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Implementation of Information Communication Technologies and Machine Learning in Tanzania for Precise Agriculture: A Review

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ABSTRACT

Precision agriculture is needed possibly in the future to increase the quality of products from agriculture and services. Information Communication Technology (ICTs)-based and Machine Learning (ML) applications are to be used to cut costs and improve trade. The goal of this study is to design the most common uses of ICTs and how they are used in agriculture, weather forecasting, prediction of minimum and maximum rainfall, soil fertility, minimum and maximum temperature, unnecessary fertilizer, pesticide use, detection of soil nutrients, crop management, livestock monitoring, and water management are all examples. The study focuses on presenting a comprehensive assessment of studies on machine learning applications in an agricultural production system and ICTs studies from various scholars for ten years (2011-2021). By employing ICTs and ML in topics mentioned above the challenges related to traditional data management techniques would be solved.

Keywords: Agriculture, weather forecasting, ICTs, ML, crop management, and livestock monitoring.

1. INTRODUCTION

ML is a scientific subject that enables machines to learn without being explicitly programmed. Weather forecasting is the application of science and technology to forecast the state of the atmosphere in a specific area. Weather forecasts are based on the collecting of quantitative data on the current state of the atmosphere as well as the use of scientific knowledge of atmospheric processes to forecast how the atmosphere will evolve in the future. (Abhishek et al., 2012; Sannakki et al., 2013). ICTs are telecommunications-based technologies that give access to information internet, wireless networks, mobiles, and other communication technologies. These are examples of agriculture whereby, the use of ML and ICT is emerging into a potential field for extracting information from enormous data sets, increasing production, and lowering costs of investment ML and ICT can employ novel technologies and platforms to generate, process, and visualize enormous amounts of data to make predictions and make decisions in the future. Remote sensing devices, Geographical Information System (GIS), Global Positioning System (GPS), Wireless Sensor Network (WSN), Climatically conditions, and weather conditions are essential for data collecting and real-time decision assistance in precision agriculture (Bendre et al., 2016; Chauhan et al., 2016; Mohammed & Bello, 2021). ICT data collection, analysis, and visualization of different applications. In comparison to countries with thriving agricultural sectors, Tanzania's usage of ICT in agriculture is still minimal. The bulk of farmers relies on conventional agricultural knowledge and methods. ICT plays a critical role in bridging the communication gap produced by geographic boundaries. Tanzania is a good example of the difficulties in reaching out to people in rural places. Rural people have not had access to good education and knowledge in agriculture, human resource development, capacity building, and training for agricultural advancement because of ICT transfer mechanisms from haves to haves (Rohila et al., 2017; Singh et al., 2015). In Tanzania’s case, temperature, rainfall, and humidity are all essential weather-related characteristics for agricultural systems. Crop productivity is lost due to weather volatility and incorrect farming methods. As a result, weather forecasting plays a critical role in addressing these issues. Incorporating projected weather data into crop management evaluations could give important and timely information for reducing possible losses and increasing crop productivity and income. Weather-based forecasting systems lower production costs by adjusting the frequency and timing of control activities, and they protect farmers, consumers, and the environment by minimizing chemical use (Fathi et al., 2021; Gupta & Tyagi, 2018).

Related Works

Need of ICTs in Tanzania`s agriculture

In one village, the farmer-to-extension officer ratio is 100:1, making it difficult for extension professionals to reach out to a larger number of farmers. For this, we need to introduce ICTs to upgrade ways of information. Tanzania is moving to the fourths industrial revolution and the main phases of the agriculture industry all require ICT to modernize the process. These processes are Crop Cultivation, Water Management, Livestock Monitoring, Notification of new breeding, Application of Fertilizer, Fumigation, Controlling Pests, Harvesting, Post-Harvest Handling, Food/Food Product Transportation, Packaging, Preservation of food, Food Processing, Food Quality Managing, Food Security, Food Storing, Food selling. To handle these phases effectively, all players in the agriculture industry require information and expertise about them. Any system used to obtain information and knowledge for making decisions in any industry should provide accurate, complete, and concise data promptly (Dlodlo & Kalezhi, 2015; Glendenning & Ficarelli, 2012; Lin et al., 2017; Mahant et al., 2012; Mubin et al., 2015; Riaz et al., 2017). When applying ICTs in farming and livestock keeping simplifies works and notification will be via short message or an e-mail.

