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Adoption of Artificial Intelligence in Agriculture in the Developing Nations: A Review

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Abstract

While most developing nations rely largely on rain fed agriculture and use of traditional mechanisms to mitigate and control emergency crop pests and disease invasion and their effects, global warming has severely affected the agricultural productivity in these regions making them vulnerable to food insecurity. Inadequate extension services and hardly accessible information from agricultural agencies both at the local and national governments has made arable lands in these countries unproductive. In an attempt to address this problem, this paper argues that leveraging digital tools could support the farmers to improve the productivity of their farms amidst the aforementioned challenges. Emerging technologies such as artificial intelligence (AI) and machine learning (ML) enable development of applications that could provide the farmers with timely, accurate and relevant agricultural information needed to support decision making process. Thus, this paper seeks to establish the role of AI in agriculture in mitigating the challenges faced by farmers in developing nations.

Keywords: *Artificial Intelligence (AI), e-agriculture, Information Communication and Technology (ICT), Internet of Things (IoT), Smart Farming, Support Vector Machines (SVM), Unmanned Aerial Vehicles (UAV)*

1. Introduction

Pravar, J. (2020) notes that by the year 2050, the global population is expected to reach 9 billion. The article notes that agriculture plays a significant role in the economic sector contributing $5 trillion in the industry worldwide. As the world population is increasing every day, the demand for land and water resources is also increasing. Therefore, there is need to plan and ensure that proper structures are put in place for effective 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 global climatic changes, AI can help the farmer in providing accurate and timely weather conditions that are favorable to planting. By use of soil and crop health monitoring system, AI provides information on the right type of soil and the right type of crop to be planted. Therefore, AI in agriculture has helped the farmers in managing the water efficiently, carrying out crop rotation, timely harvesting, planting the right kind of crops, and pests and disease management.

Dmytro, L., (2021) in his article agrees that the farmers are under intense pressure due to rising demand in food consumption, thus challenging them to think of ways of increasing food production. He further reiterated the need of moving away from traditional methods of farming. In this regard, AI is seen as an enabler in achieving more results with less effort while reaping a lot of benefits. If combined with other technologies, AI can handle big data on a digital platform and lead to better solutions for the farmers. This therefore guarantees that AI helps in making informed choices due to use of predictive analytics, cutting down on farm input costs as a result of precision farming, reducing the cost of labor due to use of AI-based robots for harvesting, smart irrigation and use 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 notes that approaches such as using ML-based surveillance systems in monitoring the field crops has provided effective mechanisms in safeguarding remote facilities, enhancing crops and putting off the trespassers and also recognizing the staff who are working onsite. Also, by use 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 predicted due to yield rates that help in determining the total volumes produced. Agribots and robotics have greatly reduced the number of agricultural workers keeping the operation costs low and reaping the full benefits from crop yields.

In his effort to understand the extent and use of AI to achieving the big four agenda in Kenya, Mvurya, M., (2020) noted that agriculture is one of the big four agenda items that needs the influence of AI for it to be fully realized. He highlighted that data mining techniques will assist in making decisions that supports agriculture. The study recognizes ML as a driving force in enhancing the process of agricultural activities. This is as a result of employing the use of techniques such as support vector machines (SVM) and neural networks which have been used as classifiers and k-means for clustering. The study proposed a model where the government of Kenya could establish a policy framework where a central database is created to avail access to institutions of higher learning so as to support and nurture AI research with a pool of domain experts.

In this paper we look at the use of ICT in agriculture, challenges faced by the farmers while using ICT technologies and review of AI tools in supporting the contribution made in improving agricultural production specifically targeting the rural small holder crop farmers in developing nations.

2. Problem Definition

To this end, this paper posits that leveraging digital tools such as mobile phones could support the farmers to improve the productivity of their farms amidst the challenges described in section 5. This is built on the premise that emerging technologies such as artificial intelligence and machine learning enable development of applications that could provide the farmers with timely, accurate, and relevant information but also extension services that they need to support their decision making. Thus, this paper seeks to establish the role of AI in agriculture in mitigating the challenges faced by farmers in developing nations.

3. Research Methodology

In this research two types of articles that were published in the last ten years were reviewed and classified:

A) Articles on ICT in agriculture, the challenges involved and overcoming the challenges especially among the developing nations.
B) Articles on using AI in agriculture and especially the latest technologies in place.

The selection criteria used in choosing high impact and innovative articles were based on:

A) Published within the last ten years but focus made on the last four years for the AI in agriculture session.
B) Articles that carries out relevant agriculture technologies published as journals, conference proceedings and high impact organizational, governmental and individual blogs.

To identify 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 achieved by using the keywords tied to the title of the paper as well as the relevant supporting ICT technology topics in agriculture. While using Google Scholar, we checked on the articles that provided relevant articles. If one of the citing articles showed high impact and relevance, this was downloaded. To improve on the search, there was need to expand by including relevant websites, blogs, patents, and presentations on major AI technologies and applications. Finally, we selected 56 papers to support AI in Agriculture technologies as well as ICT use in Agriculture study.

