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An Examination of the Implementation of Artificial Intelligence in Agricultural Extension of Developing Nations: A Comprehensive Analysis

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Abstract *Developing nations primarily depend on rain-fed agriculture and traditional methods to manage and prevent crop pests and diseases. However, the impact of global warming has significantly reduced agricultural productivity in these regions, making them more susceptible to food insecurity. The lack of sufficient extension services and limited access to information provided by agricultural organizations at both local and national levels has resulted in the decreased productivity of arable lands in these countries. This research contends that utilizing digital tools can assist farmers in enhancing farm output in the face of the aforementioned issues. Artificial intelligence (AI) and machine learning (ML) are advanced technologies that can be used to create applications that offer farmers with precise and up-to-date agricultural information, which is crucial for making informed decisions. This research aims to determine the role of artificial intelligence (AI) in agriculture to address the issues encountered by farmers in developing countries.*

Keywords: Artificial Intelligence, e-agriculture, Information Communication and Technology (ICT), Internet of Things (IoT), Smart Farming,

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INTRODUCTION

Pravar, J. (2020) predicts that the world's population will reach 9 billion by 2050. The report adds that agriculture plays a big part in the economic sector generating $5 trillion in the industry worldwide. As the world population is expanding every day, the demand for land and water resources is also increasing. Therefore, there is need to plan and guarantee that adequate infrastructures are put in place for productive farming. The farming industry is evolving fast, and in order to meet demands of growing population, there is need to adopt AI technologies which will assist in ensuring increased harvests, pests and diseases control, and monitoring of soil and growing conditions, as a way of freeing the farmers from farming tasks and creating opportunities for them to utilize farming data. With worldwide climatic changes, AI can help the farmer in giving accurate and timely meteorological conditions that are beneficial to sowing. By usage of soil and crop health monitoring system, AI delivers information on the proper type of soil and the right type of crop to be planted. Therefore, AI in agriculture has assisted the farmers in managing the water properly, carrying out crop rotation, timely harvesting, planting the right kind of crops, and pests and disease management. Dmytro, L., (2021) in his article acknowledges that the farmers are under strong pressure due to rising demand in food consumption, thus forcing them to think of ways of raising food production. He further highlighted the significance of shifting away from traditional techniques of farming. In this aspect, AI is considered as an enabler in attaining more results with less work while reaping a lot of benefits. If integrated with other technologies, AI can handle massive data on a digital platform and lead to improved solutions for the farmers. This therefore guarantees that AI aids in making informed choices owing to use of predictive analytics, cutting down on farm input prices as a consequence of precision farming, reducing the cost of labor due to use of AI-based robots for harvesting, smart irrigation and usage of automated tractors.

Louis, C., (2021) in his contribution to Forbes, a leading media company, highlighted that AI, ML and the IoT sensors which generate real time-data by use of defined algorithms have led to increased efficiency in agriculture, improved crop production and reduction of the costs relating to food production. He states that ways such as applying ML-based surveillance systems in monitoring the field crops has given successful mechanisms in safeguarding remote facilities, increasing crops and putting off the trespassers and also recognizing the people who are operating onsite. Also, by utilization of visual analytics data from drones, the crop prediction yields are guaranteed with support from real-time sensor data. The prices of the crop produce are also forecasted according to yield rates that help in predicting the total volumes produced. Agribots and robotics have substantially reduced the number of agricultural personnel keeping the operation expenses low and getting the full benefits from crop harvests. In his effort to explore the extent and usage of AI to attaining the big four agenda in Kenya, Mvurya, M., (2020) observed that agriculture is one of the big four agenda items that needs the influence of AI for it to be fully fulfilled. He underlined that data mining tools will assist in making judgments that benefits agriculture. The study considers ML as a driving force in increasing the process of agricultural activities. This is as a result of adopting the usage of techniques such as support vector machines (SVM) and neural networks which have been employed as classifiers and k-means for grouping. The study offered a concept where the government of Kenya may construct a policy framework where a central database is created to avail access to institutions of higher learning so as to encourage and nurture AI research with a pool of domain experts. In this study we look at the usage of ICT in agricultural extension, issues faced by the farmers while using ICT technology and examination of AI tools in supporting the contribution made in enhancing agricultural production notably targeting the rural small holder crop farmers in emerging nations.

Problem Definition

To this end, this article suggests that harnessing digital tools such as mobile phones could enable the farmers to improve the production of their farms. This is predicated on the concept that developing technologies such as artificial intelligence and machine learning enable creation of applications that might supply the farmers with timely, accurate, and relevant information but also extension services that they need to support their decision making. Thus, this study tries to establish the significance of AI in agriculture in reducing the issues faced by farmers in developing nations.

Research Methodology

In this research two sorts of publications that were published in the recent ten years were reviewed and classified:

A) Articles on ICT in agricultural extension, the obstacles involved and overcoming the challenges especially among the developing nations.

B) Articles about using AI in agricultural extension and specifically the latest technology in place.

The selection criteria utilized in identifying high impact and innovative papers were based on:

A) Published within the last 10 years but concentrate put on the last four years for the AI in agricultural session.

B) Articles that carry out relevant agricultural extension technologies published as journals, conference proceedings and high impact organizational, governmental and individual blogs.

To select the relevant literature for review, literature search was conducted on Google Scholar, ACM Digital Library, IEEE Xplore, Science Direct and Springer Link. The search was done by employing the keywords connected to the title of the study as well as the relevant supporting ICT technology subjects in agriculture. While using Google Scholar, we looked on the papers that supplied related articles. If one of the cited articles indicated high influence and relevance, this was downloaded. To improve on the search, there was need to expand by include relevant websites, blogs, patents, and talks on significant AI technology and applications. Finally, we picked 56 publications to support AI in Agriculture technologies as well as ICT use in Agriculture study.

