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FACTORS AFFECTING ADOPTION OF INTERNET OF THINGS IN SELECTED GREENHOUSE FARMS IN KENYA

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Abstract

Purpose: The current study sought to investigate the factors affecting the adoption of IoT in agriculture with a focus on greenhouse farming in Kenya. In particular, the objectives are to establish the effect of farmer perception of technology, product-related, farm and environmental factors on the adoption of IoT technology in the selected greenhouse farms in Kenya.

Methodology: A descriptive cross-section research design was used. The study targeted 198 greenhouse farm managers who were sampled to 130 greenhouse farm managers by a proportionate (stratified) sampling technique. The unit of analysis was the selected 3 greenhouse farms (Amiran Kenya Ltd farms, Illuminum Greenhouses Kenya farms and East Africa Growers Ltd (EAGA) farms). The unit of observation was the greenhouse farm managers and the greenhouse staff of the respective greenhouse farms. Primary data was collected using self-questionnaires. The collected data were coded and analyzed to generate both descriptive statistics as well as inferential statistics. Quantitative data was presented in Tables and figures while qualitative information was evaluated using content analysis, and the findings were presented thematically.

Findings: The findings indicate that farm factors (β=0.413, p=0.000), farmer perception of technology (β=0.139, p=0.005 respectively), product-related factors (β=0.349, p=0.000 respectively) and environmental factors (β=0.383, p=0.000 respectively) have a positive and significant relationship with the adoption of IoT Technology in the selected greenhouse farms in Kenya.

Unique contributions to theory, policy and practice: Theoretically, the findings form the basis of understanding and validating the factors that inform the adoption of IoT among greenhouse farmers. Policy makers and stakeholders in the greenhouse industry are able to assess the areas that are disadvantaged in terms of IoT and increase the awareness, training and usage of such technology to help the farmers identify the benefits of IoT. This information guides the direction of the agricultural industry and the readiness to embrace new technology, the farmers need to be sensitized on the available IoT devices that can boost their yields and optimize production. There is a need for the authority to intensify the sensitization of the use of IoT technology to ensure optimum application of resources to achieve high crop yields and reduce operational costs this is called precision agriculture. The study recommends the policymakers, that is, the Communications Authority of Kenya (CAK) who is responsible to facilitate and intensify the development and spread of the information and IT to the agricultural sector on the need for technological integration in their operation. The study to that extent recommends (based on the advantages that outweigh the disadvantages of IoT) that the farmers have a positive attitude towards the use of IoT. This forms a basis for them to develop and sustain a competitive advantage against their competitors in the industry.

Keywords: *Adoption of Internet of Things Farm Factors Farmer Perception of Technology Product-Related Factors Environmental Factors*

INTRODUCTION

Farms' adoption of technology is crucial for raising food production and thus addressing nutrition and health challenges in Africa. Sinja, Karugia, Baltenweck, Waithaka, Miano, Nyikal and Romney (2004) provide evidence that consumer expectations for commodity qualities are usually subjective. When engaged in participatory experiment and exchange, the subjective preferences of farmers for the characteristics of new agricultural technologies and their knowledge and perceptions may influence their adoption behaviour. It will also result in the accumulation of information and the modification of initial expectations, which can affect behaviours that can contribute to technological acceptance (Meijer, Catacutan, Ajayi, Sileshi & Nieuwenhuis, 2015). Farmer awareness and expectations are intrinsic factors that affect the choice to implement technologies, whereas the features of technologies, the external climate and the adopter (structural) are the extrinsic factors that influence farmer decisions (Alomia-Hinojosa, Speelman, Thapa, Wei, McDonald, Tittonell & Groot, 2018).

Small-scale agricultural production represents 75 per cent of complete horticultural yield where creation happens on ranches averaging somewhere in the range of 0.5 and 7.5 sections of land. Secured creation frameworks like nurseries comprise a construction with a clear cover, wherein farming items can be developed. In Kenya, greenhouse farming has gained popularity and in 2015 this number increased to about 10 million (FAO, 2017). Production in greenhouses requires specialized management and thus for effective activities, greenhouse growers need to have abilities in crop creation works, promotion and monetary administration. This course accordingly tries to bestow the necessary information and foster the skills needed to guarantee a reasonable nursery creation plan of action (Odhiambo, 2018).

While some farms have appreciated the existence of the technology others have received little or no benefits from the technology (Omoro, 2014). Kenyan farmers are still incapable to afford greenhouses and, as a result, frequently prefer to build their own. In the case of self-built greenhouses, the wooden construction is frequently selected since it is simple to construct and easily accessible to farmers at retail outlets. They may offer the same benefits as greenhouses erected by experts if built correctly (Van der Spijk, 2018). Because of the small-scale character of the greenhouses, they frequently lack any form of circulation, making them unsuitable for hot climates. These greenhouses are frequently not as high on the sides as medium-level greenhouses, making them unsuitable for vertical tomato growth. This is because of the low technology level (low-tech) greenhouses available to greenhouse farms, especially in the rural areas since they are the major producers of agricultural products (Birch, 2018; Van der Spijk, 2018).

Adoption of Iot in Kenyan Agriculture

The introduction of IoT in Kenya has gained its way into the Kenyan agricultural sector owing to the introduction of the mobile phone which started a revolution in the way of communication. The overall state of ICT Infrastructure penetration in Kenya is growing and augers well for the future (Netherlands Enterprise Agency, 2019). With a growing network coverage with a 3G, 4G and the introduction of 4G, ICT has scaled up in the agricultural sector, making Kenya the leader in Internet penetration in Africa with a total Internet penetration of 40.0% in 2021 and at 42.0 per cent at the start of 2022 (World Bank Data, 2020). This has significantly grown from 0.3% in 2000, 7.2% in 2010, 17.8% in 2017 and 22.6% in 2019 (World Bank Data, 2019).

Innovative ICT solutions in the agricultural sector gained prominence in the past decade owing to the overall adoption of ICT in Kenya. This has ranged from the use of mobile phones to advanced technologies such as blockchain, artificial intelligence, cloud computing, Internet of Things (IoT) and big data analytics (Ayim et al., 2020). As much as it is critical, it is the main challenge for ICT-Agri companies in Kenya, particularly for smallholder farmers and other actors in the agriculture value chain (Netherlands Enterprise Agency, 2019). At the beginning of the last decade (early 2000), the general rate of adoption of digital agriculture was found to be at an infant stage with little documentation to prove it.

Little has been documented on the adoption rate of digital technologies in agriculture since its inception of digital technologies. However, with the increased penetration of internet services and the use of technological solutions, Kenyan digital agriculture has been improving from year to year, but not quickly enough to keep pace with other countries. As such, it remains in the lower 30% of countries worldwide, and well below the international average (ICT Development Index, 2019). By 2020, Kiarie (2020) in his study indicated an adoption rate of agricultural technologies at 18.5%. The low adoption rate has been attributed to low technological literacy, high technology costs, low digital literacy, limited infrastructure access, and a weak enabling policy environment since early 2000 (Ayim et al., 2020; Netherlands Enterprise Agency, 2019). Low adoption rates of modern agricultural technologies have also been linked to poor access to credit and loan facilities by farmers in the sense that the small-scale farmers often lack access to adequate financial resources to meet the high required initial start-up cost required to acquire modern technology facilities (Kiarie, 2020).

Therefore, international and local stakeholders have taken a key interest in the developments. This has been shown by the international donors, such as the World Bank, CGIAR, USAID, the African Development Bank, and the Gates Foundation who are the major sources of finance for Kenyan digital agriculture as well as the network operators such as Safaricom and Telkom that offer general services, such as connectivity and mobile money, that are readily applied to the agricultural sector (FAO, 2021). Currently, private-sector organizations are also spearheading the use of the most advanced technologies, including big data, analytics, and artificial intelligence in agricultural value chains. Such technologies are currently used by only 2% of all producers in Kenya and are unfamiliar to most development and research professionals in the field. Likewise, several digital solutions in agriculture have been piloted over the last few years. This suggests important opportunities for digital solutions to several major challenges plaguing Kenyan agriculture, including poor access to crucial services; supply chain traceability and management; agricultural mechanization; and product quality assurance (FAO, 2021). The current study, therefore, finds ground in such arguments and aligns its objective to the same to seek to investigate the factors affecting the adoption of Internet of Things technology among the selected greenhouse farms in Kenya.

Statement of the Problem

Tremendous technology development in the field of the Internet of Things (IoT) has been indicated to have a major improvement in the production of agricultural products. However, many barriers have been indicated to add to the low entrance of exactness agriculture strategies in smallholder farms in non-industrial nations like the significant expense of executing arrangements in far-off regions, low mindfulness among farmers and rural expansion administrations, and difficulties in associating ground estimations to further developed farm productivity (van der Spijk, 2018).

