoption and use in agriculture companies, e-government direct services, mobile agriculture, computerized back-end developed systems, use of networking in agriculture, use of geographic information systems improving agriculture, use of global positioning systems improving agriculture, use of satellite enhancing agriculture, e-commerce, ICT in agricultural supply chains, empowering local agricultural communities through information and ICTs, and providing broader information on agriculture, empirical methods were expected in these research areas. The empirical methods were divided into eight categories, namely case study, survey and experiment, design of system/method/model/solution, information mapping, field study, industry report, and grounded theory. The papers related to each method and their frequency are listed and included in table 13.

Research methods	Empirical papers	Frequency
Case study	[44], [41], [32], [73], [15], [69], [54], [14], [4], [3], [47], [48], [31], [8], [33], [18], [26], [27], [13], [9]	20
Survey	[70], [61], [54], [5], [22], [36], [34], [74], [20], [57], [65], [35]	12
Experiment	[73], [52], [53], [43], [59]	5
Industry report		---
Design of system/ method/model/ solution	[69], [26], [54], [64], [49], [50], [4], [22], [12], [74], [40], [29], [59], [35]	
Information mapping	[39], [61], [26], [56], [32], [47], [48], [16], [12], [68], [36], [30], [66], [29], [60], [1], [2], [11], [55], [74], [46], [76], [20], [37], [28], [42], [25], [65], [19], [38]	30
Field study	[61], [26]	2
Grounded theory	[4] [3]	2

Table 13: Research methods

Table 13 indicates that empirical methods have been considered in this study. In some papers, the authors have not indicated the research method, but the researcher managed to interpret these methods. Each research method was categorized and interpreted from the literature. Among the 64 pertinent papers, information mapping was the most used research method by authors in their studies (30 papers, 46.8%), followed by the use of a case study in 20 papers (31.2%). The third most used research method was the design of a system/ method/model/solution, discussed in 14 papers (21.8%); followed by survey with a contribution of 12 papers (18.7%). The fifth most used research method was experiment, discussed in five papers (7.8%). The least used research method was industry report with a contribution of nil papers (0%); followed by grounded theory and field study with two papers (3.1%), each.

RESEARCH APPROACH

The investigation of the types of research papers was built into the research questions in the field of e-agriculture research in the South African context to identify the research approach used by researchers in conducting their studies. The paper sought to determine the epistemological position on which a section of the study is based (Boell & Cecez-Kecmanovic, 2014). Different types of research approaches were expected to be used by researchers. A list of papers related to each approach and the corresponding frequency is included in table 14.

Research approaches	Papers	Frequency
Interpretivism	[15], [4], [3], [36], [30], [57]	6
Objectivism	[22]	1
Constructionism	[22]	1

Table 14: Different research approaches used by researchers in their studies

Among the 64 papers used in this study, six papers (9.3%) discussed the interpretive approach. The interpretive qualitative approach was used to determine the research question and analyze pertinent information [15]; it enabled the researcher to gather empirical data directly from the correspondents by sitting with participants to gather their detailed expectations, perceptions, and points of views on the topic. The interpretive qualitative approach was based on qualitative methods [4] [3], and used to analyze data in the context of operations, strategy and policy, and the impact on the efficiency and effectiveness of incorporated GISs [36]. The approach was used to locate the topic area and the land cover for two images [30]. Finally, it was also used for spatial soil information [57]. The results indicate that a large number of topics, all aligned with interpretivism, focused on use of satellite enhancing agriculture, providing broader information on agriculture, and empowering local agricultural communities through information and ICTs. The least used research approach was objectivism and constructionism with a contribution of one paper (1.5%) each. The objectivist and constructionism approaches were used to develop a system with limited resources and access to traditional technologies such as telephones and computers to facilitate and allow rural farmers to access their information sources or advertise their products [22].

THEORETICAL LENS

The investigation of the types of research papers was built into the research questions in the field of e-agriculture research in the South African context to identify the theoretical lens used by researchers in conducting their studies. Different types of theoretical lenses were expected to be used by researchers. In many papers, the authors have not indicated the use of a theoretical lens in their studies. Among the 64 pertinent papers, diffusion of innovation (DoI) was the only theoretical lens used by authors in their studies with a contribution of two papers (3.1%). First, DoI was used as the best existing model to explain the elements influencing ICT use in agriculture [73]. Secondly, DoI and development theories containing development support communication and the participatory approach were used to investigate the effect of ICTs for agricultural development in the Alice rural community [5].