4. ICT in agriculture

FAO (2017) notes that ICT in agriculture plays a vital role in bridging the gap between agricultural researchers, extension agents, farmers, and other stakeholders in enhancing agricultural production. Secondly, ICTs in agriculture create a wider interaction among the local communities who include the women and youth thereby bringing closer existing business opportunities which eventually improve their livelihoods. Also, ICTs helps in delivering more efficient and reliable data from the different regional and global bodies who collect and analyze them. Furthermore, government agencies and other corporate entities use ICTs to implement regulatory frameworks and policies geared towards monitoring and evaluation processes. Finally, ICTs provide actionable points to be used by the local authorities and the government during the emergence of unplanned invasion of pests and diseases. ICTs will then assist in real-time mitigation advice and techniques to be employed.

In their study on smallholder farmers ICT-adoption and use through their personal information space, Csótó, M., (2017) opined that ICT has now found opportunity in the agricultural production cycles and farm management activities. Information management of farmers in the study showed that farmers have different preferences regarding using information sources as per the different distinct group categories. This showed that many small holder farmers can be reached using simple communication methods, for instance, use of text messaging whereby the farmers do not require adopting other practices that are different from what they are currently utilizing. Therefore, agricultural educational programmes should incorporate the use of online sources of information, and this should be integrated into the daily management tasks geared towards providing solutions and enhancing efficiency.

In their work to determine how farmers are making the most of digital technologies in East Africa, Pye-Smith, C., (2018) noted 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 work indicated that agriculture could provide a great avenue to get rid of poverty, but most small holder farmers lack adequate knowledge and skills necessary for transforming their farming practices. However, digital technologies that have been ushered by the Technical Centre for Agricultural and Rural Cooperation (CTA) have shown unprecedented opportunities in transforming agriculture in Africa. These innovations have opened exciting opportunities to young entrepreneurs at different stages of agricultural value chain. The availability of extensive data has helped in boosting farm productivity, improved resource use efficiency, and reduced the need for expensive input. These technologies have therefore assisted the farmers to access information on weather, market prices, best practices in agriculture and controlling pests and diseases.

Agriculture plays a pivotal role in growth and expansion of Kenya's economy. The study by Apraku, A., Morton, J. F., & Apraku-Gyampoh, B. (2021) on climate change and small-scale agriculture in Africa notes that agriculture contributes to about 24% of the country's Gross Domestic Product. Furthermore, the sector provides employment to more than 70% of its labour force who are involved in small holder rural farming. The devolved function in Kenya makes this sector crucial in addressing food and nutrition security. ICTs have played a pivotal role in transforming information needs 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 mobile phone. ICTs can be used to improve agricultural productivity by reduce transaction costs, improve service delivery, creating opportunities for jobs especially to youth and women, generation of new sources of revenue and utilization of locally available resources.

According to Awuor, F., Kimeli, K., Rabah, K., & Rambim, D. (2013), agriculture plays a key role, especially for rural communities in most developing countries. There have been noted challenges in particular with regard to increase in agricultural production to meet the needs of the population, declining soil fertility, water shortages and climate change among others. Despite these challenges, ICT in agriculture has the potential of increasing the efficiency, productivity and aligning towards the component of sustainability through leveraging on information and knowledge sharing. By developing a solution architecture (e-agriculture framework), the farmers will be able to get enough information which assist them on pre-harvest, post-harvest, prices, and weather conditions.

According to the study by Oduor, E., Waweru, P., Lenchner, J., & Neustaedter, C. (2018, April) on Practices and Technology Needs of a Network of Farmers in Tharaka Nithi County, in Kenya, farmers desired more knowledge crucial in improving on the overall yield of farm produce. The study found out that the small holder farmers were using mobile phones in setting up meetings with the agricultural extension officers when they faced challenges with emerging plant diseases. In this case, the farmers could make quick phone calls or send text messages informing the officers about the meetings, dates proposed, and venue discussed. Once this was agreed, the selected farmer could cut the infected crop and take it to the meeting so that the experts could make their observations and advice accordingly. This provided immediate feedback to the farmers guiding them on what needed to be done.

5. Challenges of ICT in Agriculture

ICT has been investigated by different government agencies and it has been found to be playing a big role in the transfer of knowledge and skills on modern agriculture to farmers. However, the potential of ICT has not been fully utilized by the small holder farmers because of several factors which include digital divide, cost and low literacy among others.

5.1 Digital divide

Panganiban, G. G. F. (2019) in their study describing how the Philippines' Department of Agriculture e-government mandate to promote agricultural development and the lives of farmers, argues that lack of physical access and inability to use the innovations provided by the government leads to the digital divide. This is specifically noted in the rural poor areas and in the developing countries. This contributes to minimal opportunities for the citizens to achieving the full benefits derived from government efforts in making the ICT services accessible and useful.

In their publication to evaluate gender issues in ICT for agriculture 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 publication mentioned that in the year 2017, the International Telecommunication Union (ITU) gave 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.

5.2 Cost of technology ownership

In their study on empirical investigation of factors affecting information and communication technologies (ICTs) in Agri-Business among small scale farmers in Esan Community, Edo State, Nigeria Awojide, S., & Akintelu, S. O. (2018) pointed out that there are factors which limit the use of ICT among small holder farmers. From their inferential statistics, the cost of technology became one of the factors limiting the use of ICT on farming.