ICT in agricultural extension

FAO (2017) says that ICT in agriculture plays a critical role in bridging the gap between agricultural researchers, extension agents, farmers, and other stakeholders in boosting agricultural production. Secondly, ICTs in agriculture provide a larger contact among the local populations who include the women and youth hence bringing closer current economic prospects which eventually improve their livelihoods. Also, ICTs assists in delivering more efficient and reliable data from the numerous regional and worldwide bodies who gather and evaluate them. Furthermore, government agencies and other corporate entities employ ICTs to create regulatory frameworks and policies aimed towards monitoring and assessment procedures. Finally, ICTs enable actionable points to be exploited by the local authorities and the government during the onset of unplanned invasion of pests and illnesses. ICTs will then aid in real-time mitigation recommendations and approaches to be implemented. In their study on smallholder farmers ICT-adoption and use through their personal information space, Csótó, M., (2017) argued that ICT has now found potential in the agricultural production cycles and farm management operations. Information management of farmers in the study demonstrated that farmers have diverse preferences for using information sources as per the different distinct group groups. This indicated that many small holder farmers can be reached using basic communication strategies, for instance, use of text messaging whereby the farmers do not require adopting other practices that are different from what they are now utilizing. Therefore, agricultural educational programme should embrace the use of online sources of information, and this should be integrated into the everyday management activities focused towards giving solutions and boosting efficiency.

In their investigation to identify how farmers are making the most of digital technology in East Africa, Pye-Smith, C., (2018) stated that two-thirds of the population in Africa are absorbed in the field of agriculture where most of this population is made up of small holder farmers. Their studies suggested that agriculture could be a tremendous route to get rid of poverty, however most small holder farmers lack basic information and skills necessary for improving their farming techniques. However, digital innovations that have been pioneered by the Technical Centre for Agricultural and Rural Cooperation (CTA) have showed tremendous prospects in revolutionizing agriculture in Africa. These advances have created great prospects to young entrepreneurs at many stages of the value chain. The availability of extensive data has assisted in raising farm output, enhanced resource use efficiency, and reduced the requirement for pricey input. These technologies have consequently allowed the farmers to get information on weather, market pricing, best practices in agriculture and managing pests and illnesses. Agriculture plays a crucial part in growth and expansion of Kenya’s economy. The study by Apraku, *et al.,* (2021) on climate change and small-scale agriculture in Africa indicates that agriculture contributes to around 24% of the country’s Gross Domestic Product. Furthermore, the industry provides employment to more than 70% of its labour force who are active in small holder rural farming. The devolved function in Kenya makes this sector vital in addressing food and nutrition security. ICTs have played a crucial role in transforming information demands of farmers in both developing and developed countries. This is because farmers use ICTs in accessing supply of farm inputs, extension services and access to information by use of cell phone. ICTs can be utilized to boost agricultural output by decrease transaction costs, improve service delivery, generating possibilities for jobs especially to youth and women, generation of new sources of revenue and utilization of locally available resources.

According to Awuor *et al*., (2013), agricultural extension plays a crucial role, especially for rural communities in most developing countries. There have been observed concerns in particular with relation to rise in agricultural production to fulfill the demands of the population, deteriorating soil fertility, water limitations and climate change among others. Despite these limitations, ICT in agriculture has the possibility of boosting the efficiency, production and aligning towards the component of sustainability through capitalizing on information and knowledge sharing. By establishing a solution architecture (e-agriculture framework), the farmers would be able to acquire adequate information which aid them on pre-harvest, post-harvest, prices, and weather conditions. According to the study by Oduor *et al*., (2018) on Practices and Technology Needs of a Network of Farmers in Tharaka Nithi County, in Kenya, farmers requested additional knowledge vital in improving on the overall production of farm produce. The study found out that the small holder farmers were using mobile phones in setting up meetings with the agricultural extension officials when they confronted issues with developing plant diseases. In this instance, the farmers might make fast phone calls or send text messages telling the cops about the meetings, dates proposed, and place considered. Once this was approved, the selected farmer may cut the affected crop and take it to the conference so that the experts could make their findings and suggestions accordingly. This provided instant input to the farmers advising them on what needed to be done.

CHALLENGES OF ICT IN AGRICULTURAL EXTENSION SERVICE DELIVERY

ICT has been researched by many government organizations and it has been determined to be playing a large role in the transfer of knowledge and skills on modern agriculture to farmers. However, the potential of ICT has not been completely leveraged by the small holder farmers because of numerous problems such include digital divide, cost and low literacy among others.

Digital divide

Panganiban, G. G. F. (2019) in their paper explaining how the Philippines’ Department of Agriculture extension e-government mandate to promote agricultural extension development and the lives of farmers, believes that lack of physical access and incapacity to exploit the innovations supplied by the government leads to the digital gap. This is notably highlighted in the rural poverty areas and in the emerging countries. This contributes to low opportunities for the population to achieving the full benefits gained from government efforts in making the ICT services accessible and useful.

In their publication to analyze gender concerns in ICT for agricultural extension and rural development, Treinen, S., Van der Elstraeten, A., & Pedrick, C. (2018) confirmed that people who live in rural areas suffer from digital and gender divide. The article mentioned that in the year 2017, the International Telecommunication Union (ITU) supplied data whereby the penetration of using internet by women was at 12% lower than the combined proportion of men worldwide. In Africa, it is 25% lower than the proportion of men using the internet.

