URBAN AGRICULTURE, SUSTAINABILITY, AND INTERNET-OF-THINGS: APPLYING UTAUT TO DETERMINE THE BEHAVIOURAL INTENTION TO USE IOT

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URBAN AGRICULTURE, SUSTAINABILITY, AND INTERNET-OF-THINGS: APPLYING UTAUT TO DETERMINE THE BEHAVIOURAL INTENTION TO USE IOT

ABSTRACT

The Internet of Things (IoT) is approaching the maturity stage of the technology adoption lifecycle in Sub-Saharan Africa (SSA). By 2025, most of the world's population will be living in urban areas. In South Africa, 66.8% of the population currently resides in urban areas with nearly two-thirds of these households experiencing food insecurity. Urbanisation affects food security in South Africa as people and physical resources migrate from the rural areas where food production typically happens. As such, there is a need to localise Sustainable Development Goals (SDGs) to make them more relevant and context-specific to urban farmers to ensure participation in working towards achieving these goals. Along with localising SDGs, IoT advancements should be considered by urban farmers to not only increase efficiency but to assist in realising the goal of sustainability and sustainable development.

The study aims to adapt the unified theory of unified technology acceptance and use of technology (UTAUT) by introducing sustainability as a construct to determine how it influences urban farmers in Johannesburg and their behavioural intention to adopt IoT. This will contribute to making the theory robust to the determinants that influence individuals' use of IoT, which aligns with recommendations made by the originators of the theory that researchers should identify constructs that serve to edify the prediction of intention and behaviour beyond what has already been studied.

The results produced in the study are based on a pragmatist mixed methods approach. The quantitative approach was an online 25-question survey based on the existing UTAUT questionnaire items with the addition of the sustainability construct. This questionnaire was distributed to Gauteng-based urban farmers with active agribusinesses. The qualitative approach was a case study in the form of a semi-structured interview with three urban farmers in Gauteng with businesses currently in operation. The findings show significant relationships between behavioural intention and effort expectancy, as well as social influence, indicating that urban farmers' behavioural intention to use IoT will be influenced by its ease of use and whether people they deem important, or look to for leadership, believe they should adopt IoT to be more sustainable. There was a non-significant relationship between behavioural intention and sustainability despite urban farmers' belief that sustainability is important, with most being willing to explore any available means of ensuring the sustainability of their farms, including IoT. Based on the interviews and other data, this is due to constraints such as funding, accessibility, the effects of the COVID-19 pandemic on their businesses, the state of the economy and load-shedding.

The study focuses on urban farms operating in cities around the province of Gauteng. This sector can be considered a niche, and this limited our sample size.

Keywords: UTAUT, IoT, sustainability, urban agriculture, mixed methods

DEDICATION

I dedicate this thesis to my first educators (and actual teachers once upon a time), my parents, who instilled a passion for education by prioritising love, ensuring that I never felt like a failure, and making it accessible to me no matter how I performed. I love you.

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1 INTRODUCTION

1.1 BACKGROUND INFORMATION

The Internet of Things (IoT) is approaching the ascension stage of the technology adoption lifecycle in Sub-Saharan Africa (SSA). The development of IoT was initially driven by the needs of corporations that were transforming their processes. Recently, the development and application of IoT has become widespread and is no longer limited to industrialised and large-scale corporations as it is used as a tool for social and economic development across the region and throughout the world (Kshetri, 2022; Madakam, Ramaswamy & Tripathi, 2015). IoT is applied in domains such as smart cities, water and energy management, supply chain management, environmental monitoring, and the health industry (IoT Week, 2017). The GSMA Intelligence Enterprise in Focus 2019 Survey revealed that 52% of businesses around the world believe IoT is transformational to their company and their industries at large, making them central to the improvement of productivity and efficiency in everyday processes (Okeleke & Suardi, 2020). It has played a key role in revamping the agriculture industry with IoT-based applications such as GPS field mapping, sensors in farm equipment that also serve to collect data, machine optimisation tools, self-driving tractors, and drones (Muangprathub et al., 2019; Pillai & Sivathanu, 2020).