The adoption of the IoT technology in greenhouses in Kenya has consistently been poor and has been attributed to obstacles experienced by farms given their less advanced steps in agricultural technology. For instance, the Internet of Things requires highly sophisticated equipment and given the economic capacity of Kenyan farmers, the affordability of the equipment such as sensors (especially on a large scale) is a challenge (Antony, Leith, Jolley, Lu & Sweeney, 2020). Besides, some of the technology is highly dependent on strong internet connectivity, however, in rural areas which are the roots of commercial agriculture, access to these kinds of technological connectivity such as the 4G internet, fibre cable connection, etc. low. For example, an off-the-shelf soil moisture sensor in Kenya costs approximately 500 USD which is a cost that can easily be foregone by the local farmer in Kenya (Antony, Sweeney & Lu, 2019). The problem of poor technological application results in poor quality products and as well as food wastage which is attributed to insufficient proper facilities in the greenhouses. About 17% of agricultural produce is lost annually (Mujuka et al., 2020). However, with the increased penetration of internet services and the use of technological solutions, Kenyan digital agriculture has been improving from year to year, but not quickly enough to keep pace with other countries. As such, it remains in the lower 30% of countries worldwide, and well below the international average (ICT Development Index, 2019). By 2020, Kiarie (2020) in his study indicated an adoption rate of agricultural technologies at 18.5%. The low adoption rate has been owed to low technological literacy, high technology costs, low digital literacy, limited infrastructure access, and a weak enabling policy environment since early 2000 (Ayim et al., 2020; Netherlands Enterprise Agency, 2019).

Likewise, it has been noted that there are limited empirical studies conducted across the country in a bid to investigate the reasons for the low adoption. For instance, Kanake (2016) carried out an investigation in Kiambu County based on the problem that the existing IoT prototype was not effective for monitoring environmental conditions due to the unpredictable weather changing conditions and poor real-time information records. However, the study did not explain the reasons behind low adoption and only focused on the environmental factors thus presenting a conceptual gap. According to Antony, Sweeney and Lu (2019), Internet of Things for Smallholder Agriculture, the greenhouse IoT on vegetable cultivation was based in Nyeri. In the reviewed studies, there is scarce clarity on what factors influence IoT adoption in agriculture, particularly in Kenya. This study empirically investigates how product-related factors, farm factors, farmer perception of IoT technology and environmental factors related with the adoption of the Internet of things technology among the selected greenhouse farms in Kenya. The study targeted the selected farms and was limited to the information from the greenhouse farm managers of the respective greenhouse farms. These farms are Amiran Kenya Ltd farms, Illuminum Greenhouses

Kenya farms and East Africa Growers Ltd (EAGA) farms. The study targeted 198 greenhouse farm managers who were sampled to 130 greenhouse farm managers by a proportionate (stratified) sampling technique. The research took a duration of eight months from December 2021 through July 2022.

Research Objective

i. To investigate the effect of farm factors on the adoption of IoT technology in the selected greenhouse farms in Kenya.
ii. To establish the effect of farmer perception of technology on the adoption of IoT technology in the selected greenhouse farms in Kenya.
iii. To investigate the effect of product-related factors on the adoption of IoT technology in the selected greenhouse farms in Kenya.
iv. To determine the effect of environmental factors on the adoption of IoT technology in the selected greenhouse farms in Kenya.

Research Questions

i. What is the relationship between farm factors on the adoption of IoT technology in the selected greenhouse farms in Kenya?
ii. What is the relationship between farmer perception of technology on the adoption of IoT technology in the selected greenhouse farms in Kenya?
iii. What is the relationship between product-related factors on the adoption of IoT technology in the selected greenhouse farms in Kenya?
iv. What is the relationship between environmental factors on the adoption of IoT technology in the selected greenhouse farms in Kenya?

LITERATURE REVIEW

Theoretical Framework of the Study

Resource-Based View Theory

RBV theory was first brought to perspective in the late 50s by Penrose (1959), to indicate the assumption that companies may be conceived of packages of economic capital, and that each firm has a unique set of these assets. This is the concept of asset heterogeneity in firms (Penrose & Penrose, 2009). Barney (1991) solidified the argument by suggesting that organizational resources are the basis of the performance of a firm and that it possesses unique resources to bring about its competitiveness. In this case, RBV explains how resources are bundled, channeled and utilized to bring competitiveness (Ramon et al., 2019). Competencies are unique and challenging to replicate or reproduce since they are firmly ingrained in organizational culture, making them the most probable bearers of competitiveness, Therefore, based on the principles of RBV, the current study finds the theory worthwhile in explaining the link between firm-specific resources that is farm-factors and the adoption of IoT Technology.

Diffusion of Innovation Theory

The theory was first coined in 1903 by Gabriel Tarde, who traced the first S-shaped dispersion curve, followed by Ryan and Gross (1943), who presented the classifications of the adopters which were then used in the current hypothesis promoted by Everett Rogers. Katz (1957) is also credited with presenting for the first time the idea of the pioneers of the assessment, the followers of the conclusions and how the media connect to influence these two encounters. In the late 1990s, the theory began to work with the inauguration of Rogers (1995), who argued that dissemination is the process by which an innovation communicates over time among participants in a social system. That is, the theory of innovation diffusion is founded on the premise that the acceptance of an invention involves the accidental or deliberate dissemination of new ideas. According to Rogers, originality is defined as a new concept, activity, or thing (Rogers, 1995). The theory forms basis of understanding the factors that inform the adoption of IoT among greenhouse farmers. Policy makers and stakeholders in the greenhouse industry are able to assess the areas that are disadvantaged in terms of IoT and increase the awareness, training and usage of such technology to help the farmers identify the benefits of IoT.

Technology Acceptance Model (TAM)

Davis (1986) developed this approach to simulate the user acceptability of digital technologies. The idea has developed to describe several elements of technological occurrences. The Technology Acceptability Approach emerged as a popular model for analyzing user acceptance variables (Davis et al., 1989). According to TAM, perceived utility and perceived ease of using impact one's inclination toward usage intent which influences behavioural willingness to use a technological system (Venkatesh & Davis, 2000). Therefore, the model informs the current study in informing the user acceptability, their behavioural intentions, norms and attitudes towards a given technology. Thus, given the importance placed on the adoption of IoT by greenhouse farmers, the model is found informative by laying the fundamentals that underlie the acceptability of the technologies by the farmers.

Technology-Organization-Environment (TOE) Model

The Technology-Organization-Environment-TOE theory identifies three aspects of the context of a project, as determinants and propellers, in the adoption and implementation of technological innovation (Tornatzky & Fleischer, 1990). The framework identifies that the process of adoption and execution of technological innovation is guided by: environmental background, corporate background and technological background. They range from technological progress to the dynamic ability of a company, to the aggressiveness of a company (Chatterjee, Grewal & Sambamurthy, 2002) and the state of the industry (Awa, Ukoha & Emecheta, 2016). The TOE model is in line with the DOI theory (Tiago & María, 2011), as seen previously, the DOI model has established that the individual characteristics and internal and external characteristics of a company are the main drivers of innovation in that company in particular. However, the TOE