Cost of technology ownership

In their paper on empirical investigation of factors impacting information and communication technologies (ICTs) in Agri-Business among small scale farmers in Esan Community, Edo State, Nigeria Awojide, S., & Akintelu, S. O. (2018) noted that there are factors which hinder the usage of ICT among small holder farmers. From their inferential data, the expense of technology became one of the issues restricting the use of ICT on farming.

Tata, J., & McNamara, P. (2016) in their study which looked at the association between the obstacles faced by extension agents testing the Farmbook (a novel ICT tested by Catholic Relief Services (CRS)) application and selection of socio-economic aspects affecting their employment. In the study, socio-economic factors such as high cost of broadcast equipment, high charges for the radio and television presentations, high cost of accessing interconnectivity to electricity are among the constraints which affects the ICT utilization by agricultural extension officers in Niger Delta, Nigeria.

Culture and beliefs

The study by Ashraf, M. U., Asif, M., Talib, A. B., Ashraf, A., Nadeem, M. S., & Warraich, I. A. (2019) on socio-economic impediments in usage of modern mechanized technological ideals in agriculture sector, Pakistan, pointed out that socio-economic factors such as the age, level of education, culture, religion, and societal values among others are affecting the farmers in making decisive actions in adopting digital facilities in the agriculture sector. In addition, Pakistan contains of different blended cultures because to multi-lingual variety. This language diversity impedes the farmers in gaining the needed knowledge on new practices in agriculture as seen in the varied geographical locations. Gill, G.S. (2021) while addressing ICT and difficulties in Indian agriculture highlighted that variety in terms of language, culture and insufficient knowledge base has created a huge difficulty in bringing together rural India to a common communication highway. He proposed putting in the necessary financial resources and adequate infrastructure in training its inhabitants on ways to handle current communication tools and services.

Farayola *et al.,* (2020) on promoting youth engagement in digitalized agriculture in poor countries like Nigeria established that the challenges included social aspects such as gender, marital status, land ownership culture and customs among others. ME, A., & Odularu, G. (2021) notes states that women are affected by social issues such as lack of education, unbalanced sharing of property, inadequate control over resources which makes access to loans and other money difficult. Lack of access to loans and cash restricts the advancement of the women farmers in Nigeria. In some circumstances, when the owner of the land as collateral dies, traditional monarch rarely award property rights to women. In Southern area of Nigeria, ancestral land rights are thought to belong to men who could be the sons or the spouses.

Low Literacy

Singh, P., Bardhan, D., & Tripathi, S. C. (2015) in their study attempting to understand the limits faced by the dairy farmers using ICT in plain and hill areas of India were able to come up with numerous variables contributing to this. One of these causes was illiteracy. The farmers could not use any languages apart from vernacular. Also, they could not easily understand how to utilize the computers, internet related services and electronic mail in communication.

on their article to explore the influence of ICT based systems on agriculture at Rwanda, Balraj, P. L., & Pavalam, S. M. (2012) found revealed that by employing a market tool, popularly known as e-Soko, information gaps have been realized due to acknowledged illiteracy among small holder farmers. This has contributed to lack of understanding with regards to the technology making its adoption not attainable.

Technophobia

Pignatti, E., Carli, G., & Canavari, M. (2015) opines that small holder farmers' attitude towards innovation plays a crucial role in their ability to adopt ICT technologies to help their operations. The study creates traits such as fear of technology, low esteem and having inferiority complex towards super technologies and strong electronic gadgets not to be used because of attitude towards the new technology brought about by the advancements. This readily provides discouragement to the farmers and a feeling of rejection in adopting the use of the equipment because of the poor level of information, concepts, and skills. In addition, this lack of competence and obstacles brought about in adopting a new technology end up in unsuccessful experiences and the inclination of creating a failure in mind.

The study by Boniface, P. J., Jose, A. M., & Husain, A. S. (2019) analyzing the obstacles faced by farmers and agricultural extensionists in adopting selected Information Technology Enabled Systems (ITES) for agriculture found that even technophobia occurs among computer knowledgeable farmers which hampers the adoption and utilization of ITES. It comes because of perplexity and fear of failure.

Power shortages and connectivity

The study by Dhaka & Chayal (2016) looked at the attitude of farmers towards ICT as a source of information and restrictions impacting them were evaluated. Among the various restrictions reported by the respondents in employing ICT were poor infrastructure facility such as the provision of power supply. This affected the ICT take off at the rural areas of India.

In Sudan, the study by Musa *et al.,* (2012) in defining the primary elements impacting the usage of ICT and problems associated in conveying information to farmers came up with four basic categories which are categorized into socio-economic, cultural, technical, and infrastructural support factors. By looking at infrastructure support component, absence of power comes out as one of largest concerns hurting the farmers in Sudan. The study further assessed the availability of energy in facilitating the spread of farm knowledge. They found out that biggest percentage of the population (47.5%) suffered from not getting power at all followed by 37.5% who did not have stable power thus affected by outages and black outs. This explained the difficulty in using ICT gadgets such as the televisions.

Poor links between extension officers and other stakeholders

In establishing the association between the issues faced by extension agents (using a novel ICT tool called Farm book) and socio-economic indicators including gender, Tata, J., and et.al. (2016) noted that the age of the agents played a key influence in adopting farm book application. Furthermore, the level of educational background for the extension agents is vital in deciding use and spread of the technology in agriculture. The results suggested that highly educated extension agents were very likely to propagate and handle complicated components of the technology.
In their article to investigate trends, difficulties, and possibilities for small holder farmers in East Africa, Salami *et al.,* (2017) highlighted that extension and research services have a divergence in as far as technological transformation is concerned. The report revealed that most African countries spend less of their revenue on carrying out research on agricultural research and innovation therefore separating the efficacy of research and extension services.