Tata, J., & McNamara, P. (2016) in their study which looked at the relationship between the challenges faced by extension agents testing the Farmbook (a novel ICT tested by Catholic Relief Services (CRS)) application and selection of socio-economic factors affecting their work. 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.

5.3 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 comprises of different mixed cultures because of multi-lingual diversity. This lingual diversity impedes the farmers in attaining the desired knowledge on advanced methods in agriculture as seen in the different geographical settings. Gill, G.S. (2021) in addressing ICT and issues in Indian agriculture noted that diversity in terms of language, culture and poor knowledge base has brought a big challenge in bringing together rural India to a common communication highway. He suggested putting in the necessary financial resources and appropriate infrastructure in educating its citizens on ways to handle modern communication tools and services.

Farayola, C. O., Adebisi, L. O., Akilapa, O., & Gbadamosi, F. Y. (2020) on enhancing youth participation in digitalized agriculture in developing countries like Nigeria established that the problems included social factors such as gender, marital status, land ownership culture and traditions among others. ME, A., & Odularu, G. (2021) notes argues that women are affected by social factors such as lack of education, unbalanced sharing of property, inadequate control over resources which makes access to loans and other funds difficult. Lack of access to loans and funds limits the progress of the women farmers in Nigeria. In some instances, when the owner of the land as a collateral dies, traditional ruler rarely grant property rights to women. In Southern region of Nigeria, ancestral land rights are considered to belong to men who could be the sons or the husbands.

5.4 Low Literacy

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

In their paper to explore the impact of ICT based systems in agriculture at Rwanda, Balraj, P. L., & Pavalam, S. M. (2012) found out that by using a market tool, popularly known as e-Soko, information gaps have been realized due to identified illiteracy among small holder farmers. This has resulted to lack of awareness with regards to the technology making its adoption not achievable.

5.5 Technophobia

Pignatti, E., Carli, G., & Canavari, M. (2015) opines that small holder farmers' attitude towards innovation plays a pivotal role in their ability to use ICT tools to support their operations. The study makes characteristics such as fear of technology, low esteem and having inferiority complex towards super devices and powerful electronic gadgets not to be used because of attitude towards the new technology brought about by the innovations. This easily brings discouragement to the farmers and a feeling of rejection in adopting the use of the devices because of the low level of knowledge, ideas, and skills. In addition, this lack of expertise and challenges brought about in adopting a new technology end up in unsuccessful experiences and the tendency of developing a failure in mind.

The study by Boniface, P. J., Jose, A. M., & Husain, A. S. (2019) identifying the constraints faced by farmers and agricultural extensionists in using selected Information Technology Enabled Systems (ITES) for agriculture showed that even technophobia exists among computer literate farmers which hinders the adoption and use of ITES. It comes because of confusion and fear of failure.

5.6 Power shortages and connectivity

The study by Dhaka, B. L., & Chayal, K. (2016) looked at the attitude of farmers towards ICT as a source of information and constraints affecting them were analyzed. Among the various constraints experienced by the respondents in utilizing ICT were inadequate infrastructure facility such as the provision of power supply. This affected the ICT take off at the rural areas in India.

In Sudan, the study by Musa, N. S., Githeko, J. M., & El-Siddig, K. (2012) in identifying the key factors influencing the use of ICT and challenges involved in disseminating information to farmers came up with four main categories which are grouped into socio-economic, cultural, technical, and infrastructural support factors. By looking at infrastructural support component, lack of electricity came out as one of greatest problems affecting the farmers in Sudan. The study further analyzed the availability of electricity in supporting the dissemination of agriculture information. They found out that greatest percentage of the population (47.5%) suffered from not accessing power at all followed by 37.5% who did not have reliable power thus affected by outages and black outs. This explained the difficulty in using ICT devices such as the televisions.

5.7 Poor linkages between extension officers and other stakeholders

In establishing the relationship between the challenges faced by extension agents (using a new ICT tool called Farmbook) and socio-economic indicators including gender, Tata, J., and et.al. (2016) noted that the age of the agents played a critical role in using Farmbook application. Furthermore, the level of educational background for the extension agents is crucial in determining use and dissemination of the technology in agriculture. The results indicated that highly educated extension agents were highly likely to disseminate and handle sophisticated aspects of the technology.

In their paper to investigate trends, challenges, and opportunities for small holder farmers in East Africa, Salami, A., Kamara, A. B., & Brixiova, Z. (2017) reiterated that extension and research services have a disconnect in as far as technological transformation is concerned. The study noted that most African countries spend less of their income on carrying out research on agricultural research and innovation thus disconnecting the usefulness of research and extension services.

6. Overcoming ICT Challenges in Agriculture

In Africa, gender issues has been addressed by bridging the gap in inequalities and social support systems and structures have now been put in place (Geopoll, 2019). In this case, mobile applications have been developed to connect the rural small holder women in agriculture to overcome gender-based obstacles. The apps allow the female farmers in Africa with the necessary skills to obtain and inherit the portion of the land through correct legal channels giving them ownership and begin farming the land.