Figure 1: Example of smart farming by using ICT, source (Tanwar et al., 2019)

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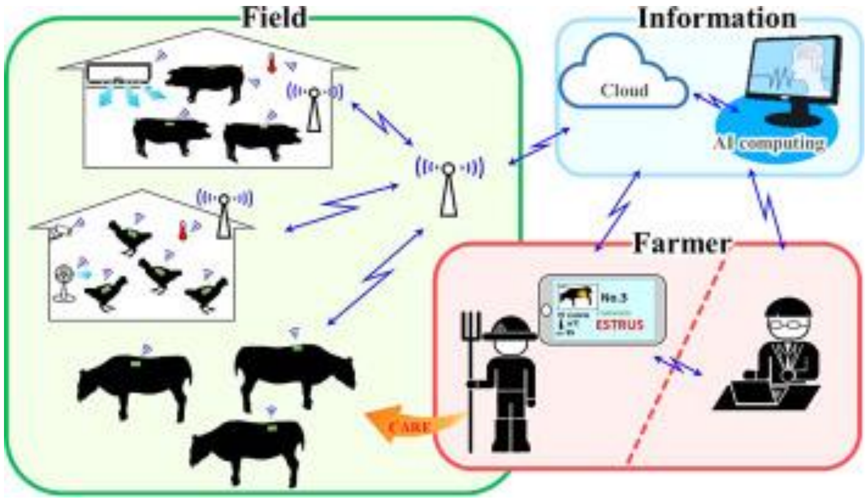

Figure 2. Smart livestock, source (Iwasaki et al., 2019)