By 2025, most of the world's population will live in urban areas (U.N., 2016). In Africa, the urban population was estimated at 400 million in 2010 and is projected to be 1.3 billion by the year 2030 (Cobbinah, Erdiaw-Kwasie & Amoateng, 2015). As of 2021, 67.85% of South Africa’s population lived in urban areas (O’Neill, 2022) with almost two-thirds of such households experiencing food insecurity in 2019 (Stats S.A., 2019). The growth and development of society does not happen in isolation, as advancement can be tied to negative externalities (Nhamo, Togo & Dube, 2021). The concentration of populations in cities presents a set of environmental challenges, including a strain on water supply, higher levels of air pollution and land in cities being predominantly used for everything but agriculture. Rapid urbanisation across cities around the world has also exacerbated the challenge of growing food consumption patterns which directly affect food production and supply (Szabo, 2016). Furthermore, urbanisation affects food security in South Africa as people and physical resources migrate from the rural areas where food production typically happens (Jonah & May, 2020). This increase in urban migration has resulted in an increase in urban agricultural activities (Carrion, Huerta & Barzallo, 2018) and places a greater focus on activities that help achieve SDGs by addressing issues of poverty, hunger, and other needs of urban populations (Nhamo, Togo & Dube, 2021).

The United Nations Conference on Environment and Development (UNCED), dubbed the Rio Earth Summit, was held in 1992 in Rio de Janeiro, Brazil. During this conference, more than 178 nations agreed to implement Agenda 21, a comprehensive plan of action to build global cooperation for sustainable development to improve society and guard the environment (U.N, 2015). In 2000, there was a unanimous decision to adopt the eight Millennium Development Goals to reduce poverty by 2015. This eventually led to the United Nations Conference on Sustainable Development, also known as Rio+20, where leaders reconciled socio-economic development and environmental goals by developing a set of SDGs built on the Millennium Development Goals. In 2015, the General Assembly began the process of establishing a post-2015 development agenda which led to the adoption of the 2030 Agenda for Sustainable Development, where the initial 17 SDGs were adopted. The SDGs aim to guide the global community in addressing sustainable development challenges such as poverty, inequality, climate change, environmental degradation, peace, and justice (U.N., 2015). In this thesis, the SDGs in focus will be No Poverty, Zero Hunger and Sustainable Cities and Communities.

Addressing poverty in the context of the SDGs is clearly stated under SDG1, which sets out to "end poverty in all its forms everywhere" (U.N, 2015). To attain this goal by 2030, there are seven targets that each have indicators. SDG2, called Zero Hunger, sets out to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture". SDG11, or Sustainable Cities and Communities, sets out to "make cities and human settlements inclusive, safe, resilient and sustainable". See table 1 for more details on the targets and their indicators.

Table 1: SDGs and their targets (U.N., 2015)

SDG	TARGET
SDG 1: NO POVERTY	1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day 1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions.

	1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable. 1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance. 1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters. 1.a Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions 1.b Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies to support accelerated investment in poverty eradication actions.
SDG 2: ZERO HUNGER	2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round 2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons 2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment 2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality 2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilisation of genetic resources and associated traditional knowledge, as internationally agreed 2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries 2.b Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round 2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility

SDG 11: SUSTAINABLE CITIES AND COMMUNITIES	11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums 11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons 11.3 By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries 11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage 11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations 11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management 11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities 11.a Support positive economic, social and environmental links between urban, per-urban and rural areas by strengthening national and regional development planning 11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels 11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

Urban agriculture (UA) is defined as the growing of crops and livestock in urban settings with the intention to promote sustainable development (Zezza & Tasciotti, 2010; Chaminuka et al., 2021). Urban farming can serve as a means for urban households to feed themselves and for commercial purposes (Chaminuka & Dube, 2017). Furthermore, urban farming can be at the core of the development of a sustainable urban landscape since it is the link between cities and their environments, presenting an increasingly beneficial tool for sustainable urbanisation (Haysom, 2020). Findings have shown that UA can help reduce poverty and hunger and contribute to the health and well-being of households (Chaminuka et al., 2021). As a result, urban farming is recognised as one of the means to achieve SDGs 1 and 2, with IoT being an appropriate technological innovation for addressing the growing concerns around rapid urbanisation and resource constraints (Pillai & Sivathanu, 2020). Although Innovative Urban Agriculture (IUA) seems to use less water and soil for food production than regular farming (Rothwell et al., 2016), it may require more material and energy than conventional UA to properly function as a complete food production system