To counter the problem related to the cost of technology ownership, some ICT initiatives in India were realized to strengthen the agriculture portfolio (Singh, R., Priya, A., Singh, P., & Singh, M., 2011). Key among them include use of call centers created to provide the extensive services to the farming community. This call centers will allow the small holder farmers to seek the needed advice by engaging a toll-free number. In a country like Kenya, it is important for the government to intervene by lowering taxes and other related tariffs that are levied on ICT products and devices especially mobile phones to allow key players like small holder farmers acquire them. Also, in Market-to-Market classroom (2019), the policies that are being employed by the government must be able to balance the costs and benefits to farmers. These policies also affect the consumers, the environment, planned government budget and other competing factors that are of interest to the small holder farmers. The government can enact policies that will attract investment of ICT in Agriculture. This will include among others provision of grants and loans to small holder farmers to acquire and use information technology devices. This would boost the farmers' morale in adopting ICT in Agriculture.

In order to solve culture and beliefs issues specifically touching on women and girls owning land, Witinok-Huber, R., Radil, S., Sarathchandra, D., & Nyaplue-Daywhea, C. (2021) argued that women and girls can be sensitized by the extension officers regarding their legal rights of owning and inheriting land. Girls could specifically be reached through education.

In overcoming the bottlenecks for illiteracy by the farmers, Singh, P., et al. (2015) suggested that enough training need to be conducted targeting the farmers. These trainings include how to use the computers, accessing communication features such as the internet and e-mail. The study also highlighted creation of awareness programmes to the farmers by utilizing avenues such as local dailies and television. Moreover, access to internet services should be made available because this allows the small holder farmers gain access to opportunities granted by the ICTs. To increase the knowledge base for the farmers and tackle the issue of illiteracy, Jose, A. M., & Lokeswari, K. (2018) on their study to understand the use of ICT among farmers and factors hindering their usage in India, opined that there is a great need to establish the Community Internet Centres which should be guided under the state department of information. Furthermore, there is need for forming the farmers' association groups. These strategies will promote and provide the required practical skills to the farmers on utilizing ICT for prosperity and sustainability. This idea agrees with GOK mandate of establishing training Centres (ICT Centres) is highly recommended where small holder farmers can be trained on how to use the different information technologies that will help them address emerging issues in farming. It will also act as a Social Centre to engage and share ideas to propagate use of information technology in Agriculture. Kenya for instance have rolled out County ICT Centers and other areas have Constituency Innovation Hubs (CIH) which will spur the growth of ICT use in agriculture through trainings. According to United States Department of Agriculture (USDA, 2019), training is a catalyst that assist small holder farmers to incorporate the latest scientific advancement and technology tools into their daily operations. In addition to countering illiteracy, the farmers need to be trained on basic mobile phone features to learn and understand basic menus and navigating using the keypad functions for simple to use applications. Some application packages need to also be interpreted into local languages for easy interpretations.

Regarding technophobia, Pignatti, E., et al. (2015) propose that openness towards innovation is key when putting the farmers' needs into consideration. There should also be integration with other existing technologies to ease in adoption. Therefore, support from relevant stakeholders in bringing successful experiences will influence both farmers' knowledge and perception of innovations and determine the level of trust against new tools and equipment. Boniface, P., et al. (2019) recommends that farmers and extension workers technophobia issues can be addressed through capacity development and training programmes tailored for each individual group. According to Mavhunduse, F., & Holmner, M. (2019), there is need to demystify the presumption that use of smart phones is time wasting by training the farmers in digital literacy and encouraging them to invest in smartphones that have better capabilities allowing access to rich 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 would be achieved, and many youths will be reached to facilitate internet and mobile services. This agrees with Houngbonon, G. V., & Le Quentrec, E. (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 "Off-grid solar access project" which has tremendously granted access to 14 million Kenyans between the year 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 suggests that to sort out fluctuating and unreliable power supply, there is need of power back up devices like power banks that can be used to charge mobile phones once there is no electricity. This would ensure consistent use of the mobile phones. Also, electronic devices such as mobile phones, need to be put on power saving mode to avoid high consumption of power. The study also counters the bottlenecks seen in digital divide issues because rural areas are beginning to power their ICT devices just like the urban population.

To sort out poor linkages between extension officers and extension agents, Farmbizafrica, (2020), counties in Kenya assigning digital extension officers up to10,000 farmers each noted that the budget for the extension officers from the county and national governments have been reduced. This has made extension officers work output decline because they no longer receive adequate field facilitation support. On average, the extension officers receive between 20 and 50 calls from farmers which requires their immediate action. It is because of this issue which has prompted the extension officers to use their mobile phones to sort out the common pests and diseases issues from farmers thereby reducing the physical interaction with the farmers. Currently, the extension officers request the farmers to send pictorial images of crops that are devastated by crop pest invasion and diseases by use of WhatsApp tool. This is then analyzed by the extension officers who then gives feedback to the farmers on the right action to be done to get rid of the problem and future prevention mechanisms. In their paper on how Africa is promoting agricultural innovations and technologies amidst the COVID-19 pandemic, Fernando, A. J. (2020) notes that there are several digital solutions to assist smallholder farmers. They include e-Soko rolled out in Ghana to support overall farm management and FarmCrowdy platform in Nigeria which supports extension services to farmers. Other mobile apps such as Tumaini and Nuru support the smallholder farmers in tracking pests and diseases by providing recommendations and advice for the problems detected. Regulations under COVID-19 will therefore be sorted using mobile phone technology as compared to physical meetings bringing solutions to the small holder farmers without affecting their health that arises from physical meetings. According to Balaji, V., et al. (2007) in their paper on ideas of building effective linkages between the research and agricultural extension systems, highlighted that ICTs play a key role in improving the relationship between the two entities. This study in India has demonstrated that ICTs can help the extension workers in obtaining information, processing it, storing and retrieval which greatly assists the rural families in obtaining the information. Thus, the results done by the ICRISAT project showed that ICT based extension system is a powerful tool which can bring in close access to information that can always be utilized at required places to the right audience. Therefore, strengthening linkages between the research and agricultural extension components are vital in addressing the bottlenecks. 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 demands for agriculture. These guidelines and standards should always be reviewed and updated frequently. Successful implementation of these standards and guidelines is pegged on systems put in place, procedures to be followed, institutional frameworks, capacity building to stakeholders and policy makers, political support, resources available, collaboration and networking.