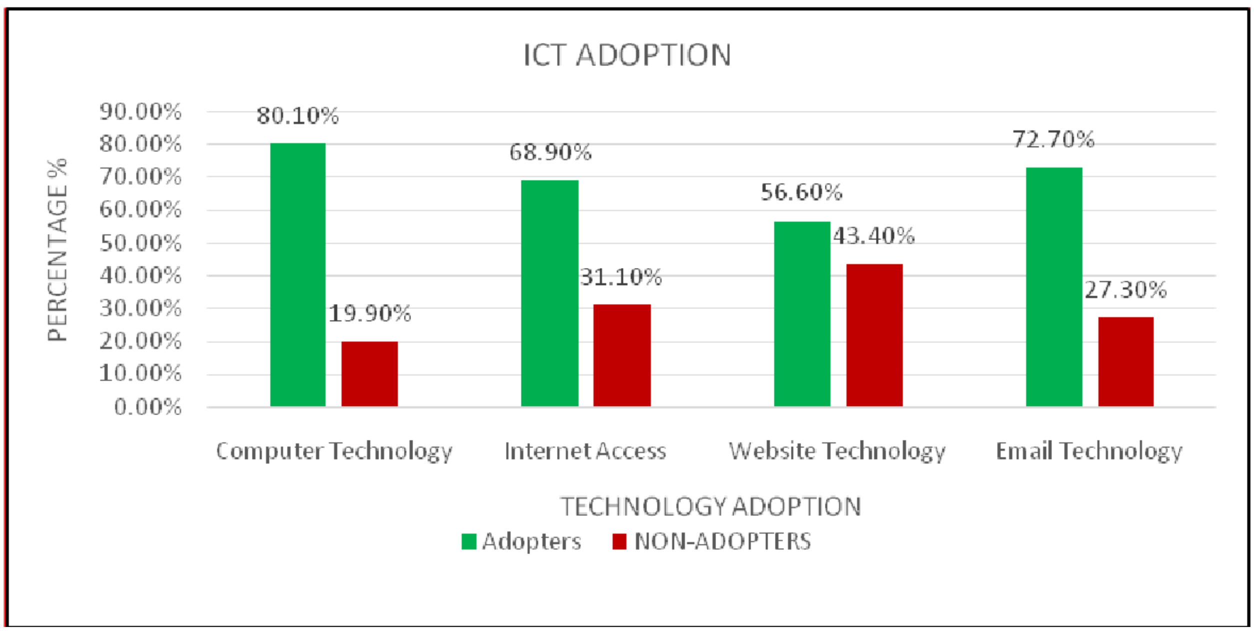

Figure 3. ICTs adoption in Tanzania, source (Msuya et al., 2018)

Implementation of ML in agriculture

An introduction to machine learning types (unsupervised or supervised), learning models (classification, regression, clustering, and dimensionality reduction), and the learning models used to accomplish the given task are all used to classify ML tasks. Implement the selected task such as soil factors such as carbon-based and moisture content, crop yield prediction, crop management, livestock production, fertility of animal's pattern disease and detection of weeds in crops, and detection of species (Liakos et al., 2018; Sharma et al., 2020; Swain et al., 2020).

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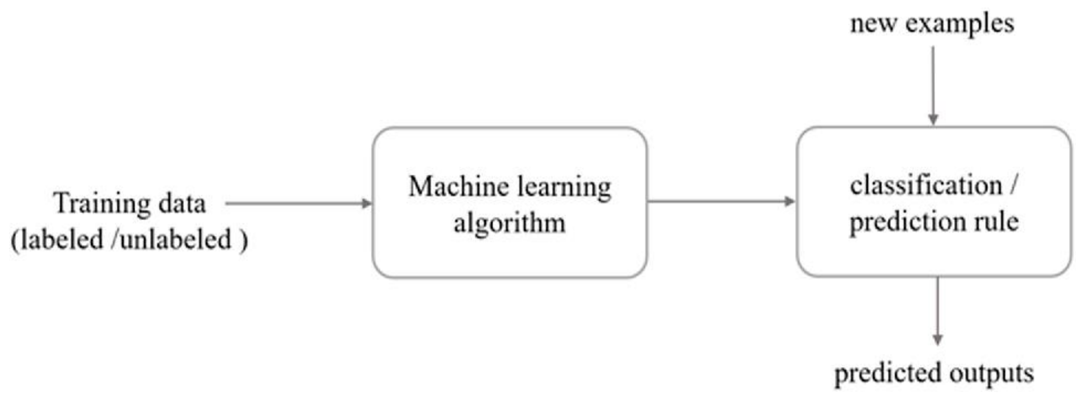

Figure 4. Atypical machine learning approach, source (Liakos et al., 2018)

Decision Support System

Decision support tools (DSS) are meant to assist users in making better-informed decisions that are successful by bringing and making clear decision phases and displaying the possibility of various outcomes arising from various options (Rose et al., 2016). The main necessities in agriculture are presented in the fourth evolution of farming technology, which is increasing production, judiciously managing resources, adjusting to climate change, and reducing food waste are all priorities (Kukar et al., 2019; Zhai et al., 2020). ML and ICTs tools such as decision support system (DSS) concerning weather forecasting describe the potential of knowing soil nutrient and soil fertility, insects, fungi, water contents acidity, alkalinity, and pest management (Lindblom et al., 2017). These will lead to enhanced crop production and selection of fertile land without the use of excessive fertilizers pesticides. During cultivation, farmers will handle the crops safely in automated ways (Bonfante et al., 2019).