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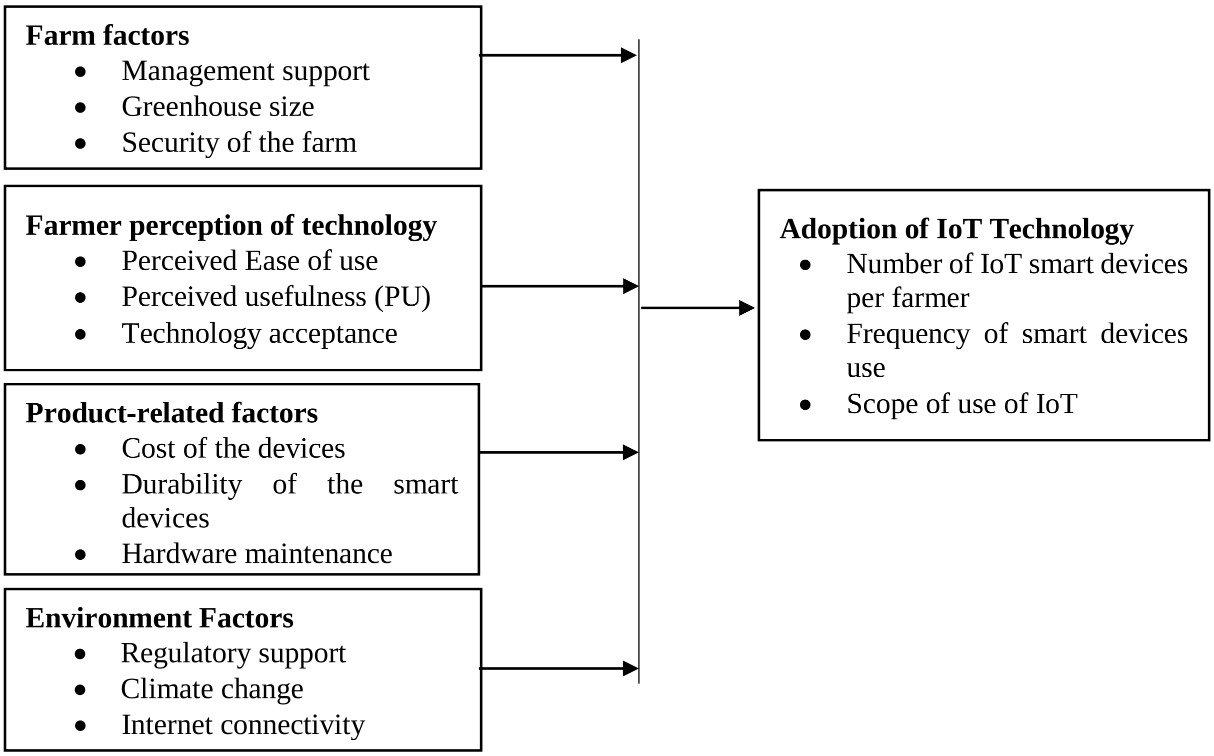
model adds a unique construction, i.e., an environmental background that focuses on the opportunities and limits for technological innovation (Tornatzky & Fleischer, 1990).

Conceptual Framework



Independent Variables **Dependent Variable**

Figure 1: Conceptual Framework

Critique of Existing Literature

Based on the literature reviewed, the current study has found considerable literature in support of the adoption of the internet of things (IoT) in agriculture in various contexts given the various factors under the current study scope. For instance, Oliveira *et al*. (2014), as well as Kinyangi (2014), indicate that market forces (availability of manpower, need for technological resources, size of the farm, level of expected benefits/advantages and level of exertion/effort needed to carry out the innovation); social elements (age of the supportive potential, economic wellbeing of ranchers, level of instruction and perspectives identified with sexual orientation, family size and agricultural endeavours); the board factors (enrollment of associations, loaning limit and concerns identified with natural corruption and human strength of ranchers) and institutional/mechanical conveyance systems (admittance to data, augmentation administrations and preventive investment and preparing on bug control rehearses) can impact the adoption of technology. However, there have been indications of the current subject under discussion experiencing limitations. These limitations have been presented in several ways for instance by looking at the weaknesses the studies had in the methods of conducting the research. Others have shown that the studies, despite being relevant, lacked various conceptual aspects that make the study generalizable to an entire population even to other geographical contexts (Yang et al., 2018; Debnath et al., 2018). In addition, Gomes and Osman (2019) theoretically focus on only one theoretical aspect thus not being able to spread the scope to other theoretical backgrounds that explain the factors as well as the adoption of IoT in Agriculture.

AlHogail (2018) did not consider explicit areas of IoT products. This requires the model to be upgraded with reasonable norms and execution markers for further developing confidence in IoT products and reception of IoT. This investigation consequently, presents a conceptual gap. Moreover, this examination investigated the components impacting purchaser reception of IoT innovation in one local area, consequently, introducing a contextual gap. Because of some changes in social convictions or legislative guidelines in correlation with different networks. Therefore, to offer more concise and applicable findings to greenhouse farms, this gap necessitates a study in Kenya to fill the conceptual and contextual gaps. Farooq (2020)'s study presents a conceptual and contextual gap since the focus was not directed to the use of technology in greenhouse farming. The study by Jayashankar et al. (2018) on IoT adoption in agriculture: the role of trust, perceived value and risk bases its conclusions on the context of the USA with the farmers having a better economic capacity in a developed economy. This is not the case in Kenya among other developing African countries whose technological capacities are yet to actualize. In addition, the study does not focus on the role of these factors in greenhouse farming. Therefore, the study presents a contextual as well as a conceptual gap that needs to be filled for a more generalizable finding. The study by Yang et al. (2018) on customers' behavioural intentions, was focused on the adoption of the smart home. Although the study explained the adoption behaviour given the type of automation of the smart devices, the scope of the study was on households rather than the agricultural sector which is a clear contextual gap.

The study by Gomes and Osman (2019) presents a theoretical gap (due to reliance on one theory-diffusion innovation theory) which is evidenced by the instances where the theory did not correspond to the experience in reality about how today's innovations behave in certain circumstances. This presented problems in the theoretical validation. While Rogers recognizes the impact of the client in the dispersion of innovation, he neglected to recognize their impact on the cycle of coordination/integration. Nonetheless, these days products, particularly nonphysical ones, are continually changing and advancing even after they are first conveyed (refreshes, new forms, and so on), subsequently, the improvement interaction of numerous items and developments in the present is nonstop, which is likewise gotten from the discoveries of the contextual investigations. The study has found significant evidence in support of the adoption of IoT technology in greenhouse farming. Various studies have shown that there is a relationship between the following factors: farm factors, farmer perception of technology, product-related factors and environmental factors and the adoption of IoT. However, there are very few studies that have narrowed down to the Kenyan context and specifically the case of Amiran Kenya Ltd farms, Illuminum Greenhouses Kenya farms and East Africa Growers Ltd (EAGA) farms. Therefore, based on the above gap, the current study seeks to establish the role of farm factors, farmer perception of technology, product-related factors and environmental factors in the adoption of IoT at Amiran Kenya Ltd farms, Illuminum Greenhouses Kenya farms and East Africa Growers Ltd farms. Thus, it is evidenced that there are various research gaps presented in the process. Based on the above, the study presents several research gaps identified in the reviewed literature.

METHODOLOGY

A descriptive cross-section research design was used. The study targeted 198 greenhouse farm managers who were sampled to 130 greenhouse farm managers by a proportionate (stratified) sampling technique. The unit of analysis was the selected 3 greenhouse farms (Amiran Kenya Ltd farms, Illuminum Greenhouses Kenya farms and East Africa Growers Ltd (EAGA) farms). The unit of observation was the greenhouse farm managers and the greenhouse staff of the respective greenhouse farms. The greenhouse farm managers as shown in Table 1:

Table 1: Target Population

Company	List of Greenhouses	Number of greenhouse managers
Illuminum Greenhouses Kenya	Aburi Agricultural Project	12
	Capsicum Farming Project	14
	Home Garden Project	5
	Naela Women Group	17
	Screen houses for BSF	14
Amiran Kenya Ltd farms	Siberia	11
	Genesis Seeds Limited	11
	Paskal Greenhouse solutions	14
	Agro-Nutrition	17
	Azrom Agricultural Innovations	14
	Baltoncp Amiran Kenya	13
East Africa Growers Ltd	Shalimar Farm	11
	Woodland Farm	17
	Jessy Nikki Farm	5
	Daisa Farm	11
	Rift Valley Vegetables Farm	12
Total		**198**

Source: Amiran Kenya Ltd, 2020; Illuminum Greenhouses Kenya, 2020; East Africa Growers Ltd (2020).

The population was targeted using convenient random sampling that is those that are ready to respond to the questionnaires, to arrive at adequate sample size. The study undertook a probabilistic sampling technique using the Fishers' formula (Fisher *et al*., 1993). Therefore, the study sampled 130 greenhouse farm managers. The population was proportionately distributed and sampled by use of the stratified random technique as shown in Table 2.

Table 2: Study Sample

Company	Greenhouses	Number of greenhouse managers	Sample size
Illuminum Greenhouses Kenya	Aburi Agricultural Project	12	8
	Capsicum Farming Project	14	9
	Home Garden Project	5	3
	Naela Women Group	17	11
	Screenhouses for BSF	14	9
Amiran Kenya Ltd farms	Sineria	11	7
	Genesis Seeds Limited	11	7
	Paskal Greenhouse solutions	14	9
	Agro-Nutrition	17	11
	Azrom Agricultural Innovations	14	9
	Baltoncp Amiran Kenya	13	8
East Africa Growers Ltd	Shalimar Farm	11	7
	Woodland Farm	17	11
	Jessy Nikki Farm	5	3
	Daisa Farm	11	7
	Rift Valley Vegetables Farm	12	8
Total		**198**	**130**

*Source: Proportionate allocation: nf = Ni/N*n. Where; nf = the sample in each stratum, Ni = target population in each stratum, N = the target population and n = the desired total sample size.*

Primary data was collected using self-questionnaires. The collected data were coded and analyzed to generate both descriptive statistics (frequencies, means, standard deviations, central tendencies and percentages) as well as inferential statistics (correlation and regression coefficients). The subjective/qualitative information was evaluated using content analysis, and the findings were presented thematically. R^2, F statistic, t statistics, beta and p values were used to test for a causative link between the variables and the statistical threshold was set at a 0.05 significance level.