7. Leveraging mobile phone technology in Agriculture

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 saving their time and energy by connecting easily with their customers and marketing brokers thereby leading to improved 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 established that 35% of farmers are affected by pests as one of the factors affecting the yield during the past season. This was ranked as the second highest factor after the climate change which contributed to 50%. On the same study, pests and diseases emerged as highest contributor of challenges faced by farmers in Kenya which stood at 41%. The same study noted that mobile penetration in Kenya is currently standing at 95% as indicated by the Communication Authority of Kenya (CAK). The study further indicated that all the 972 farmers who had been recruited and subsequently surveyed, owned either basic feature phone or smartphone. It's worth to note that 53% of the farmers as using a smartphone while 47% have access to either a basic feature phone with SMS or one that has basic internet access.

According to Science Africa (2018) report on using technology to provide agricultural solutions, notes that mobile phones and the internet are being utilized by the agricultural experts and researchers in providing solutions to problems such as plant pests and diseases. In the report, Plantwise Knowledge Bank is a mobile phone application which connects the key players such as government agencies, researchers, farmers, and extension workers to the information needed in making quick decisions against invasion of crop pests and diseases. This application has a free online and resources that can be downloaded. Furthermore, during the 2018 Big Data in Agriculture convention convened by Consultative Group for International Agricultural Research (CGIAR) in the city of Nairobi which provided a platform to different stakeholder players in agriculture to share ideas and innovations that are coming up. Some of these innovations include "Nuru", which is an artificial intelligence system providing diagnosis on crop pest and diseases by use of a mobile phone. Another innovation included Marple diagnostics, which is a real time mobile diagnostic tool used in diagnosing wheat rusts.

8. Internet of Things (IOT) and smart farming

Islam, N., Rashid, M. M., Pasandideh, F., Ray, B., Moore, S., & Kadel, R. (2021) notes that smart farming will utilize Unmanned Aerial Vehicles (UAVs) and Internet of Things (IoT) technologies in realizing sustainability efforts in agriculture. In their case studies, they proposed and evaluated meshed Long Range Wide Area Network (LoRaWAN) gateways to sort out the connection issues with Smart Farming. In their second case study, they explored on the use of satellite communication systems to offer connectivity to smart farms in remote areas. IoT in smart farming enriches the value of collected data by enhancing automation processes, analysis and connecting different devices like the sensors, relays and gateways thus making sure that there is continuous data flow. The study notes that IoT plays a key role in mitigating against climate change by making use of real-time responses as a result of weeds invasions, detection of pests and diseases, prediction of weather changes, and the soil conditions. Both UAV and IoT enabled systems in farming have been applied in areas such as crops monitoring, monitoring and tracking of animals grazing in open fields, control of green houses, controlling the humidity and temperature required for the crops like straw and hay.

Sajoy, P. B. (2021) in their paper supports that IoT in agriculture boosts agricultural production and improve the quality of food products which are delivered to the consumers. IoT is able to transform physical data such as temperature, humidity, pressure, speed, and flow into an identifiable virtual or electronic form without any human involvement. This data assists farmers to get real-time information concerning the health of the crop, weather patterns and conditions, and the soil quality without going to the farm in person. Therefore, IoT has been applied in agriculture and food supply management to increase agriculture production and reduce losses in the process agriculture produce. Use of IoT however has drawbacks such as devices malfunctioning due to harsh weather conditions like high temperature, rain and humidity. Also, low literacy by the farmers in dealing with IoT devices and its technology affects its adoption. Increased costs are also incurred in the process of huge volumes of data being protected. Finally, IoT network is vulnerable to cyber-attacks by the cyber criminals. This results to huge added costs involved in maintaining cyber security measures.

9. Artificial Intelligence in Improving Agriculture

Agriculture being the mainstay in occupation in many countries in the world, has seen steady rise in population, which will put more pressure on land under cultivation. Food production must increase to meet the growing population. This is driving farmers and agro-related stakeholders to come up with new ways of reducing waste and increasing production. Artificial Intelligence (AI) is emerging as a widely accepted technology in bringing revolution in agriculture. In agriculture, AI can be used to solve a wider range of issues such as crop and soil monitoring, autonomous robots for crop harvests, precision spraying of crops with pests and diseases, prediction of the crop yield, price forecasts, and disease diagnostics.