2. METHODOLOGY

Extraction of relevant literature on the various roles of ICT and ML models in agriculture, as well as abstracts and citations, was done using a Google scholar of published articles by various experts of various countries between January 2011 and December 2021. This analysis is based on primarily secondary data. This study relied heavily on data from many published publications, journals, and book reviews. This is completely a review paper. The data gathered from these sources were synthesized to meet the goals of this review publication. It was compiled using Internet searches, in-depth analyses of numerous articles available in various journals, as well as books and proceedings held in libraries and university repositories see Table 1 below.

Table 1. ML and ICTs approaches in various fields of agriculture

S/No	Study	Approach	References
1	Crop production	ML used in the production of maize and rice and fruits	(Balakrishnan & Muthukumarasamy, 2016; Ip et al., 2018; Kale & Patil, 2019; Kumar et al., 2015; Mishra et al., 2016)
2	Weather forecasting	ML for weather conditions such as rainfall, temperature	(Dorling, 2014; Feleke, 2015; Guravaiah & Raju, 2020; Hansen et al., 2011; Veenadhari et al., 2014)
3	Crop disease detection	ML detection of diseases in Tomatoes, maize and rice	(Agarwal et al., 2020; Ashqar & Abu-Naser, 2018; Camardo Leggieri et al., 2021; Dhau et al., 2018; Sethy et al., 2018; Sharma & Kukreja, 2021)
4	Soil fertility	ML detection of soil nutrients such as nitrogen, phosphorous, potassium, moisture alkalinity, and acidity.	(Benedet et al., 2021; Ghadge et al., 2018; Koley, 2014; Nawar et al., 2019; Pandith et al., 2020)

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5	Water management	ML and ICTs by using sensing moisture, the temperature of underground and relative humidity	(Goap et al., 2018)
6	Detection of Soil nutrients	Application of ICTs in detection and testing soil nutrients in cultivation lands	(Alfin & Sarno, 2017; Lavanya et al., 2020; Na et al., 2016; Veena et al., 2018)
7	Agriculture Field monitoring	Uses of ICTs in crops monitoring and protection and reduce labor costs.	(Doshi et al., 2019; Eitzinger et al., 2019; hari Ram et al., 2015; Mohanraj et al., 2016; Patil & Kale, 2016; Rao & Sridhar, 2018; Sreekantha & Kavya, 2017)
8	Livestock health monitoring, and diseases prediction.	Implementation of ML and ICTs in livestock farming	(Brock et al., 2021; Chaudhry et al., 2020; Garcia et al., 2020; Kleanthous et al., 2018; Wang et al., 2021)

3. DISCUSSION
The study consists of research articles and reviews articles whereby some approaches and models were observed. From the above table, Machine Learning was applied in crop management by such as weather forecasting, crop disease detection, soil fertility, and detection of soil nutrients. In addition, water management, livestock, and disease prediction of animals. ICTs were applied in Water management, and soil nutrients detection. By 76% the Machine Learning and Information Communication and Technologies were applied in crop management, 11% in Livestock, 10% IN Weather forecasting, and 3% in Water management.

4. CONCLUSION
Agricultural production is heavily influenced by the weather. It has a big impact on a crop's growth, development, and yields, as well as pest infestations. In terms of changes in nutrient mobilization owing to water strains, as well as the timeliness and effectiveness of preventive and cultural operations on crops, diseases, water needs, and fertilizer requirements. Extreme weather and natural disasters disproportionately affect the poor, particularly those living in rural areas. Crop, fruit, and livestock output and productivity are predicted to improve as technological expertise and information become more readily available. For long-term agricultural production, an ICT-enabled information distribution system is essential. As technical knowledge and information become more widely available, crop, fruit, and livestock yield and productivity are expected to improve. It is necessary to attempt to improve rural people's and marginal landowners' educational levels. Traditional data management systems, intuition prediction, and invalid technology all of this could remedied by using machine learning in weather forecasting.

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Conflicts of interests
The authors declare that there are no conflicts of interests.

Data and materials availability
All data associated with this study are present in the paper.

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