(Armanda, Guinee & Tukker, 2019). Considering that industries such as agriculture are restructuring in ways that are environmentally sustainable, it is believed that governments should fund this green technology restructuring to strike a balance between being innovative and sustainable, as technologies can help feed us and save the environment (Addicott, 2020). As such, there is a need to localise SDGs so that they become more relevant and context-specific to urban farmers (Nhamo, Togo & Dube, 2021) to ensure participation in working towards achieving the SDGs. Along with localising SDGs, IoT advancements should be considered by urban farmers to not only increase efficiency but to assist in realising the goal of sustainability and sustainable development. The results of this study can contribute to growing discussions on the use of IoT in the urban agriculture landscape which will contribute to discussions on the role of urban farming and technological innovations on international development policies like the SDGs. Developers can better understand how to develop technologies with urban farmers and the current demands of the urban population in mind. It can also help inform local policies to support urban farmers in realising sustainability in a way that will be profitable for them.

1.2 PURPOSE OF THE STUDY

The following are the aims and objectives of the study:

- To develop the theory of unified technology acceptance and use of technology (UTAUT) by introducing sustainability as a construct to understand its influence on urban farmers in Gauteng and their behavioural intention to adopt IoT.
- To contribute to making UTAUT more robust to the determinants that influence individual and organisational use of IoT, as well as contribute to the theory on UTAUT.
- To contribute towards frameworks and literature on the use of IoT in urban farming in South Africa with emphasis on the importance of sustainability in the use of technological innovations. This will support the researcher's intentions of making recommendations to policymakers and developers on how IoT technologies can be developed to complement SDGs 1, 2 and 11, as discussed above, as well as how these technologies and the SDGs can be localised with urban farmers in mind.
- To understand urban farmers' perceptions and thoughts on IoT technologies, as well as on sustainability and sustainable development goals and whether the two can be linked to one another.

1.3 PROBLEM STATEMENT

Sustainability has many definitions across different industries and sectors. The Merriam-Webster Dictionary defines sustainability as being capable of lasting without interruption or being depleted; “of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged” (Merriam-Webster, n.d). At an organisational level, IoD (2016) defines sustainability as “organisations intentionally interacting with, and responding to, the opportunities and challenges presented by the dynamic system of the economy, society and environment the organisation operates in and the capitals that the organisation uses with the aim of creating value over time”. The United Nations Brundtland Commission in 1987 defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Imperatives, 1987). This definition comprises two important concepts identified by Heeks (2016), namely the concept of needs, which is the essential needs of the world's poor to which priority should be given, and the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs. Haysom (2010) identifies the four key factors that contribute to the advancement or decline of sustainability as shelter, energy, transport, and agriculture.

Developing countries must deal with rapid environmental changes and trends as well as economic crises and health epidemics (Heeks & Ospina, 2016). The recent COVID-19 pandemic has seen countries responding by implementing national lockdowns in an effort to safeguard their populations, though they have conversely resulted in socio-economic crises (Sardar et al., 2020). In the South African context, the national lockdown presented food supply interruptions that resulted in riots that escalated to confrontations with security forces and the military (Stiegler & Bouchard, 2020). These crises further threaten the ability of future generations to meet their needs. A country's ability to withstand, recover from, adapt to, and transform amid change and uncertainty is identified as the solution for developing countries facing these challenges. Heeks (2016) refers to this ability as resilience. The pandemic impacted the global digital landscape and illuminated the value of staying connected for our socio-economic well-being when measures were put in place to prevent the spread of COVID-19. This highlighted the importance of an inclusive digital economy supported by access to fast and reliable internet and digital services (Okelele & Suardi, 2020). South Africa has seen an increased focus on UA with initiatives such as the

Urban Agriculture Initiative (UAI) in partnership with Johannesburg Inner City Project (JICP), Wouldn't It Be Cool (WIBC), SEDA and National School of Arts (NSA), to name a few. UAI's aim was to "create a space where residents can learn the fundamentals of urban agriculture and how to develop their own urban farms in limited spaces, such as rooftops or unused parking lots, thus driving local job creation. The sustainable, fresh produce grown from these farms can then be sold at affordable prices to residents in and around Joburg Inner City". This initiative sought to develop and incubate sustainable farming businesses throughout Johannesburg, which has seen the establishment of hydroponic greenhouses and tunnel farms on rooftops and other unused spaces. Their 2020 impact measurement included the establishment of 12 farms (11 hydroponic farms and one seedling farm), five farms that were previously not operational being operational, 7460kg of produce distributed and 29 980 litres of water saved (UAI, 2020).