Kumari, N., Kumawat, S., & Rajpurohit, T. S. (2020) argues that demands brought about by increasing population, changing weather conditions and COVID-19 pandemic issues will make AI play a critical role by enhancing farming efficiency, increasing the returns which leads to new agricultural inventions. This is expected to meet the needs of increase in population and addressing the aspect of social distance during the pandemic. This is achieved by using the robots in carrying out human tasks 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 applied. This will therefore save the farmer a lot of time which would have otherwise been used in trekking in the field for survey. The International Crop

Research Institute for Semi-Arid Tropics (ICRISAT) and Microsoft have developed an app used in India to assist during sowing and the results have shown that, there is an increased yield of 30% per acre. Predictive analysis also helps the farmers to increase their levels of production. This is as a result of AI tools that predicts the weather pattern, prediction of pests and diseases through algorithms that captures images and converts into computer data, thus providing correct timing of applying pesticides and fungicides.

In their paper on Internet of Things (IoT) in Agriculture, Vadlamudi, S. (2020) describes IoT as a tool which helps in knowing the situation of the crops in the field by making use of sensors in controlling and monitoring the crops. This has brought a lot of change to traditional farming due to the adoption of smart agriculture. IoT has made it possible to have an effective pest management practices. The study also notes that IoT based systems have drastically reduced 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 proposed to make farming smart by connecting intelligent detecting and water system framework via a remote enabled strategy. The findings show an indication of reduced costs for the sensor network gadgets and the automated irrigation system. Also, the composition of the various nutrients in the fertilizers have been done precisely due to the smart innovations of IoT. Therefore, IoT has contributed greatly in making farming more efficient and reliable.

Agriculture Technologies (AgriTech) has been undergoing great transformations over the last decade. Spanaki, K., Sivarajah, U., Fakhimi, M., Despoudi, S., & Irani, Z. (2021) in their study on the changing field of disruptive technology, opined that the disruptive contribution of AI in agriculture is mainly concentrated at the operations research level. With industrial revolution, agriculture has evolved and adopted technologies that assist in ploughing, planting, weeding, harvesting, use 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.

9.1 Machine Learning Technology in Agriculture

Zhang, X. D. (2020), notes that Machine Learning (ML), being a branch of AI is a technology that builds on mathematical model based on sample data which is known as “training data”. This “training data” makes predictions or decisions without being explicitly programmed to carry out a specific task.

Liu, S. Y. (2020) argues that AI techniques have proven to be reliable in diverse areas of agricultural research. He noted that AI-powered technologies have resulted to providing knowledge and direction on crop rotation, timely planting, management of water and soil fertility, crop pest and disease management, sourcing for market, food storage and handling. The study notes that ML has assisted the farmers in making decisions due to the use of precise irrigation systems and by improving tools that are used determining the right quantities of fertilizers to be used on corn.

Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018), notes that ML approach involves a learning process whose aim is to learn from "experience" (training data) to carry out a specified task. In the field of agriculture, ML is used in agricultural production systems. They include crop management involving harvest output, detection of pests, weeds detection and the quality of crops. Furthermore, ML in agriculture is used in crop management, livestock management, water, and soil management. By involving ML in sensor data, farm management systems are constantly changing into real time artificial intelligence programs which caters for important insights for farmer in making conclusions. The study notes that crop management incorporates yield prediction to assist in mapping the yield, making estimations, and increasing productivity. An example involves a yield mapping system that identifies green citrus which has not matured in a citrus grove under outdoor conditions. This system assists the farmers with yield specific information to maximize profits and optimize yields. This example makes use of support vector machine (SVM) model whereby the results showed an accuracy of 80.4%. SVM model is a binary classifier making a line of distinction in classifying data instances. This classification can be improved by transforming the original features into a higher dimension by using a "kernel trick". Commonly used SVM algorithms are support vector regression, least squares support vector machines and successive projection algorithm-support vector machine. Other areas where crop management are applied include disease detection, weed detection, and crop quality and species recognition.

In their study, Gattim, N. K., Pallerla, S. R., Bojja, P., Reddy, T. P., Chowdary, V. N., Dhiraj, V., and Ahammad, S. H. (2019) on plant leaf disease detection using SVM technique, opined that plant diseases exist because of insects. They worked on an SVM for recognition and categorizing of four-leaf diseases to provide effective solutions to the farmers. The study, therefore, utilized SVM and K-Means algorithm written in a MATLAB code that provides the automatic disease prediction and estimate of the affected area. Their model is indicated in the figure 1.1 below.