FINDINGS AND PRESENTATIONS

Response rate

Data was collected from different sectors of the organizations as displayed in Table 3. A total of 130 questionnaires were issued from which 102 were filled and returned which represents a response rate of 78.46%.

Table 3: Response Rate

Response	Frequency	Per cent (%)
Returned	102	78.46%
Unreturned	28	21.54%
Total	**130**	**100.00%**

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Descriptive Analysis

Descriptive statistics were done to show the summary of the findings by including, counts, frequencies, mean and standard deviation.

Adoption of IoT

The respondents were asked to indicate whether they have automated their crop farming activities. Table 4, reveal that 37.30% of the greenhouse farmers have automated their farming activities with 62.70% of them operating their greenhouse farming activities manually. This indicates that the adoption rate of IoT in Kenyan greenhouses is still low standing at 37.3% according to the findings of the current study.

Table 4: Automation of Greenhouse Farming Activities

Have you automated your crop farming activities	Frequency	Per cent
No	64	62.70%
Yes	38	37.30%
Total	**102**	**100.00%**

The respondents in the selected greenhouse farms were also asked to respond to the questions regarding the adoption of IoT in their greenhouses. Figure 2 indicates that the average percentage of staff/farmers who use IoT in greenhouse farm production averaged 20% in 2017, 22% in 2018, 35% in 2019, 30% in 2020 and 26% in 2021. It was also noted that the percentage of area under the concerned IoT averaged 15% in 2017, 27% in 2018, 36% in 2019, 52% in 2020 and 51% in 2021. However, none of the greenhouse managers responded to the total costs and total revenue from IoT use.

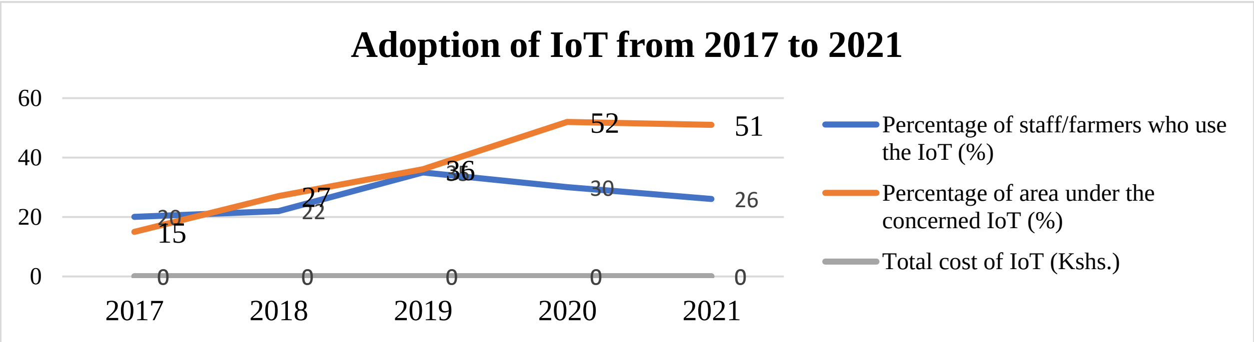

Figure 2: Adoption of IoT from 2017 to 2021

For those farmers who use IoT, Table 5, indicates that 33.30% of the greenhouse farmers revealed that the smart devices in the greenhouses are mainly used to detect moisture changes, 42.20% of them indicated that they are used to monitor soil temperature, 33.30% of them indicated that they are used to monitor soil pH while 28.40% of them indicated that they are used to monitor security cases in the farms.

Table 5: Purpose of the Smart Device in the Greenhouse

Variable	Category	Frequency	Percentage
Moisture changes	No	68	66.70%
	Yes	34	33.30%
Temperature	No	59	57.80%
	Yes	43	42.20%
pH	No	68	66.70%
	Yes	34	33.30%
Security cases	No	73	71.60%
	Yes	29	28.40%

The respondents were also requested to respond to the statement regarding the adoption of IoT. Table 6 indicates that 67.6% of the respondents acknowledged that they are willing to continuously use the IoT in greenhouse farming (mean=3.77≈4, SD=1.31). The results also indicate that 46.1% of the respondents acknowledged that they believe that the smart devices help in different environmental control for example temperature, moisture, and pH (mean=3.23≈3, SD=1.39). The results also indicate indicates that 47.0% of the respondents acknowledged that they believe in investing in technology for improved crop performance in the greenhouse (mean=3.37≈3, SD=1.33). The results indicate that 48% of the respondents acknowledged that they believe that the device can enrich their ultimate performance and lifestyle (mean=3.23≈3, SD=1.50). The results indicate that 47.1% of the respondents acknowledged that they believe that the use of the smart devices ensures minimum crop failures unlike before the use of the devices (mean=3.44≈3, SD=1.31). In conclusion, the average mean of the responses was 3.41 when viewed on a scale of five points presenting a standard deviation of 1.37. This means that the majority of the respondents believed that they have not subscribed to the use of IoT but are willing and believe its application could improve greenhouse production.

Table 6: Percentages, Mean and Standard Deviation of the Adoption of IoT

Statements	1	2	3	4	5	M	SD
You are willing to continuously use the IoT in the greenhouse farming	9.8%	8.8%	13.7%	29.4%	38.2%	3.77	1.31
You believe that the smart devices help in different environmental control for example temperature, moisture, pH	12.7%	23.5%	17.6%	20.6%	25.5%	3.23	1.39
You believe in investing in technology for improved crop performance in the greenhouse	8.8%	20.6%	23.5%	18.6%	28.4%	3.37	1.33
You believe that the device can enrich your ultimate performance and lifestyle	16.7%	22.5%	12.7%	17.6%	30.4%	3.23	1.50
You believe that the use of the smart devices ensures minimum crop failures unlike before the use of the devices	6.9%	20.6%	25.5%	15.7%	31.4%	3.44	1.31
Average						**3.41**	**1.37**

Note: 1=Strongly Disagree, 2=Disagree, 3=don't Know, 4=Agree and 5=Strongly Agree, M=Mean, SD= Standard Deviation

Farm factors and adoption of IoT

The respondents were asked to indicate their perceptions of farm factors and the adoption of IoT. Table 7 indicates that the majority of the greenhouse farmers (95.1%) perceive farm factors to affect their choice of IoT in greenhouse farming.

Table 7: Perceptions toward Farm Factors and Adoption of Iot

Perceptions toward farm factors	Frequency	Percentage
No	5	4.90%
Yes	97	95.10%
Total	**102**	**100.00%**

The respondents were also requested to respond to the statement regarding the perceptions towards farm factors and adoption of IoT. Table 8 indicates that 52.7% of the respondents acknowledged that the volume of the datasets from the software of the IoT device is within the capacity of their management (mean=3.32≈3, SD=1.54). The results also indicate that 71.0% of the respondents acknowledged that the information from the database software tools to are captured, stored, managed, and analyzed automatically (mean=3.84≈4, SD=1.24). The results also indicate indicates that 63.1.1% of the respondents acknowledged that the data from the device is quality, reliable, and overall confidence (mean=3.61≈4, SD=1.41). The results indicate that 46.1% of the respondents acknowledged that the greenhouse is large enough to accommodate the technology for commercial production (mean=3.21≈3, SD=1.40). The results indicate that 46.1% of the respondents were not sure that the number of IoT devices to be purchased is based on the crop grown and the size of the greenhouse (mean=3.34≈3, SD=1.30). The results indicate that 46.1% of the respondents acknowledged that the greenhouse is secure to allow safe installation and operation of the IoT devices (mean=3.17≈3, SD=1.15). The results indicate that 47.1% of the respondents indicated that the greenhouse is not at a safe distance to allow strong internet connectivity with their homes (mean=2.77≈3, SD=1.41).

In conclusion, the average mean of the responses was 3.32 when viewed on a scale of five points presenting a standard deviation of 1.41 implying that farm factors affect their adoption of IoT. The findings agree with Brous *et al*. (2017) and Saiz-Rubio and Rovira-Más (2020) who affirmed that predictable information about ranches prompts ideal choices where agrarian administration frameworks are needed to deal with ranch information so that outcomes are coordinated to address altered answers for each homestead.