OVERCOMING ICT CHALLENGES IN AGRICULTURAL EXTENSION

In Africa, gender issues have been addressed by bridging the gap in inequality and social support systems and institutions have now been put in place (Geopoll, 2019). In this situation, mobile applications have been built to connect the rural small holder women in agriculture to tackle gender-based impediments. The apps allow the female farmers in Africa with the requisite abilities to get and inherit the piece of the land through the legal processes giving them ownership and begin farming the land.

To offset the difficulty associated to the expense of technology ownership, certain ICT projects in India were realized to boost the agriculture portfolio (Singh *et al*., 2011). Key among these are utilization of call centers built to deliver the vast services to the farming sector. This call centers would allow the small holder farmers to obtain the needed counsel by engaging a toll-free number. In a country like Kenya, it is necessary for the government to intervene by cutting taxes and other related tariffs that are placed on ICT products and equipment like mobile phones to help critical stakeholders like small holder farmers purchase them. Also, in Market-to-Market classroom (2019), the policies that are being implemented by the government must be able to balance the costs and advantages to farmers. These policies also affect the customers, the environment, planned government budget and other competing elements that are of relevance to the small holder farmers. The government can establish policies that will promote investment of ICT in Agriculture. This will entail among others provision of subsidies and loans to small holder farmers to acquire and use information technology gadgets. This would increase the farmers' morale in using ICT in Agriculture.

In order to tackle culture and ideas difficulties notably impacting on women and girls owning land, Witinok *et al*., (2021) claimed that women and girls might be informed by the extension officers regarding their legal rights of owning and inheriting land. Girls could specifically be reached through education. In overcoming the barriers for illiteracy by the farmers, Singh, P., et al.(2015) proposed that enough training need to be conducted targeting the farmers. These trainings include how to operate the computers, accessing communication services such as the internet and e-mail. The study also highlighted creation of awareness initiatives to the farmers by utilizing avenues such as local dailies and television. Moreover, access to internet services should be made available because this lets the small holder farmers get access to opportunities given by the ICTs. To expand the information base for the farmers and fight the issue of illiteracy, Jose & Lokeswari (2018) on their study to understand the use of ICT among farmers and problems impeding their usage in India, observed that there is a major need to construct the Community Internet Centres which should be supervised under the state department of information. Furthermore, there is necessity for organizing the farmers' organization groups. These initiatives will encourage and teach the essential practical skills to the farmers on harnessing ICT for prosperity and sustainability. This proposal aligns with GOK mandate of building training Centres (ICT Centres) is highly suggested where small holder farmers can be instructed on how to use the many information technologies that would assist them address rising difficulties in farming. It will also operate as a Social Centre to engage and share ideas to disseminate usage of information technology in Agriculture. Kenya for instance have launched up County ICT Centers and other places have Constituency Innovation Hubs (CIH) which will encourage the growth of ICT use in agriculture through trainings. According to United States Department of Agriculture (USDA, 2019), training is a catalyst that aid small holder farmers to apply the newest scientific advances and technology tools into their daily operations. In addition to battling illiteracy, the farmers need to be instructed on fundamental mobile phone capabilities to learn and understand basic menus and navigating using the keypad operations for simple to use applications. Some application packages need to also be interpreted into local languages for easy interpretations.

Regarding technophobia, Pignatti *et al.,* (2015) believe that openness towards innovation is crucial when bringing the farmers' requirements into consideration. There should also be integration with other existing technologies to help in uptake. Therefore, cooperation from important stakeholders in delivering successful experiences will influence both farmers' knowledge and perception of innovations and determine the level of trust against new instruments and equipment. Boniface, P., et al. (2019) proposes that farmers and extension workers technophobia issues can be addressed by capacity development and training programmes adapted for each unique group. According to Mavhunduse and Holmner (2019), there is need to debunk the premise that usage of smart phones is time wasteful by training the farmers in digital literacy and encouraging them to invest in smartphones that have improved capabilities giving access to valuable agriculture information.

Regarding power connections and electricity issues, the study to understand the relationship between the youth and ICTs for agricultural development in India, Bhattacharjee, S., & Saravanan, R., (2013) pointed out that by scaling up the adoption of last mile connectivity, ICTs can penetrate hard to reach areas with no access to electricity. Once this is done, knowledge and transfer of information will be attained, and many adolescents will be reached to facilitate internet and mobile services. This corresponds with Houngbonon and Quentrec (2019) in their study evaluating the impact of access to electricity on ICT usage in Sub-Saharan Africa, gave Kenya as an example of countries whose government has tried in implementing the "last mile connectivity" and "Offgrid solar access project" which has tremendously granted access to 14 million Kenyans between the years 2012 to 2016. This is an ongoing activity, and many Kenyans are expected to be connected to the grid by the year 2030. The author advises that to sort out fluctuating and unstable power supply, there is need of power back up devices like power banks that may be used to charge mobile phones once there is no energy. This would ensure regular use of the mobile phones. Also, electronic gadgets such as mobile phones, need to be switched on power conservation mode to avoid high consumption of power. The report also opposes the obstacles identified in digital divide issues because rural areas are beginning to charge their ICT gadgets much like the urban population.