UNIT OF ANALYSIS

The investigation of the types of research papers was built into the research questions in the field of e-agriculture research in the South African context to identify the unit of analysis used by researchers in conducting their studies. Since this study was related to ICT adoption and use in agriculture companies, e-government direct services, mobile agriculture, computerized back-end developed systems, use of networking in agriculture, use of geographic information systems improving agriculture, use of global positioning systems improving agriculture, use of satellite enhancing agriculture, e-commerce, ICT in agricultural supply chains, empowering local agricultural communities through information and ICTs, and providing broader information on agriculture, different unit of analysis types were expected to be used by researchers.

Unit of analysis	Papers	Frequency
Technology	[39], [44], [41], [15], [43], [56], [14], [47], [48] , [72], [40], [8], [18], [31], [27], [13], [9], [35]	18
Viticultural terroir	[76]	1
Land use/cover and soil	[61], [26], [32], [16], [30], [11], [74], [20], [37], [57], [28], [65], [19]	13
Water resources	[64], [67], [38]	3
Vegetation	[52], [68], [59], [1], [2], [46], [42], [25], [77]	9
Humans	[70], [32], [73], [69], [54], [4], [5], [3], [22], [36], [33], [23], [34], [66]	14
Animal	[53], [50]	2
Pesticides	[12]	1
Vineyard	[29]	1
Plant species	[55], [60]	2

Table 15: Different unit of analysis types

The results of this study show that technology was the most used unit of analysis by researchers in their studies (18 papers, 28.1%), followed by humans (14 papers, 21.8%), land use/cover and soil (13 papers, 20.3%), vegetation (nine papers, 14%) and water resources (three papers, 4.6%). Viticultural terroir, pesticides, and vineyard were the least used units of analysis with one paper (1.5%) each, followed by animal (two papers, 3.1%) and plant species (two papers, 2.6%). The most used units of analysis were focused on ICT adoption and use in agriculture companies, use of geographic information systems improving agriculture, use of global positioning systems (GPSs) improving agriculture, and use of satellite enhancing agriculture.

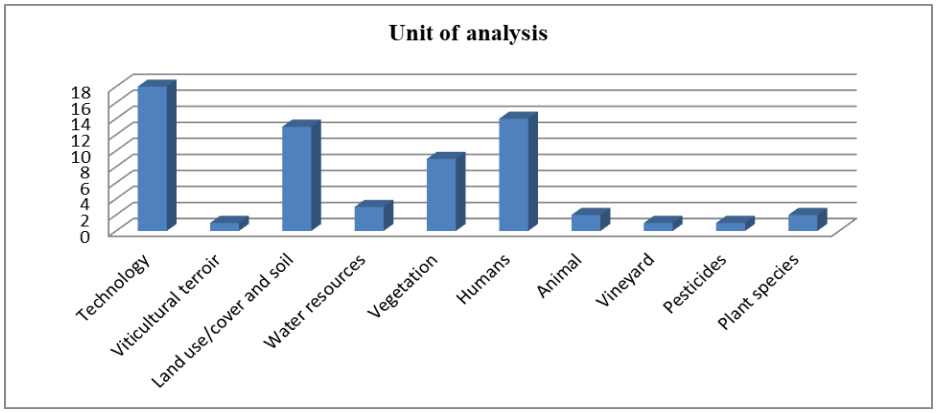

Figure 2: Different unit of analysis types

UNIT OF OBSERVATION

The investigation of the types of research papers was built into the research questions in the field of e-agriculture research in the South African context to identify the units of observation used by researchers in conducting their studies. Since this study was related to ICT adoption and use in agriculture companies, e-government direct services, mobile in agriculture, computerized back-end developed systems, use of networking in agriculture, agricultural information systems, use of geographic information systems improving agriculture, use of global positioning systems improving agriculture, use of satellite enhancing agriculture, e-commerce, ICT in agricultural supply chains, empowering local agricultural communities through information and ICTs and providing broader information on agriculture, different unit of observation types were expected to be used by researchers.

Unit of observation	Papers	Frequency
Technology	[39], [44], [41], [15], [43], [56], [49], [14], [47], [48], [72], [48], [8], [18], [27], [31], [57], [13], [9], [35]	20
Trees	[76], [46], [77]	3
Land use/cover and soil	[61], [26], [16], [30], [20], [57], [28], [65], [19]	9
Water resources	[25], [67], [38]	3
Plant species	[68], [60], [55], [37], [42]	5
Humans	[70], [32], [73], [69], [5], [4], [3], [22], [36], [33], [23], [34], [66]	13
Vegetation	[1], [2], [52]	3
Foliage	[49], [59]	2
Animal	[50], [53]	2
Vineyard	[64], [29]	2
Pesticides	[12]	1
Leaf area index	[11]	1