Table 8: Percentages, Mean and Standard Deviation of Farm Factors and Adoption of IoT

Statements	1	2	3	4	5	M	SD
The volume of the datasets from the software of the IoT device is within the capacity of your management	21.1%	10.5%	15.8%	21.1%	31.6%	3.32	1.54
The information from the database software tools to are captured, stored, managed, and analyzed automatically	7.9%	7.9%	13.2%	34.2%	36.8%	3.84	1.24
The data from the device is quality, reliability, and overall confidence	13.2%	10.5%	13.2%	28.9%	34.2%	3.61	1.41
The greenhouse is large enough to accommodate the technology for commercial production	13.7%	22.5%	17.6%	21.6%	24.5%	3.21	1.40
The number of IoT devices to be purchased is based on the crop grown and the size of the greenhouse	7.8%	22.5%	23.5%	19.6%	26.5%	3.34	1.30
Your greenhouse is secure to allow safe installation and operation of the IoT devices	20.6%	19.6%	13.7%	14.7%	31.4%	3.17	1.55
The greenhouse is at a safe distance to allow strong internet connectivity with your home	25.5%	21.6%	17.6%	20.6%	14.7%	2.77	1.41
Average						**3.32**	**1.41**

Note: 1=Strongly Disagree, 2=Disagree, 3=Don't Know, 4=Agree and 5=Strongly Agree, M=Mean, SD= Standard Deviation

Farmer Perception of Technological Factors and Adoption of IoT

The respondents were asked to indicate their perceptions of technological factors and the adoption of IoT. Table 9 indicates that more than half of the greenhouse farmers (91.2%) perceive technological factors to affect their choice of IoT in greenhouse farming.

Table 9: Perceptions toward Technological Factors and Adoption of IoT

Perceptions towards technology	Frequency	Percentage
No	9	8.80%
Yes	93	91.20%
Total	**102**	**100.00%**

The respondents were also requested to respond to the statement regarding the perceptions towards technological factors and adoption of IoT. Table 10 indicates that 43.1% of the respondents acknowledged that IoT device trackers can be applied to a wide range of domains for more than just one use for example they can track temperature changes based on different crops (mean=3.36≈3, SD=1.12). The results also indicate that 89.4% of the respondents acknowledged that the device is user-friendly for them and their workmates in the greenhouse (mean=4.34≈4, SD=0.91). The results also indicate indicates that 89.4% of the respondents acknowledged that the device is easily portable and sizable (mean=4.14≈4, SD=0.95). The results indicate that 89.5% of the respondents acknowledged that the information from the device is easy to acquire, understand and interpret events as they occur (mean=4.32≈4, SD=1.04). The results indicate that 94.8% of the respondents acknowledged that the IoT device is compatible with other software used in computer packages (mean=4.37≈4, SD=0.79). The results indicate that 36.9% of the respondents acknowledged that the IoT device is operational under fluctuating weather (mean=2.95≈3, SD=1.47).

The results indicate that 50.0% of the respondents acknowledged that the IoT device tracker can be easily maintained or repaired at the farm (mean=3.29≈3, SD=1.64). The results indicate that 42.1% of the respondents disagreed that the applications take place in, actual time immediately on the job site, to administer varying rates of reagents in apparatus with variable rate application technology (mean=2.87≈3, SD=1.32). The results indicate that 50.0% of the respondents disagreed that the device can operate alongside other devices with minimum friction (mean=2.71≈3, SD=1.21). In conclusion, the average mean of the responses was 3.60 when viewed on a scale of five points presenting a standard deviation of 1.16 implying that technological factors affect their adoption of IoT. The findings agree with Farooq (2020) demonstrating that the most encouraging reality is that this space of exploration is being belittled by the legislatures of different nations, and numerous nations have their IoT agribusiness arrangements. Various associations and ventures are utilizing various types of gadgets/sensors for quite a while, yet the creation of IoT has taken headways of gadgets/sensors absolutely at an alternate level. Generally utilized sensors are temperature sensors, dampness sensors, soil design checking sensors, wind stream sensors, area sensors, CO_2 sensors, and pressure sensors. The critical attributes of IoT gadgets/sensors that make them appropriate for horticulture include conveyability, dependability, memory, strength, power, computational productivity and inclusion.

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Table 10: Percentages, Mean and Standard Deviation of Perceptions towards Technological Factors

Statements	1	2	3	4	5	M	SD
IoT device trackers can be applied to a wide range of domains for more than just one use for example they can track temperature changes based on different crops	4.9%	16.7%	35.3%	23.5%	19.6%	3.36	1.12
The device is user-friendly for you and your workmates in the greenhouse	2.6%	2.6%	5.3%	36.8%	52.6%	4.34	0.91
The device is easily portable and sizable	5.3%	0.0%	5.3%	52.6%	36.8%	4.16	0.95
The information from the device is easy to acquire, understand and interpret events as they occur	5.3%	2.6%	2.6%	34.2%	55.3%	4.32	1.04
The IoT device is compatible with other software used in computer packages	2.6%	0.0%	2.6%	47.4%	47.4%	4.37	0.79
The IoT device is operational under fluctuating weather	23.7%	15.8%	23.7%	15.8%	21.1%	2.95	1.47
The IoT device tracker can be easily maintained or repaired at the farm	21.1%	18.4%	10.5%	10.5%	39.5%	3.29	1.64
Applications take place in, the actual time immediately on the job site, to administer varying rates of reagents in apparatus with variable rate application technology.	18.4%	23.7%	23.7%	21.1%	13.2%	2.87	1.32
The device can operate alongside other devices with minimum friction	15.8%	34.2%	21.1%	21.1%	7.9%	2.71	1.21
Average						**3.60**	**1.16**

Note: 1=Strongly Disagree, 2=Disagree, 3=Don't Know, 4=Agree and 5=Strongly Agree, M=Mean, SD= Standard Deviation

Product-Related Factors and Adoption of IoT

The respondents were asked to indicate their perceptions of product-related factors and the adoption of IoT. Table 11 indicates that more than half of the greenhouse farmers (90.20%) perceive product-related factors to affect their choice of IoT in greenhouse farming.

Table 11: Perceptions toward Product-Related Factors and Adoption of IoT

Perceptions of product-related factors	Frequency	Percentage
No	10	9.80%
Yes	92	90.20%
Total	**102**	**100.00%**

The respondents were also requested to respond to the statement regarding the perceptions towards product-related factors and adoption of IoT. Table 12 indicates that 53.9% of the respondents acknowledged that the cost of the smart device is affordable (mean=2.90≈3, SD=1.24). The results also indicate that 68.6% of the respondents acknowledged the smart device functionality is very specific to the operations in the greenhouse (mean=3.80≈4, SD=1.29). The results also indicate

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indicates that 50.0% of the respondents acknowledged that they can custom the smart device to suit their specifications (mean=3.29≈3, SD=1.47). The results indicate that 44.8% of the respondents acknowledged that the device has long-lasting and reliable quality in the greenhouse (mean=3.18≈3, SD=1.56). The results indicate that 43.1% of the respondents acknowledged that they have developed a higher level of trust toward IoT and intend to start using or continue using it (mean=3.24≈3, SD=1.32). The results indicate that 42.2% of the respondents acknowledged that the device can provide them with timely and responsive output (mean=2.92≈3, SD=1.53). The results indicate that 52.6% of the respondents acknowledged that there is unlimited storage of the greenhouse data and thus it can predict the conditions of the greenhouse (mean=3.39≈3, SD=1.37).

The results indicate that 55.3% of the respondents acknowledged that devices may help them by preventing unpleasant shocks (mean=3.34≈3, SD=1.42). The results indicate that 52.6% of the respondents acknowledged that monitoring and tracking enable the collection of a variety of information along the production process (mean=3.39≈3, SD=1.37). In conclusion, the average mean of the responses was 3.27 when viewed on a scale of five points presenting a standard deviation of 1.40 implying that product-related factors affect their adoption of IoT. The findings agree with Yang, Lee and Lee (2018) that people generally seek relatively safer and more effective remote management features rather than highly advanced automated services. People may want the devices of a smart home to be under their control rather than being fully automated because a home is safe and represents their personal space where they can rest. Hsu and Lin (2018) that perceived usefulness and perceived enjoyment significantly affect behavioural intention through perceived value.