To sort out inadequate links between extension officers and extension agents, Farm biz africa, (2020), counties in Kenya allocating digital extension officers up to10,000 farmers per stated that the funds for the extension officers from the county and national governments have been lowered. This has made extension officers work output fall because they no longer receive adequate field facilitation support. On average, the extension agents receive between 20 and 50 calls from farmers which necessitates their quick intervention. It is because of this issue which has pushed the extension officers to use their cell phones to sort out the common pests and diseases issues from farmers hence lowering the direct engagement with the farmers. Currently, the extension agents request the farmers to transmit visual photographs of crops that are ravaged by agricultural pest invasion and illnesses by use of WhatsApp tool. This is then analyzed by the extension staff who then gives comments to the farmers on the proper action to be done to get rid of the problem and future prevention strategies. In their research on how Africa is fostering agricultural innovations and technology within the COVID-19 pandemic, Fernando (2020) says that there are numerous digital alternatives to aid smallholder farmers. They include e-Soko rolled out in Ghana to improve overall farm management and Farm Crowdy platform in Nigeria which promotes extension services to farmers. Other smartphone apps such as Tumaini and Nuru enable the smallholder farmers in tracking pests and illnesses by providing recommendations and advice for the problems encountered. Regulations under COVID-19 will therefore be sorted utilizing mobile phone technology as compared to physical meetings delivering solutions to the small holder farmers without damaging their health that emerges from physical meetings. According to Balaji *et al*. (2007) in their work on ideas of developing successful links between the research and agricultural extension systems, noted that ICTs play a major role in improving the relationship between the two institutions. This study in India has showed that ICTs can help the extension workers in acquiring information, processing it, storing and retrieval which considerably assists the rural families in receiving the information. Thus, the outcomes done by the ICRISAT project revealed that ICT based extension system is a powerful tool which may bring in close access to knowledge that can always be utilized at required places to the proper audience. Therefore, increasing linkages between the research and agricultural extension components are crucial in overcoming the obstacles. Furthermore, GOK (2017), notes that to improve on linkages between the extension officers and the farmers especially in Kenya, there must be guidelines that provide effective but simplified approaches, methods, and standards for coordinating and managing delivery of agricultural extension and advisory services. This will ensure that efforts are put in place to cope with the new and changing needs on agriculture. These principles and standards should constantly be examined and updated often. Successful implementation of these standards and recommendations is predicated on systems put in place, procedures to be followed, institutional frameworks, capacity building to stakeholders and policy makers, political backing, resources available, collaboration and networking.

Leveraging mobile phone technologies in Agricultural Extension

Razaque, A., & Sallah, M. (2013) in their study indicated that the use of mobile phone technology in developing nations is playing a key role in agricultural marketing issues, weather forecast patterns to assist in determining appropriate farm inputs such as fertilizers, application of pesticides, assisting farmer to farmer communication. This has seen the farmers save their time and efforts by interacting quickly with their consumers and marketing brokers consequently resulting to enhanced flow for their income. According to the study conducted by Geopoll (2018) in Kenya to provide insights on farming in Kenya and mobile phone usage found that 35% of farmers are affected by pests as one of the reasons affecting the yield during the last season. This was identified as the second largest factor after the climate change which contributed to 50%. On the same study, pests and illnesses appeared as largest contributor of issues encountered by farmers in Kenya which stood at 41%. The same report revealed that cellphone penetration in Kenya is now standing at 95% as indicated by the Communication Authority of Kenya (CAK). The study further found that all the 972 farmers who had been recruited and subsequently surveyed, possessed either basic feature phone or smartphone. It's interesting to note that 53% of the farmers as utilizing a smartphone while 47% had access to either a simple feature phone with SMS or one that has rudimentary internet connectivity.

According to Science Africa (2018) article on leveraging technology to deliver agricultural extension solutions, highlights that mobile phones and the internet are being utilized by the agricultural specialists and researchers in providing solutions to challenges such as plant pests and illnesses. In the article, Plant wise Knowledge Bank is a mobile phone application which connects the important stakeholders such as government agencies, researchers, farmers, and extension workers to the knowledge needed in making timely decisions against invasion of crop pests and diseases. This program provides a free online and resources that may be downloaded. Furthermore, during the 2018 Big Data in Agriculture convention organized by Consultative Group for International Agricultural Research (CGIAR) in the city of Nairobi which provided a forum to diverse stakeholder groups in agriculture to exchange ideas and innovations that are coming up. Some of these developments include "Nuru", which is an artificial intelligence system delivering diagnosis on crop pest and diseases by use of a cell phone. Another innovation is Marple diagnostics, which is a real time mobile diagnostic instrument used in diagnosing wheat rusts.

Internet of Things (IOT) and smart farming

Islam *et al.,*(2021) notes that smart farming will leverage Unmanned Aerial Vehicles (UAVs) and Internet of Things (IoT) technologies in fulfilling sustainability initiatives in agriculture. In their case studies, they developed and analyzed meshed Long Range Wide Area Network (LoRaWAN) gateways to sort out the connectivity issues with Smart Farming. In their second case study, they examined on the utilization of satellite communication technologies to deliver connectivity to smart farms in remote places. IoT in smart farming increases the value of acquired data by boosting automation processes, analysis and connecting different devices like the sensors, relays and gateways thus making sure that there is continuous data flow. The report states that IoT plays a vital role in mitigating against climate change by making use of real-time responses as a result of weeds invasions, detection of pests and diseases, forecast of weather changes, and the soil conditions. Both UAV and IoT enabled systems in farming have been deployed in areas such as crops monitoring, monitoring and tracking of animals grazing in open fields, control of green buildings, controlling the humidity and temperature required for the crops like straw and hay.