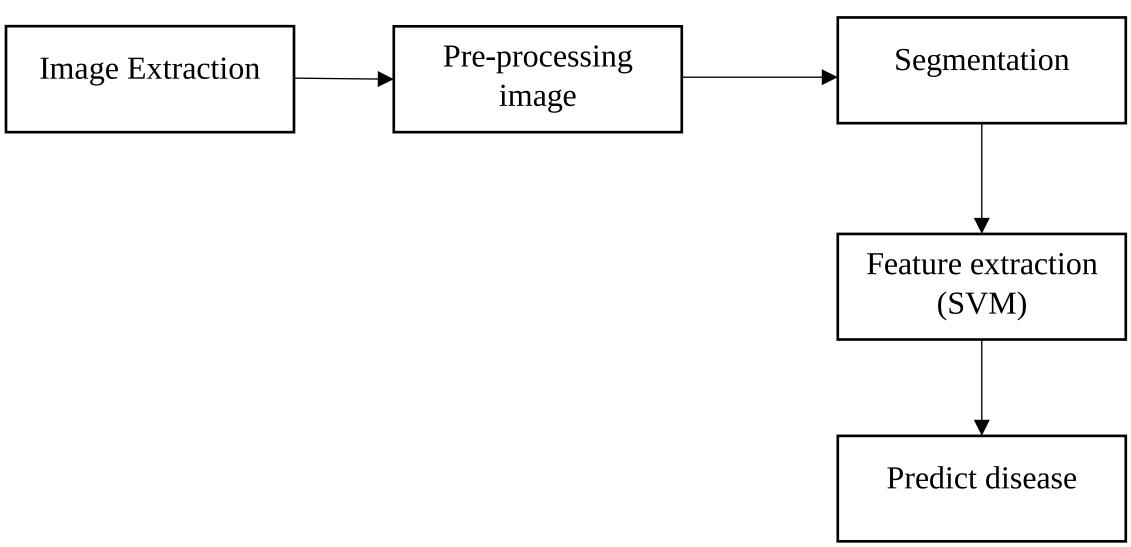

Figure 1: Steps for Plant Disease Detection and Classification (Gattim, N. K., et al, 2019)

In Figure 1.1, the first step involves extracting the image which is taken from the database. Here, the database is available at plant village website containing thousands of pictures affected with diseases and pictures with healthy leaves. One of the images is taken for further analysis from the many. In the second step, the chosen leaf will have noise removed from unwanted areas then highlight the diseased part of the leaf. Median filter is used to minimize the noise, and this gives better results as compared with mean filter. The intensity level of the pixels of the leaf image for further classification. The third step involves the use of k-means algorithm for the partitioning of the image. This helps in determining the affected region in a leaf. The fourth step is features extraction and it is where MATLAB pre-defined codes are used in extracting parameters for SVM classifiers. These features include the Mean, Standard Deviation and Variance among others. The last step predicts the leaf disease. This is achieved by training the algorithm with huge number of data collected. Once training has been achieved, the testing part is done based on parameters range matching which predicts the disease.

The study by Francis Tusubira, J., Nsumba, S., Ninsiima, F., Akera, B., Acellam, G., Nakatumba, J., and Oyana, T. (2020) on improving in-field cassava Whitefly pest surveillance with ML noted that Whiteflies are the major pests that are responsible for adverse destruction in tropical environments. The study proposes a solution that automatically count the Whiteflies on cassava leaves using computer vision technique. For it to happen, the team collected images of cassava plants which were affected by Whiteflies. They then trained a computer vision detector using Haar Cascade and Deep Learning methods. The two techniques were incorporated into the study to identify the pest in the images and return a count. The results showed a Whitefly count with a high precision. By use of Faster Regional proposal Convolutional Neural Network (Faster RCNN), the input data was used in converting cassava images and their corresponding observations stored as XML files from the initial dataset into Tensorflow record files. The data format is needed as input for training when utilizing Tensorflow object detection Application Programming Interface (API) used to conduct the experiment. Therefore, the task of counting Whiteflies on cassava leaves is made possible by use of machine learning image analysis techniques. However, more work on this study needs to be done involving experiments that evaluate the use of custom feature extractor for the Faster RCNN model instead of transfer-learning with ResNet 101.

In evaluating machine learning algorithms used for predicting maize yield under conservation agriculture in Eastern and Southern Africa (ESA), Mupangwa, W., Chipindu, L., Nyagumbo, I., Mkuhlani, S., & Sisito, G. (2020) argues that ML has proved to be a promising AI tool to be used in crop production models. In the study, six algorithms estimation and accuracy were assessed to select the most precise one. These algorithms were grouped into linear and non-linear. Linear algorithms included logistic regression (LR) and linear discriminant analysis (LDA). Non-linear algorithms included K-nearest neighbor (KNN), classification and regression trees (CART), Gaussian naive Bayes (NB) and support vector machine (SVM). Random number seeds were carried out to make sure that each algorithm worked using the same data splits. 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 non-linear (NB, KNN, CART and SVM) under the similar circumstances during the study. Thus LDA algorithm proved to be the best tool while SVM performed the lowest in maize yield prediction. Therefore, farmers in ESA regions could utilize the tools in generating information that assists in future planning of cropping systems.

Pallathadka, H., Mustafa, M., Sanchez, D. T., Sajja, G. S., Gour, S., & Naved, M. (2021) notes that ML and deep learning are the two most leading AI technologies to be used by businesses, government agencies and individuals to predict and learn from data. In agriculture, AI has been used in improving crop production, continuous monitoring of diseases, effective supply chain management and increasing the efficiency of operations. In the study, ML algorithms were grouped into generative models and discriminative models. Nave Bayes method is an example of generative model while KNN and SVM are discriminative models. The application of AI and ML showed that this algorithms can be used in detecting the crop diseases, smart irrigation, soil analysis, monitoring and tracking of crops.