Table 12: Percentages, Mean and Standard Deviation of Product-Related Factors and Adoption of IoT

Statements	1	2	3	4	5	M	SD
The cost of the smart device is affordable to you	4.90%	49.00%	14.70%	13.70%	17.60%	2.9	1.24
The smart device functionality is very specific to the operations in the greenhouse	9.80%	6.90%	14.70%	30.40%	38.20%	3.8	1.29
You can custom the smart device to suit your specifications	15.80%	18.40%	15.80%	21.10%	28.90%	3.29	1.47
The device has long-lasting and reliable quality in the greenhouse	21.10%	15.80%	18.40%	13.20%	31.60%	3.18	1.56
I have developed a higher level of trust toward IoT and intend to start using or continue using it	8.80%	26.50%	21.60%	18.60%	24.50%	3.24	1.32
The device can provide you with timely and responsive output	26.30%	18.40%	13.20%	21.10%	21.10%	2.92	1.53
There is unlimited storage of the greenhouse data and thus it can predict the conditions of the greenhouse.	7.90%	26.30%	13.20%	23.70%	28.90%	3.39	1.37
Users may help them by preventing unpleasant shocks.	18.40%	7.90%	18.40%	31.60%	23.70%	3.34	1.42
Monitoring and tracking enable the collection of a variety of information along the production process.	13.20%	13.20%	21.10%	26.30%	26.30%	3.39	1.37
Average						3.27	1.4

Note: 1=Strongly Disagree, 2=Disagree, 3=Don't Know, 4=Agree and 5=Strongly Agree, M=Mean, SD= Standard Deviation

Environmental Factors and Adoption of IoT

The respondents were asked to indicate their perceptions of environmental factors and the adoption of IoT. Table 13 indicates that more than half of the greenhouse farmers (82.40%) perceive environmental factors to affect their choice of IoT in greenhouse farming.

Table 13: Perceptions toward Environmental Factors and Adoption of IoT

Perceptions toward environmental factors	Frequency	Percentage
No	18	17.60%
Yes	84	82.40%
Total	**102**	**100.00%**

The respondents were also requested to respond to the statement regarding the perceptions towards farm factors and adoption of IoT. Table 14 indicates that 55.9% of the respondents disagreed that the county government provides a discount on the purchase of such devices for them as greenhouse farmers (mean=2.60≈3, SD=0.77). The results also indicate that 94.2% of the respondents acknowledged that they get financial support from the IoT providers regarding the purchase of the devices for example lipa pole pole or at a discount (mean=4.14≈4, SD=0.60). The results also indicate indicates that 82.3% of the respondents disagreed that they get subsidized internet connection charges for the practice since they own a greenhouse (mean=3.29≈3, SD=1.40). The results indicate that 45.1% of the respondents acknowledged that the market of their produce is reliable since the service and IoT providers have assured them of the purchase of the products (mean=3.29≈3, SD=1.40). The results indicate that 48.0% of the respondents acknowledged that there is fair pricing of their farm produce in the market (mean=3.17≈3, SD=1.56). The results indicate that 45.1% of the respondents acknowledged that they experience minimum and fair competition in the market (mean=3.32≈3, SD=1.37). The results indicate that 52.0% of the respondents acknowledged that the region has reliable internet connectivity that is fast and efficient (mean=3.18≈3, SD=1.17).

In conclusion, the average mean of the responses was 4.02 when viewed on a scale of five points presenting a standard deviation of 1.12 implying that environmental factors affect their adoption of IoT. The findings agree with Elmustafa and Mujtaba (2019) that IoT plays an important role in the management of environmental pollution, and natural and non-natural disasters, as well as in the control of the management of vegetation in the environment. The implementation of the IoT in applications for intelligent environments can face various challenges related to identification, data management, security and interoperability between different types of aspects of the environmental system.

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Table 14: Percentages, Mean and Standard Deviation

Statements	1	2	3	4	5	M	SD
The county government provides a discount on the purchase of such devices for you as a greenhouse farmer	1.0%	54.9%	27.5%	16.7%	0.0%	2.60	0.77
You get financial support from the IoT providers regarding the purchase of the devices for example lipa pole pole or at a discount	0.0%	0.0%	5.9%	47.1%	47.1%	4.41	0.60
You get subsidized internet connection charges for the practice since you own a greenhouse	44.1%	38.2%	10.8%	6.9%	0.0%	1.80	0.89
The market of your product is reliable since the service and IoT providers have assured you of the purchase of the products	11.8%	21.6%	21.6%	15.7%	29.4%	3.29	1.40
There is fair pricing of your farm produce in the market	21.6%	18.6%	11.8%	17.6%	30.4%	3.17	1.56
You experience minimum and fair competition in the market	10.8%	20.6%	23.5%	15.7%	29.4%	3.32	1.37
The region has reliable internet connectivity that is fast and efficient	4.9%	35.3%	7.8%	41.2%	10.8%	3.18	1.17
Average						**2.42**	**0.97**

Note: 1=Strongly Disagree, 2=Disagree, 3=Don't Know, 4=Agree and 5=Strongly Agree, M=Mean, SD= Standard Deviation

Correlation Analysis

The Pearson correlation coefficient was used to determine the association between the variables which is denoted by r (Gogtay & Thatte, 2017).

Correlation between Farm Factors, Farmer Perception of Technology, Product-Related Factors, Environmental Factors and the Adoption of Iot Technology

Table 15 revealed that there is a positive and significant association between farm factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya (r=0.686**, p=0.000). The findings agree with Gomes and Osman (2019) that company sizes and their industry types are considered to control variables that are used as a basis for follow-up research and give a more detailed understanding of other potential variables that may influence the IoT adoption process. The results further show that farmer perception of technology and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (r=0.595**, p=0.000). The findings agree with Das et al. (2019) who show that technological aspects are significant positive contributors to the adoption of IoT. For instance, cloud computing reception among the farmers is more noteworthy however, the greater part of the non-adopter ranchers shows interest in getting Cloud Computing innovation on their homesteads. Keskin and Sekerli (2016) show that farmers with few farms could not put resources into any new advancements because of low revenue/income. The results further show that product-related factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (r=0.604**, p=0.000). The findings are consistent with Debnath et al. (2018) that Perceived Cost, Perceived Usefulness, Perceived Ease of Use, Unavailability & Lack of Promotion of IoT smart devices are the most cardinal factors of IoT adoption. The results further show that environmental factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (r=0.563**, p=0.000). These findings are consistent with Yigezu et al. (2018) that household adoption decisions on inorganic fertilizer and improved maize varieties were inter-dependent. Other factors found to influence the adoption of the two technologies were farmer characteristics, plot-level factors and market imperfections such as limited access to credit and input markets, and production risks. Likewise, the intensity of adoption is positively influenced by farmers' access to credit.

Table 15: Correlation Matrix

Correlations		Adoption of IoT	Farm factors	Farmer perception of technology	Product-related factors	Environmental factors
Adoption of IoT	R	1				
	Sig					
Farm factors	R	.686**	1			
	Sig	0.000				
Farmer perception of technology	R	.595**	.449**	1		
	Sig	0.000	0.000			
Product-related factors	R	.604**	.354**	.424**	1	
	Sig	0.000	0.000	0.000		
Environmental factors	R	.563**	.342**	.356**	.235*	1
	Sig	0.000	0.000	0.000	0.017	

*** Correlation is significant at the 0.01 level (2-tailed)*
**Correlation is significant at the 0.05 level (2-tailed)*

Inferential Analysis

The study also sought to investigate the causal effect of the independent variables on the dependent variable. The findings represent the model of fitness, analysis of variance tests and the regression of coefficients.

Regression Analysis

Table 16, presents the fitness of the regression model used in explaining the study phenomena. The results imply that farm factors, farmer perception of technology, product-related factors and environmental factors are significant predictors of the adoption of IoT Technology in the selected greenhouse farms in Kenya. This is evidenced by the R square value which is 0.732 which is more than 0.5 implying that all the factors explain 73.2% of the adoption of IoT Technology in the selected greenhouse farms in Kenya.

Table 16: Model of Fitness

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.856a	0.732	0.721	0.322

Dependent Variable: The adoption of IoT Technology
Predictors: (Constant), Environmental factors, Product-related factors, Farm factors, Farmer perception of technology

Analysis of Variance (ANOVA)

Table 17 indicates that the model was statistically significant given the F statistic 66.239 where the value was greater than the critical value at 0.05 significance level, $F_{statistic} = 66.239 > F_{critical} = 2.465$ (4, 97).