Sajoy (2021) in their article suggests that IoT in agriculture enhances agricultural productivity and improve the quality of food goods which are given to the consumers. IoT is able to change physical data such as temperature, humidity, pressure, speed, and flow into an identifiable virtual or electronic form without any human interaction. This data allows farmers to acquire real-time information concerning the health of the crop, weather patterns and conditions, and the soil quality without coming to the field in person. Therefore, IoT has been utilized in agricultural and food supply management to boost agriculture productivity and reduce losses in the process farm produce. Use of IoT however has limitations such as equipment malfunctioning due to extreme weather conditions like high temperature, rain and humidity. Also, limited literacy of the farmers in dealing with IoT devices and its technology affects its acceptance. Increased costs are also paid in the process of massive volumes of data being safeguarded. Finally, IoT network is subject to cyber-attacks by the cyber thieves. This adds to substantial extra expenditures associated in maintaining cyber security measures.

ARTIFICIAL INTELLIGENCE IN IMPROVING AGRICULTURAL EXTENSION

Agriculture being the mainstay in occupation in many nations in the world, has seen constant rise in population, which would put more strain on land under cultivation. Food production must expand to meet the growing population. This is motivating agricultural extension officers, farmers and agro-related stakeholders to come up with novel means of minimizing waste and improving production. Artificial Intelligence (AI) is growing as a generally accepted technique in bringing change in agriculture. In agriculture, AI can be used to solve a larger range of difficulties such as crop and soil monitoring, autonomous robots for crop harvesting, precision spraying of crops with pests and diseases, prediction of the crop yield, pricing forecasts, and disease diagnostics.

Kumari *et al.,* (2020) says that pressures brought forth by expanding population, changing weather conditions and COVID-19 pandemic issues would make AI play a major role by better farming efficiency, increasing the returns which leads to new agricultural technologies. This is supposed to answer the needs of increase in population and addressing the element of social distance during the pandemic. This is achieved by deploying the robots in carrying out human jobs such as precision spraying of crops, and picking and packing agriculture produce. Moreover, the imaging and scanning by drones, assist in the management of fertilizers, pesticides and the required quantity of water to be sprayed. This will consequently save the farmer a lot of time which would have otherwise been invested in trekking in the field for survey. The International Crop Research Institute for Semi-Arid Tropics (ICRISAT) and Microsoft have created an app used in India to assist with sowing and the results have indicated that, there is an increased yield of 30% per acre. Predictive analysis also assists the farmers to boost their levels of production. This is as a result of AI tools that anticipates the weather pattern, prediction of pests and diseases through algorithms that takes photos and transforms into computer data, therefore enabling correct timing of applying pesticides and fungicides.

In their study on Internet of Things (IoT) in Agriculture, Vadlamudi, S. (2020) identifies IoT as a technology which assists in knowing the situation of the crops in the field by making use of sensors in regulating and monitoring the crops. This has brought a lot of change to traditional farming due to the introduction of smart agriculture. IoT has made it feasible to have an effective pest management strategy. The study also indicates that IoT based solutions have dramatically decreased the application of pesticides on the crops. This is because IoT has intelligent remote sensors, drones and robots which observes and models pest management. The study intended to make farming smart by combining intelligence detecting and water system framework via a remote enabled technique. The data provide an indication of lower expenses for the sensor network gadgets and the controlled irrigation system. Also, the composition of the various nutrients in the fertilizers have been done precisely due to the clever advances of IoT. Therefore, IoT has assisted considerably in making farming more efficient and trustworthy.

Agriculture Technologies (AgriTech) has been undergoing enormous modifications during the previous decade. Spanaki *et al.,* (2021) in their study on the changing area of disruptive technology, believed that the disruptive contribution of AI in agriculture is mostly concentrated at the operations research level. With industrial revolution, agriculture has evolved and embraced technology that assist in ploughing, planting, weeding, harvesting, application of fertilizers and seeds. The study provided potential areas requiring further research work which includes farm management processes, analytic platforms that can positively contribute to the efforts of sustainability, how sensor technology in IoT can improve the existing technology in the next decade and the role of robotics in the new agricultural dawn.

Machine Learning Technology in Agricultural Extension

Zhang (2020) posits that Machine Learning (ML), being a part of AI is a technology that builds on mathematical model based on sample data which is known as “training data”. This “training data” creates predictions or conclusions without being specifically trained to carry out a specific activity. Liu (2020) says that AI tools have proven to be dependable in many fields of agricultural research. He stated that AI-powered technologies have resulted to offering knowledge and direction on crop rotation, timely planting, control of water and soil fertility, crop pest and disease management, sourcing for market, food storage and handling. The report says that ML has benefited the farmers in making decisions owing to the usage of precise irrigation systems and by developing tools that are used deciding the proper quantities of fertilizers to be used on corn. Liakos *et al*., (2018), adds that ML technique incorporates a learning process whose purpose is to learn from “experience” (training data) to carry out a specific task. In the subject of agriculture, ML is employed in agricultural production systems. They include crop management involving harvest yield, identification of pests, weeds detection and the quality of crops. Furthermore, ML in agriculture is employed in crop management, animal management, water, and soil management. By including ML in sensor data, farm management systems are continually transforming into real time artificial intelligence programs which caters for essential insights for farmer in making judgments. The paper indicates that crop management combines yield prediction to assist in mapping the yield, establishing estimations, and enhancing production. An example involves a yield mapping system that identifies green citrus which has not developed in a citrus grove under outside settings. This method aids the farmers with yield specific information to increase earnings and optimize yields. This example takes use of support vector machine (SVM) model whereby the results indicated an accuracy of 80.4%. SVM model is a binary classifier making a line of distinction in classifying data instances. This categorization can be enhanced by translating the original features into a higher dimension by applying a “kernel trick”. Commonly used SVM methods are support vector regression, least squares support vector machines and successive projection algorithm-support vector machine. Other areas where crop management are employed include disease diagnosis, weed detection, and crop quality and species recognition.