Evidence from the literature has shown that urban farmers face a myriad of obstacles in trying to remain profitable while meeting the demands of rapid urbanisation. To achieve the goal of sustainability, urban agriculture needs to be "profitable and economically viable, environmentally sound, socially just and culturally acceptable" (FAO, 2007). When implemented well, urban agriculture plays are crucial role in food provision and food security, with larger quantities being produced while employing broader distribution and marketing channels (Polling, Mergenthaler & Lorleberg, 2016). Experts have envisioned a future that is driven by data, where IoT technology such as sensors, self-driving equipment, drones, GPS imaging and remotely controlled environment farms are leveraged for food production while simultaneously helping farmers cope with the limited supply of resources needed to farm (Jayashankar et al., 2018). In the wake of the rapid growth and urbanisation of the population, there is a growing demand for efficient farm management and optimal usage of inputs through data-driven farming decisions (Lee & Choudhury, 2017). The rising population in urban areas creates a dependency on agriculture to survive and a means to ensure food security (Bisaga, Parikh & Loggia, 2019). Evidence from the literature has also shown that to heed the call for sustainable agri-food systems, a new kind of knowledge system is required that encompasses new innovative solutions and appropriate technologies such as ICT (Hamid & Mohammed, 2018). IoT technology is identified as one of the driving technologies that can play an important role in facilitating sustainable development (Khan et al., 2020) by providing the opportunity to integrate more systems on a platform to optimise operations while making it possible to operate on a mobile device (Pernille et al., 2019). IoT's game-changing capabilities for sustainability lies in its technology and how, at its core, it aims to measure and remotely control things that were previously not connected, making it reach people and objects that prior technology could not (World Economic Forum, 2018).

UA-related issues and activities in capital cities such as Durban are not well documented, according to Bisaga, Parikh & Loggia (2019) in a study aimed at exploring the challenges and opportunities for sustainable UA as a strategy for bettering informal settlements in Durban. Historically understudied, however, is the interaction between IoT and sustainability in the South African urban farming landscape. The study is aware that UA may not be empowering for the poor, particularly innovative UA, due to resource constraints including tools, infrastructure and human capital, as these are prerequisites for being able to access natural resources (Olivier, 2019; Malan, 2015). There is a need to evaluate the influence that sustainability has on South African urban farmers' adoption of IoT with a specific focus on behavioural intention rather than actual use as, among other reasons, urban farmers should form part of the solution to making cities more sustainable. SSA currently accounts for less than 1% of cellular IoT connections globally despite the population proportion total being 14.3% in 2019, with SSA's 2025 number of IoT connections being estimated at a mere 1.19% of the global total (Kshreti, 2022). IoT has been identified as having the potential to help address Sub-Saharan Africa's challenges in key sectors like energy, water, agriculture, transportation, and logistics (Okeleke & Suardi, 2020). In SSA, however, IoT development is at its budding stage and facing several challenges, including limited investment and development of solutions that can address problems in its unique context, unpredictable power supply due to the ongoing power outages and load-shedding faced in South Africa and other regions of SSA, and the low rate with which consumers and enterprises can purchase IoT (Okeleke & Suardi, 2020).

1.4 RESEARCH QUESTIONS

The specific questions that guided this study are:

Main research question: How influential is sustainability to urban farmers' intention to use IoT?

- How do farmers perceive themselves and their farms concerning sustainability and the Sustainable Development Goals?
- What are the factors that influence urban farmers' intention to use IoT?
- How do urban farmers assess their readiness to integrate IoT into their farm management?
- What are urban farmers' thoughts and perceptions on IoT technology amid growing demands by the urban population?
- How were urban farmers' intentions to adopt IoT affected by lockdown?