Table 17: Analysis of Variance (ANOVA)

	Sum of Squares	df	Mean Square	F	Sig.
Regression	27.461	4	6.865	66.239	.000b
Residual	10.053	97	0.104		
Total	**37.514**	**101**			

Dependent Variable: The adoption of IoT Technology
Predictors: (Constant), Environmental factors, Product-related factors, Farm factors, Farmer perception of technology

Estimated Model Coefficients

Table 18 indicated that farm factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.413, p=0.000). This implies that improvement in 1 unit of the aspects related to farm factors improves the adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.413 units; vice versa is true. These findings are in line with Gomes and Osman (2019) that company sizes and their industry types are considered to control variables that are used as a basis for follow-up research and give a more detailed understanding of other potential variables that may influence the IoT adoption process.

Likewise, the findings indicated that farmer perception of technology and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.139, p=0.005 respectively). This implies that improvement in 1 unit of the aspects related to farmer perception of technology improves the adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.139 units; vice versa is true. The findings agree with Jayashankar et al. (2018) that there is a positive link between trust and perceived value and a negative association between trust and perceived danger. This means that farmers will be less likely to adopt or embrace a particular innovation due to the potential increase in hazards connected with it. Perceived value influenced IoT adoption positively, but perceived danger influenced IoT development negatively.

Likewise, product-related factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.349, p=0.000 respectively). This implies that improvement in 1 unit of the aspects related to product-related factors improves the

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adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.349 units respectively; vice versa is true. These findings are consistent with Nikou (2018) who showed that attitude toward using technology is the dominating factor influencing the intention, while the effects of relative advantage, perceived usefulness and subjective norm on the intention to use, as expected, were found to be positive.

Likewise, environmental factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.383, p=0.000 respectively). This implies that improvement in 1 unit of the aspects related to environmental factors improves the adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.383 units respectively; vice versa is true. These findings are consistent with Yigezu et al. (2018) that household adoption decisions on inorganic fertilizer and improved maize varieties were inter-dependent. Other factors found to influence the adoption of the two technologies were farmer characteristics, plot-level factors and market imperfections such as limited access to credit and input markets, and production risks. Likewise, the intensity of adoption is positively influenced by farmers' access to credit.

The empirical model is thus, presented as shown below

$$Y = -0.701 + 0.413X_1 + 0.139X_2 + 0.349X_3 + 0.383X_4 + \varepsilon$$

Where: Y= Adoption of IoT technology in greenhouse farming; β= Model constant; X_1 = Farm factors; X_2 = Farmer perception of technology; X_3= Product-related factors; X_4= Environmental factors; and ε = Error term.

Table 18: Regression of Coefficients of the Sub Variables

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	β	Std. Error	Beta		
(Constant)	–0.701	0.269		-2.604	0.011
Farm factors	0.413	0.065	0.392	6.396	0.000
Farmer perception of technology	0.139	0.049	0.180	2.840	0.005
Product-related factors	0.349	0.065	0.320	5.393	0.000
Environmental factors	0.383	0.077	0.289	4.997	0.000

Dependent Variable – The adoption of IoT Technology

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

The correlation results revealed that there is a positive and significant association between farm factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya (r=0.686**, p=0.000). The regression findings also indicated that farm factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.413, p=0.000). This implies that improvement in 1 unit of the aspects related to farm factors improves the adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.413 units; vice versa is true.

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The correlation results revealed that farmer perception of technology and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (r=0.595**, p=0.003). Likewise, the regression findings indicated that farmer perception of technology and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.139, p=0.005 respectively). This implies that improvement in 1 unit of the aspects related to farmer perception of technology improves the adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.139 units; vice versa is true.

The correlation results revealed that product-related factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (r=0.604**, p=0.000). The causality findings also indicated that product-related factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.349, p=0.000 respectively). This implies that improvement in 1 unit of the aspects related to product-related factors improves the adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.349 units respectively, vice versa is true.

The correlation results revealed that environmental factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (r=0.563**, p=0.000). Likewise, from the regression results, environmental factors and the adoption of IoT Technology in the selected greenhouse farms in Kenya have a positive and significant relationship (β=0.383, p=0.000 respectively). This implies that improvement in 1 unit of the aspects related to environmental factors improves the adoption of IoT Technology in the selected greenhouse farms in Kenya by 0.383 units respectively; vice versa is true.

Conclusion

The study concludes that there is a significant relationship between farm factors, farmer perception of technology, product-related factors, environment predictors and the adoption of IoT Technology in the selected greenhouse farms in Kenya. However, it can be concluded that the adoption rate of IoT in Kenyan greenhouses stands at 37% according to the findings of the current study which is still low considering the technological strides in the Kenyan market.

Recommendations

Findings of this research indicates that datasets obtained from IoT devices in use in their farms can be processed and no compatibility issues highlighted by the respondents. This information guides the direction of the agricultural industry and the readiness to embrace new technology, the farmers need to be sensitized on the available IoT devices that can boost their yields and optimize production. This helps them to reap the advantages of greenhouse technology (that is due to increased reliability of the technology to the farm factors). Likewise, for those farmers that are in the remote areas where connectivity is an issue, the study recommends the CAK, to ensure the internet connectivity is improved for the farmers to appreciate the full potential of the IoT.

There is a need for the authority to intensify the sensitization of the use of IoT technology to ensure optimum application of resources to achieve high crop yields and reduce operational costs is called precision agriculture. IoT in agriculture technologies comprises specialized equipment, wireless connectivity, software and IT services. Ministry of ICT and Agriculture need to work together in leveraging the fast-growing technological evolution in Kenya in guiding the farmers highlighting the benefits brought about by technology.

Based on the findings that the majority of the respondents disagreed with getting subsidized internet connection charges for the practice since they own a greenhouse, the study recommends the policymakers, that is, the Communications Authority of Kenya (CAK) who is responsible to facilitate and intensify the development and spread of the information and IT to the agricultural sector on the need for technological integration in their operation. This goes a long way in helping the farmers maximize their production/output: high yields, profitability, and protection of the environment.

The study also noted that most of the respondents were not subscribed to the use of IoT due to various reasons like high cost of purchase, lack of belief in its compatibility with other devices, etc. The study to that extent recommends (based on the advantages that outweigh the disadvantages of IoT) that the farmers have a positive attitude towards the use of IoT. This forms a basis for them to develop and sustain a competitive advantage against their competitors in the industry. It also helps them overcome environmental challenges such as drought, unfavourable humidity, moisture and soil alkalinity. This will ensure they stay productive off and on-season.

REFERENCES

AlHogail, A. (2018). Improving IoT technology adoption through improving consumer trust. *Technologies*, 6(3), 2 - 17. https://doi.org/10.3390/technologies6030064

Alomia-Hinojosa, V., Speelman, E. N., Thapa, A., Wei, H. E., McDonald, A. J., Tittonell, P., & Groot, J. C. (2018). Exploring farmer perceptions of agricultural innovations for maize-legume intensification in the mid-hills' region of Nepal. *International journal of agricultural sustainability*, 16(1), 74-93.

Amiran Kenya Ltd. (2020). *Agribusiness (Small Medium Scale Farmers).* https://www.baltoncp.com/amirankenya/agribusiness/

Awa, H. O., Ukoha, O., & Emecheta, B. C. (2016). Using TOE theoretical framework to study the adoption of ERP solution. Cogent Business & Management, 3 (1), 1196571.

Ayim, C., Kassahun, A., Tekinerdogan, B., & Addison, C. (2020). Adoption of ICT innovations in the agriculture sector in Africa: A Systematic Literature Review. *arXiv preprint arXiv:2006.13031*.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of management*, 17(1), 99-120.

Birch, I. (2018). *Agricultural productivity in Kenya: barriers and opportunities*. https://assets.publishing.service.gov.uk/media/5c70028ee5274a0ecbe9a1c2/483_Agricultural_Productivity_in_Kenya_Barriers_and_Opportunities.pdf

Brous, P., Janssen, M., Schraven, D., Spiegeler, J., & Duzgun, B. C. (2017, April). Factors Influencing Adoption of IoT for Data-driven Decision Making in Asset Management Organizations. In IoTBDS (pp. 70-79).

Chatterjee, D., Grewal, R., & Sambamurthy, V. (2002). Shaping up for e-commerce: institutional enablers of the organizational assimilation of web technologies. MIS quarterly, 65-89.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. psychometrika, 16(3), 297-334.

Das, V., Sharma, S., & Kaushik, A. (2019). Views of Irish Farmers on Smart Farming Technologies: An Observational Study. *AgriEngineering*, 1(2), 164-187.

Davis, F. D. (1986). *A technology acceptance model for empirically testing new end-user information systems*. Cambridge, MA.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. Management science, 35(8), 982-1003.