In their study, Gattim *et al.,* (2019) on plant leaf disease identification using SVM approach, stated that plant illnesses exist due of insects. They worked on an SVM for recognition and classifying of four-leaf illnesses to deliver appropriate treatments to the farmers. The study, thus, applied SVM and K-Means method implemented in a MATLAB code that gives the automatic disease prediction and estimate of the afflicted region. Their model is depicted in the picture 1.1 below.

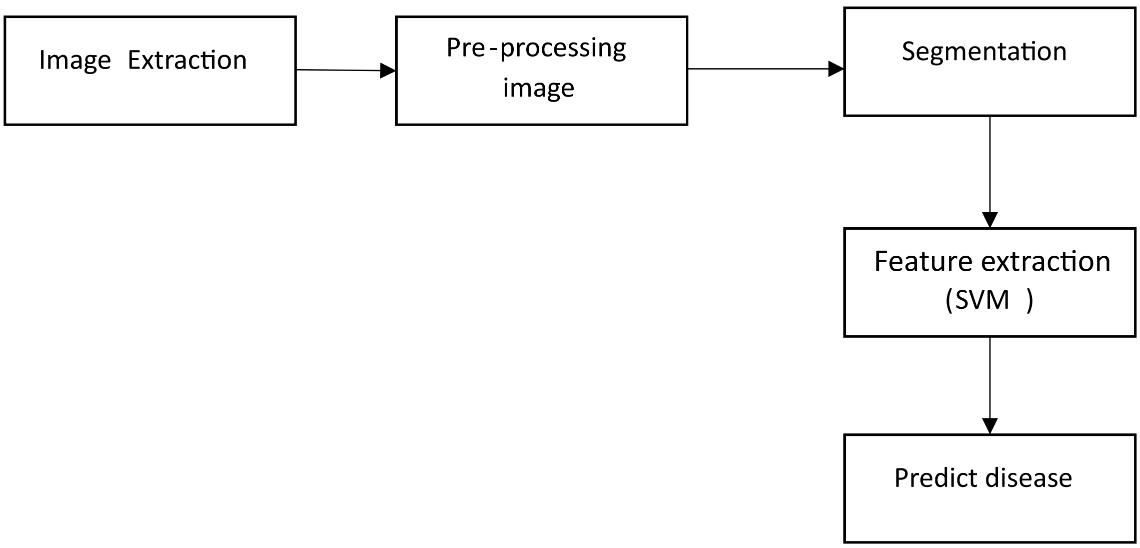

Figure 1: Steps for Plant Disease Detection and Classification (Gattim *et al*, 2019)

In Figure 1.1, the first step involves In Figure 1.1, the first step involves extracting the image which is retrieved from the database. Here, the database is provided at plant village website containing hundreds of photographs affected by illnesses and pictures with healthy leaves. One of the photos is taken for further investigation from the numerous. In the second phase, the picked leaf will have noise eliminated from undesirable parts then highlight the unhealthy part of the leaf. Median filter is used to minimize the noise, and this delivers better results as compared with mean filter. The intensity level of the pixels of the leaf image for further classification. The third phase involves the usage of k-means algorithm for the partitioning of the image. This assists in determining the afflicted region in a leaf. The fourth phase is features extraction and that is where MATLAB pre-defined routines are employed in extracting parameters for SVM classifiers. These features include the Mean, Standard Deviation and Variance among others. The last phase forecasts the leaf disease. This is performed by training the algorithm with vast number of data collected. Once training has been performed, the testing step is done based on parameters range matching which predicts the disease.

The study by Francis Tusubira *et al.,* (2020) on increasing in-field cassava Whitefly pest surveillance using ML stated that Whiteflies are the principal pests that are responsible for unfavorable destruction in tropical environments. The article provides a mechanism that automatically count the Whiteflies on cassava leaves using computer vision technique. For it to happen, the researchers took photos of cassava plants which were attacked by Whiteflies. They then trained a computer vision detector utilizing Haar Cascade and Deep Learning algorithms. The two techniques were added into the study to identify the pest in the photos and yield a count. The results showed a Whitefly count with a high precision. By usage of Faster Regional proposal Convolutional Neural Network (Faster RCNN), the input data was employed in converting cassava photos and their accompanying observations recorded as XML files from the initial dataset into Tensor flow record files. The data format is needed as input for training when utilizing Tensor flow object detection Application Programming Interface (API) utilized to conduct the experiment. Therefore, the task of counting Whiteflies on cassava leaves is made achievable by application of machine learning picture analysis algorithms. However, more work on this subject needs to be done with experiments that test the use of bespoke feature extractor for the Faster RCNN model instead of transfer-learning with ResNet 101.

In analyzing machine learning algorithms used for predicting maize production under conservation agriculture in Eastern and Southern Africa (ESA), Mupangwa *et al.,(*2020) says that ML has demonstrated to be a potential AI technique to be applied in agricultural production models. In the study, six methods estimate and accuracy were examined to identify the most precise one. These algorithms were categorized into linear and non-linear. Linear methods included logistic regression (LR) and linear discriminant analysis (LDA). Non-linear methods included K-nearest neighbor (KNN), classification and regression trees (CART), Gaussian naïve Bayes (NB) and support vector machine (SVM). Random number seeding were carried out to make sure that each method functioned utilizing the same data divides. The results showed that LDA had the highest prediction precision as compared to the rest of the algorithms. Therefore, linear algorithms (LR and LDA) predicted the maize yields more precisely as compared to nonlinear (NB, KNN, CART and SVM) under the comparable circumstances during the study. Thus LDA algorithm showed to be the greatest tool while SVM performed the lowest in maize yield prediction. Therefore, farmers in ESA zones could apply the technologies in generating information that supports in future planning of agricultural systems.