Table 16: Different unit of observation types

The results of this study showed that technology was the most used unit of observation by researchers in their studies (20 papers, 31.2%), followed by humans (13 papers, 20.3%), land use/cover and soil (9 papers, 14%), plant species (five papers, 7.8%), water resources (three papers, 4.6%), trees (three papers, 4.6%) and vegetation (three papers, 4.6%). Pesticides and leaf area indices were the least used units of observation with one paper (1.5%) each, followed by foliage (two papers, 3.1%), animal (two papers, 3.1%) and vineyard (two papers, 3.1%). The units of observation that were the most used in papers were focused on ICT adoption and use in agriculture companies, use of geographic information systems improving agriculture, use of global positioning systems (GPSs) improving agriculture and use of satellite enhancing agriculture.

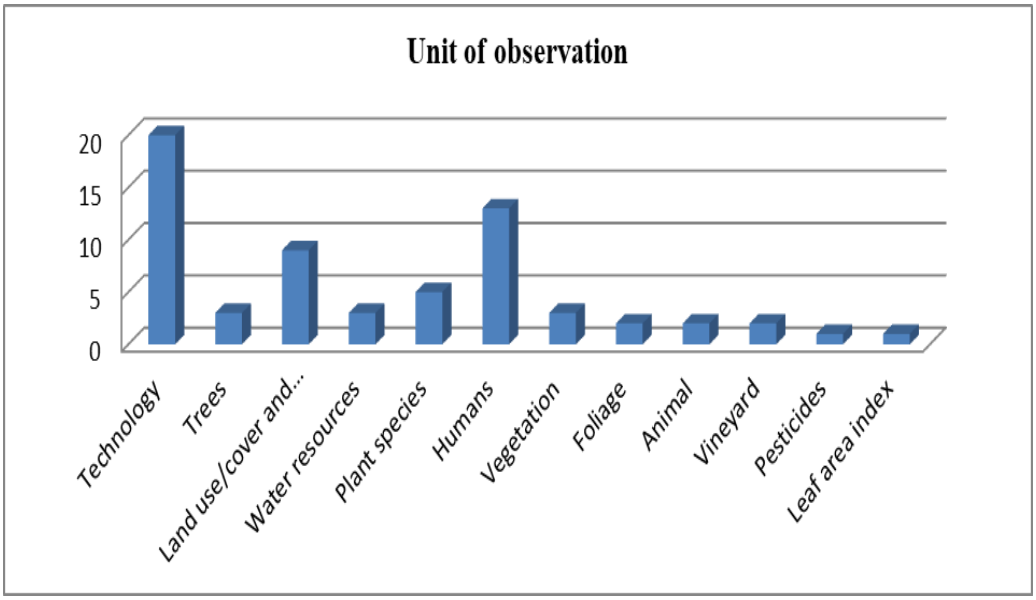

Figure 3: Different unit of observation types

PUBLICATION YEAR

The results of this systematic literature review indicate an increase in publications on e-agriculture research in South Africa during certain time periods, and a decrease during a time period. A large number of publications on e-agriculture research in South Africa were analyzed; these papers were published between 2010 and 2015. As indicated in figure 6 of this systematic literature review, 17 papers (26.5%) were published during the first two years (2010-2011) and 28 papers (43.7%) during the last two years (2014-2015). It is clear that that e-agriculture research in South Africa has increased over the last two years.