Debnath, A., Kobra, K. T., Rawshan, P. P., Paramita, M., & Islam, M. N. (2018, August). An Explication of Acceptability of Wearable Devices in Context of Bangladesh: A User Study. In 2018 IEEE 6th *International Conference on Future Internet of Things and Cloud (FiCloud)* (pp. 136-140). IEEE.

East Africa Growers Ltd. (2020). *Our Farms*. http://www.eaga.co.ke/farms.htm

Elmustafa, S. A. A., & Mujtaba, E. Y. (2019). Internet of things in Smart Environment: Concept, Applications, Challenges, and Future Directions. *World Scientific News*, 134(1), 1-51.

FAO. (2018). E-*Agriculture in Action: Drones for Agriculture.* Available at: http://www.fao.org/3/i8494en/i8494en.pdf

FAO. (2018). *Food and Agriculture Organization of the United Nations Kenya, 2018.* Available at: https://illuminumgreenhouses.com/

FAO. (2021). *Digital Agriculture Profile • Kenya*. https://www.fao.org/3/cb3958en/cb3958en.pdf

Farooq, M. S., Riaz, S., Abid, A., Abid, K., & Naeem, M. A. (2019). A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming. *IEEE Access*, 7, 156237-156271.

Farooq, M. S., Riaz, S., Abid, A., Umer, T., & Zikria, Y. B. (2020). Role of IoT Technology in Agriculture: A Systematic Literature Review. Electronics, 9(2), 2 -41.

Fisher, K. B., Davis, M., Strauss, M. A., Yahil, A., & Huchra, J. P. (1993). The power spectrum of IRAS galaxies. *The Astrophysical Journal*, 402, 42-57.

Gill, S. S., Chana, I., & Buyya, R. (2017). IoT based agriculture as a cloud and big data service: the beginning of digital India. *Journal of Organizational and End User Computing (JOEUC)*, 29(4), 1-23.

Gomes, R., & Osman, S. S. (2019). Managing Organizational Adoption of IoT: Revisiting Rogers' Diffusion of Innovation Theory. Retrieved from https://www.diva-portal.org/smash/get/diva2:1374639/FULLTEXT01.pdf

Hsu, C. L., & Lin, J. C. C. (2018). Exploring factors affecting the adoption of internet of things services. *Journal of Computer Information Systems*, 58(1), 49-57.

Illuminium Greenhouse Kenya. (2020). Greenhouses. https://synnefa.io/greenhouses/

Jayashankar, P., Nilakanta, S., Johnston, W. J., Gill, P., & Burres, R. (2018). IoT adoption in agriculture: the role of trust, perceived value and risk. *Journal of Business & Industrial Marketing*. 33 (6), pp. 804-821.

Jin, J., Ma, Y., Zhang, Y., & Huang, Q. (2018). Design and implementation of an Agricultural IoT based on LoRa. In MATEC Web of Conferences (Vol. 189, p. 04011). EDP Sciences.

Kanake, J. M. (2016). Internet of things for monitoring environmental conditions in greenhouses: a case of Kiambu County (Doctoral dissertation, Strathmore University).

Keskin, M., & Sekerli, Y. E. (2016). Awareness and adoption of precision agriculture in the Cukurova region of Turkey. Agron. Res, 14(4), 1307-1320.

Kiarie, H. (2020). D*eterminants of digital technologies adoption among small scale farmers in Kenya: A case of Embu and Kirinyaga Counties. (*Thesis, Strathmore University). http://hdl.handle.net/11071/10422

Kinyangi, A. A. (2014). Factors influencing the adoption of agricultural technology among smallholder farmers in Kakamega north sub-county, Kenya. A Research Project for Award Degree of Master of Arts in Project Planning and Management of the University of Nairobi. 87pp.

KIPPRA. (2018). Realizing the "Big Four" Agenda through Energy as an Enabler. Available at https://kippra.or.ke/index.php/publications?task=download.send&id=40&catid=6&m=0

Lai, I. K., Tong, V. W., & Lai, D. C. (2011). Trust factors influencing the adoption of internet-based interorganizational systems. Electronic Commerce Research and Applications, 10(1), 85-93.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, 13(1), 40-54.

Mujuka, E., Mburu, J., Ogutu, A., & Ambuko, J. (2020). Returns to investment in postharvest loss reduction technologies among mango farmers in Embu County, Kenya. Food and Energy Security, 9(1), e195.

Netherlands Enterprise Agency. (2019). Digital Farming in Kenya Commissioned by the Netherlands Enterprise Agency. https://www.rvo.nl/sites/default/files/2019/12/Digital-Farming-in-Kenya.pdf

Nikou, S. (2018). Consumers 'perceptions on Smart Home and Smart Living. *Research Papers*. 47. Available at: https://aisel.aisnet.org/ecis2018_rp/47

Odhiambo, P. L. (2018). Factors that influence farmers decision to adopt IOT sensing and monitoring greenhouse farming solutions in Kenya: a case study of illuminum greenhouse (Doctoral dissertation, University of Nairobi).

Oliveira, T., & Dhillon, G. (2015). From adoption to routinization of B2B e-Commerce: understanding patterns across Europe. *Journal of Global Information Management* (JGIM), 23(1), 24-43.

Omoro, P. A. (2014). Assessment of Selected Factors Affecting Performance of Greenhouse Technology in Small Scale Farms in Gusii Highlands, Kenya (Doctoral dissertation, Kisii University).

Park, C., & Park, Y. H. (2013). Validity and reliability of Korean version of health empowerment scale (K-HES) for older adults. Asian Nursing Research, 7(3), 142-148.

Paul Antony, A., Sweeney, D., & Lu, J. (2019). Seeds of Silicon: Internet of Things for Smallholder Agriculture. Available at https://dspace.mit.edu/handle/1721.1/123305

Penrose, E. (1959) The Theory of the Growth of the Firm. Basil Blackwell, Oxford.

Penrose, E., & Penrose, E. T. (2009). The Theory of the Growth of the Firm. Oxford university press.

Ramon-Jeronimo, J. M., Florez-Lopez, R., & Araujo-Pinzon, P. (2019). Resource-based view and SMEs performance exporting through foreign intermediaries: The mediating effect of management controls. Sustainability, 11(12), 3241.

Rogers, E. M. (1995). Diffusion of Innovations: modifications of a model for telecommunications. In Die diffusion von innovationen in der telekommunikation (pp. 25-38). Springer, Berlin, Heidelberg.

Rogers, E. M. (2003). Diffusion of innovations/everett m. rogers. NY: Simon and Schuster, 576.

Rogers, Everett M. (1962). Diffusion of innovations (1st ed.). New York: Free Press of Glencoe. OCLC 254636.

Ryan, B., & Gross, N. C. (1943). The diffusion of hybrid seed corn in two Iowa communities. Rural sociology, 8(1), 15.

Saiz-Rubio, V., & Rovira-Más, F. (2020). From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. Agronomy, 10(2), 1 - 21.

Sinja, J., Karugia, J. T., Baltenweck, I., Waithaka, M. M., Miano, M. D., Nyikal, R. A., & Romney, D. (2004). Farmer Perception of Technology and its Impact on Technology Uptake: The Case of Fodder Legume in Central Kenya Highlands (No. 306-2016-4861).

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). Processes of technological innovation. Lexington books.

Uddin, M. A., Mansour, A., Le Jeune, D., & Aggoune, E. H. M. (2017, November). Agriculture internet of things: AG-IoT. In 2017 27th International Telecommunication Networks and Applications Conference (ITNAC) (pp. 1-6). IEEE.

Van der Spijk, C. A. (2018). Greenhouse technology adoption among small and medium-scale tomato farmers in Kenya. Available at: https://www.3r-kenya.org/wp-content/uploads/2019/02/MSc-Thesis-Christiaan-A-van-der-Spijk.pdf

Van der Spijk, C. A. (2018). Greenhouse technology adoption among small and medium-scale tomato farmers in Kenya (Doctoral dissertation, M. Sc. Thesis, Wageningen University, the Netherlands).

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management science, 46(2), 186-204.

World Bank. (2017). *ICT in Agriculture: Connecting Smallholders to Knowledge, Networks, and Institutions*. Updated Edition. Washington, DC: World Bank.

Yang, H., Lee, W., & Lee, H. (2018). IoT smart home adoption: The importance of proper level automation. *Journal of Sensors*, 2018 (2), 1 – 11.

Yigezu, Y. A., Mugera, A., El-Shater, T., Aw-Hassan, A., Piggin, C., Haddad, A., ... & Loss, S. (2018). Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. Technological Forecasting and Social Change, 134, 199-206.