OTHER AI TOOLS THAT HAVE ENHANCED AGRICULTURAL EXTENSION

Robotics and Drones - According to Patel (2016), agricultural extension drones were finally allowed for takeoff in the United States once the federal guidelines come into force. In the new restrictions, the drones are limited to flying at a specific altitude from the ground and meeting a specified weight. The new guidelines will see freshly produced drones adapted for agricultural activities only. This will entail detection of pests and weeds, detecting the plants that are unhealthy, spraying the crops with the proper quantities for pesticides and fertilizers. By doing this the farmers will be able to tend their crops with ease and might ensure better yields. In comparing the drone with a tiny plane, drones deliver a crisper and high-resolution photograph. It also works effectively amid cloudy weather conditions. The author expedites that roughly 1.85 million farms in the United States will start benefitting from the deployment of drones. In the last decade, farmers have began employing the drones in monitoring their fields and supporting precision agriculture projects. Stehr, N. J. (2015) also revealed that 80 to 90% of predicted growth in drone market in the next decade will stem from agricultural. Drones, also known as Unmanned Aerial Vehicles (UAVs) have been experiencing tight regulation from aviation sector. UAVs can be utilized in monitoring farm fields by use of mounted cameras which can identify presence of weeds in a field and other crops pattern in the field. This technique is expected that in future the cost of acquisition would fall to permit greater employment of drones in the agriculture fields.

Adama (2017), argues that drone use in agricultural extension is taking up quite well due to its ability in carrying out big jobs. To add on that, there has been reported drop in procuring the drone equipment. Thus, the affordability of the drone and its better performance drives its usage in fields such as aerial mapping, monitoring the status of the crops, identifying any presence of weeds and if the rules of the land allow, then spraying of the crops is carried out. In their study, it is envisaged that in future multiple strings of drones would take over the job of performing spraying and preventing collisions in the air. The main concern to this is the legislation and how the military see the swarm of drones that are not regulated. This heightened with alleged terrorist operations become a challenge. Furthermore, the future of plant pollination may be conducted by the drones.

A team at Japan National Institute Science and Technology (AIST) have attempted a study on capabilities of employing drones in pollination flowers as reported on Robotics Business Review (2018). What restricts the rollout of drones is safety legislation that does not allow drones to operate for more than 500m of sight.

Neural Network - In their study containing a survey of different ML approaches in forecasting crop pests, Kim *et al*., (2014), offered an example of predicting crop pests using regression technique which had earlier been undertaken by Chtioui *et al.,* (1999) employed a generalized regression neural network and its application for leaf moisture prediction to forecast plant disease. Initially, people never imagined that leaf wetness could not be measured. However, the study states that leaf wetness could be monitored because it has an effect on plant disease break out. The analysis from meteorological parameters has influence on predicting the leaf moisture content. This example was carried out by performing comparisons between methods of prediction of leaf moisture using Generalized Regression Neural Network (GRNN) and Multiple Linear Regression (MLR). In this example, a training set and a data set were employed which contained time in units of 24 hours, moisture content, temperature, solar radiation, wind speed, soil moisture indices, among others. The experiment demonstrated that MLR gave absolute value prediction of 0.1414 for the test set and
0.1300 for the training set. With reference to GRNN, average absolute value prediction errors of 0.0491 for the test set and 0.0894 for the training set were attained. This experiment revealed that GRNN is more exact than MLR due to reduced error values.

SUMMARY AND CONCLUSION

By usage of AI tools in agricultural extension, small holder farmers can leverage mobile technology in offering defense against new crop diseases and pests which would have severe impacts on harvests. In their article, Science Daily (2019) on AI helps banana growers protect the world's most favorite crop, the new handheld instrument designed for banana farmers can scan for indicators of five key diseases and one common insect. This instrument has undergone testing in several parts of the world including Colombia, India, Benin, China, Democratic Republic of Congo and Uganda. This technology has made considerable development in delivering a chance to better crop surveillance, fast-track management and mitigation measures leading to prevention of crop losses by the farmers. This technique has been integrated into an app called "Tumaini" which is aimed to allow smallholder farmers to immediately detect a disease or a pest and this prevents detrimental consequences from taking place. The software joins the extension workers in offering intervention methods. Also, the app can link data to a worldwide ecosystem where large scale monitoring is carried out. Testing has provided better results and it's become a very valuable instrument in combating against pest and diseases breakout in plants.

AI plays a crucial role in ensuring that pests and disease invasion is managed, correct soil is used for farming and that knowledge gap between the farmers and technology is minimized. Mhlanga, D. (2021) claims that even though impoverished people are not able to buy AI-enabled equipment, they can receive AI services by use of mobile phone devices. The common example is found in the employment of "Nuru", which is a machine learning application which has aided farmers in Kenya, Tanzania and Mozambique in monitoring the pests and disease invasion which has been threatening the loss of income and revenue across the East Africa region. Farmers have been able to detect the pests and diseases damaging their crops by sharing the images with relevant authorities. To solve the low literacy restrictions, farmers have been able to deploy AI speech recognition technologies as well as speech to text features, particularly when accessing text-related applications. Robots can now assist the farmers during the seasons of crops harvest and also in anticipating the optimal methods of producing different crops. In order to address global food problem, Carnegie Mellon University have partnered up with agricultural specialists and plant scientists by developing and implementing a system called FarmView to assist in sensing, robotics and AI technologies so as to boost plant breeding and crop production.

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