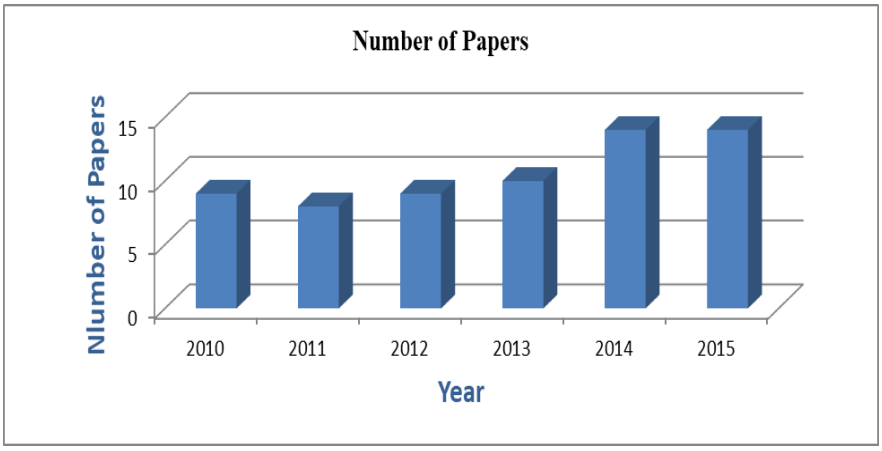

Figure 4: Papers distributed according to publication year

DISCUSSIONS

This section discusses the findings that answer the research questions considered in this systematic literature review as summarized in the previous section. The findings of this study reveal that the 64 pertinent research papers reviewed during the systematic literature review deal with a large scope of subjects; each of these papers also has a specific focus. The findings of this study reveal many unexplored themes/areas within and among these topics. In addition, only a few papers discuss closely related topics on e-agriculture research in South Africa. Furthermore, only a few studies have been mentioned in other research papers and almost no publications continue from a previous research paper. The relatively recent birth of ICT adoption in agriculture in South Africa could be the lack of focus on e-agriculture in the South African context. Information mapping is the research method that was most indicated in the papers, and many of these were conducted by academic institutions. However, it will be interesting to see other stakeholders such as industry, public civil society and public administration institutions become more involved in e-agriculture research in South Africa. Some papers have not mentioned the type of research method and tools they used. This poses a challenge for researchers who conduct investigations into a specified field by means of a systematic literature review. Therefore, researchers are advised to indicate the research method and tools they use when conducting a study. Interpretivism is the research approach that was the most used by researchers, according to the papers considered in this systematic literature review. The results of the study indicate a lack of research approaches in papers, as these approaches could only be found in a few papers. The results of this study indicate a lack of discussing theoretical lenses in the pertinent papers as (DoI) was the only theoretical lens applied by papers considered in this systematic literature review. The results of this study also point to an important number of similarities between the units of analysis and observation among the pertinent papers selected in this systematic literature review.

LIMITATIONS

Several limitations have been met in this study. Firstly, the scope of this study was limited to the period 2010-2015; pertinent research studies conducted outside this period were not taken in consideration, which means important relevant information could have been omitted. Secondly, the research method adopted for data collection might not have delivered all data related to this study. Thirdly, the study was limited to data collected from digital databases and web search engines, and could thus have missed

pertinent research archived in local public or college and university libraries. Some of the studies have not indicated any findings of the data analysis phase. Studies have shown some limitations in their conclusions.

CONCLUSION AND RECOMMENDATIONS

This study sought to investigate the current status of e-agriculture research in the South African context related to ICT adoption and use in agriculture companies, e-government direct services, mobile in agriculture, computerized back-end developed systems, networking in agriculture, use of geographic information systems improving agriculture, use of global positioning systems improving agriculture, use of satellite enhancing agriculture, e-commerce, ICT in agricultural supply chains, empowering local agricultural communities through information and ICTs, and providing broader information on agriculture in South Africa. The results of this study indicate a small number of papers during the first two years (2010-2011) and a large number of papers during the last two years (2014-2015) due to the growth of e-agriculture research in South Africa, attributed to South African authorities funding local universities according to the number of papers they publish in accredited journals (Pouris, 2015). The results of this study indicate that the use of satellite enhancing agriculture is the category e-agriculture research in South Africa has been most focused on, according to the papers selected in this study.

The results of this study indicate that information mapping is the most used empirical research method by researchers from 2010-2015. The results further indicate that interpretivism was the research approach most mentioned in the papers selected in the study, as interpretivism includes human factors—

it depends on the interpretation of information required by researchers when conducting a study. Moreover, the results indicate that (DoI) was only theoretical lens indicated in the pertinent papers as it was considered a "good" theory to investigate ICT adoption and to understand how information technology innovations grow within and between communities. The results of this study indicate that technology was the unit of analysis most indicated in the pertinent papers of the study. Also, technology was the unit of observation most indicated in the papers selected in in study.

Despite the limitation of the study to conduct a systematic literature review on e-agriculture research in South Africa only for the period 2010-2015, and thus limiting the generalizability of the outcomes of the study, the research provides an accurate and clear understanding of the current status of e-agriculture research in South Africa. It is evident that researchers still need to address certain issues or problems on e-agriculture in South Africa to improve the socio-economic transformation of farmers and the agriculture sector. These recommendations are as follows:

- Enabling a strong partnership between South African universities, public civil societies, public administrations and industries for the continuous update and clarity of contents of South African e-agriculture programs
- Financial support of e-agriculture research in South Africa by the South African government, industries, bilateral and multilateral partners
- Establishing research centers and different types of institutes that are focused on e-agriculture research papers in South Africa.

Although academic institutions, public civil society, public administration institutions, and industries play a major role in investigating e-agriculture in South Africa, other important agriculture stakeholders such as the private sector and agriculture extension officers participating in agricultural sustainability

and development should participate in future studies. Future research studies could also address the status of e-agriculture research in South Africa with a longer period of years that might be more representative.

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