9.2 Other AI Tools that have improved Agriculture

Robotics and Drones - According to Patel, P. (2016), agriculture drones were finally cleared for takeoff in the United States after the federal rules went into effect. In the new rules, the drones are limited to flying at a certain altitude from the ground and meeting a certain weight. The new rules will see newly manufactured drones customized for agricultural activities only. This will include detection of pests and weeds, spotting the plants that are diseased, spraying the crops with the right quantities for pesticides and fertilizers. By doing this the farmers will be able to tend their crops with ease and could guarantee better returns. In comparing the drone with a small plane, drones provide a clearer and high-resolution image. It also works well during cloudy weather conditions. The author expedites that about 1.85 million farms in the United States will start benefitting from the use of drones. In the last decade, farmers have begun using the drones in monitoring their fields and supporting precision agriculture programs. Stehr, N. J. (2015) pointed out that 80 to 90% of anticipated growth in drone market in the next decade will emanate from agriculture. Drones, also known as Unmanned Aerial Vehicles (UAVs) have been facing tough regulation from aviation sector. UAVs can be utilized in monitoring farm fields by use of mounted cameras which can detect presence of weeds in a field and other crops patterns in the field. This technology is believed that in future the cost of acquisition would reduce to enable wider usage of drones in the farm fields.

Adama Limited, (2017), notes that drone use in agriculture is picking up very well due to its ability in carrying out major tasks. To add on that, there has been noted decline in acquiring the drone equipment. Thus, the affordability of the drone and its improved performance spurs its usage in areas such as aerial mapping, monitoring the status of the crops, detecting any presence of weeds and if the laws of the land allow, then spraying of the crops is carried out. In their article, it is expected that in future several strings of drones will take up the role of conducting spraying and avoiding collisions in the air. The only threat to this is the legislation and how the military perceive the swarm of drones that are not controlled. This heightened with suspected terrorist activities 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 capability of using drones in pollinating flowers as seen on Robotics Business Review (2018). What limits effective rollout of drones is safety legislation that does not allow drones to operate for more than 500m of sight.

Neural Network - In their study involving a survey of different ML methods in predicting crop pests, Kim, Y. H., Yoo, S. J., Gu, Y. H., Lim, J. H., Han, D., & Baik, S. W. (2014), gave an example of predicting crop pests using regression technique which had earlier been conducted by Chtioui, Y., Panigrahi, S., & Francl, L. (1999) employed a generalized regression neural network and its application for leaf wetness prediction to forecast plant disease. Initially, people never thought that leaf moisture could not be measured. However, the study notes that leaf moisture could be measured because it has an influence on plant disease break out. The analysis from meteorological factors has influence on predicting the leaf moisture content. This example was carried out by making comparisons between methods of prediction of leaf moisture using Generalized Regression Neural Network (GRNN) and Multiple Linear Regression (MLR). In this case, a training set and a data set were used which included time in units of 24 hours, moisture content, temperature, solar radiation, wind speed, soil moisture indices, among others. The experiment showed that MLR generated absolute value prediction of 0.1414 for the test set and 0.1300 for the training set. With regards to GRNN, average absolute value prediction errors of 0.0491 for the test set and 0.0894 for the training set were realized. This experiment showed that GRNN is more precise than MLR due to low error values.

10. Summary and Conclusion

By use of AI tools in agriculture, small holder farmers can use mobile technologies in providing defense against emerging crop diseases and pests which would have adverse effects on crops. In their article, Science Daily (2019) on AI helping banana growers protect the world's most favorite fruit, the new handheld tool developed for banana farmers can scan for signs of five major diseases and one common pest. This tool has undergone testing in different parts of the world including Colombia, India, Benin, China, Democratic Republic of Congo and Uganda. This technology has made great progress in offering an opportunity to improve crop surveillance, fast-track control and mitigation measures leading to prevention of crop losses by the farmers. This tool has been built into an app called "Tumaini" which is designed to help smallholder farmers to quickly detect a disease or a pest and this prevents adverse effects from taking place. The app links the extension workers in providing intervention measures. Also, the app can link data to a global environment where large scale monitoring is carried out. Testing has yielded better results and it's becoming a very useful tool in combating against pest and diseases outbreak in plants.

AI plays a critical role in ensuring that pests and disease invasion is controlled, proper soil is used for farming and that knowledge gap between the farmers and technology is minimized. Mhlanga, D. (2021) argues that even though poor people are not able to buy AI-enabled equipment, they can access AI services by use of mobile phone devices. The common example is seen in the use of "Nuru", which is a machine learning application which has supported 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 identify the pests and diseases affecting their crops by sharing the photos with relevant authorities. To address the low literacy barriers, farmers have been able to use AI speech recognition systems as well as speech to text functions, particularly when accessing text-related applications. Robots can now assist the farmers during the seasons of crops harvest and also in predicting the correct methods of cultivating different crops. In order to address global food crisis, Carnegie Mellon University have teamed up with agricultural experts and plant scientists by developing and deploying a system called FarmView to assist in sensing, robotics and AI technologies so as to increase plant breeding and crop production.

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