1.5 ASSUMPTIONS

The following assumptions apply:

1. It is assumed that the urban farmers of the Gauteng region would cooperate in gathering the correct facts and data.
2. It is assumed that all the respondents have the necessary knowledge to make contributions to this study as informants.
3. It is assumed that all information from the different data sources is credible.
4. The urban farmers are investing in technology that will improve their farming practices.
5. Urban farmers in Gauteng understand that sustainability is an important aspect of their farming operations.

1.6 LIMITATIONS

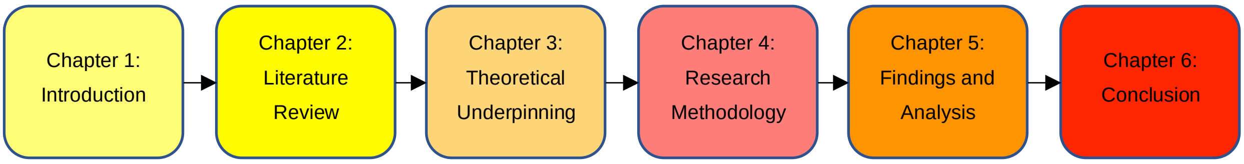
The following limitations apply:

1. This research population will consist of urban farmers in Gauteng.
2. The data collection can only be conducted over a limited period.
3. The farms in question will be limited to hydroponic, aquaponic, and controlled environment farms with greenhouse or tunnel setups.
4. The researcher is aware that her experiences, worldview, culture, and interpretations could influence the study and cause certain biases to be evident in the findings.
5. Respondents may have a low understanding of technical and abstract terms related to 4AR technology and sustainability.

6. As this is a mixed-method study, the researcher will not be making general claims but will be making analytical generalisations.
7. The study focused on behavioural intention, therefore the study opened the sample size up to more people as we acknowledged that IoT is not widely used in SA.
8. Urban farmers are the primary and only sample focused on with a minimum requirement being that they have a structure of sorts, whether it is a greenhouse tunnel or controlled environment setup.
9. The survey questionnaire was open and distributed from 2021 to July 2022 with the initial phase involving the questionnaire being distributed via social media and through word of mouth in the urban agriculture community. The second phase, which took place in July 2022, involved the researcher looking up databases of urban farmers and contacting them either via telephone or email with the purpose of distributing the questionnaire.

1.7 BRIEF CHAPTER OVERVIEW

Figure 1: Research Chapter Outline



The thesis is arranged as follows:

Chapter 1: Introduction

This chapter sets the scene by providing a background and purpose of the study. It presents the research problem, which is then supported by the research questions, assumptions, and limitations.

Chapter 2: Literature Review

In this chapter, the existing literature is reviewed and discussed in the appropriate subcategories.

Chapter 3: Theoretical Underpinning

The theory that underpinned the study is discussed in this chapter. The different adoption theories are also discussed.

Chapter 4: Research Methodology

In this chapter, the research methodology is outlined in detail. This chapter includes the research philosophy, research theory, data collection, and data analysis methods. It also considers matters of research ethics.

Chapter 5: Findings and Analysis

This chapter presents findings and narratives collected during data collection.

Chapter 6: Conclusion

In this chapter, the findings are summarised to answer the research question and align with the objectives. Recommendations are made based on the findings.

2 LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to discuss academic literature on the concepts of IoT, sustainability and urban agriculture. This discussion of past and current literature helps contextualise the evolution of technology to ascertain how IoT came to be but also how IoT intersects with urban farming to achieve sustainability/sustainable development.

2.2 THE INTERNET OF THINGS

2.2.1 The fourth industrial revolution

The diffusion of technology is widely defined as the way a new technology changes over time, resulting in a change in the usage of said products and production processes (Stoneman & Battisti, 2010). Technology diffusion not only changes the products themselves, but it may shape societies and impact the long-term economic growth and development of a country (Lechman, 2015). Lechman further emphasises that to better understand the interdependency between social and economic development and technological advancements, a brief look into the last 200 years of technological revolution is necessary. The development of technology takes time as the process of diffusion is not only made up of the technologies themselves but also the facilitating conditions that make development and diffusion possible (Taalbi, 2019). The fourth industrial revolution (4IR) has been an abstract concept that is no longer simply looming in the background, but a part of our current reality. To contextualise how 4IR came to be, this section will discuss the revolutions that preceded 4IR, namely the first, second and third industrial revolutions (1IR, 2IR and 3IR).

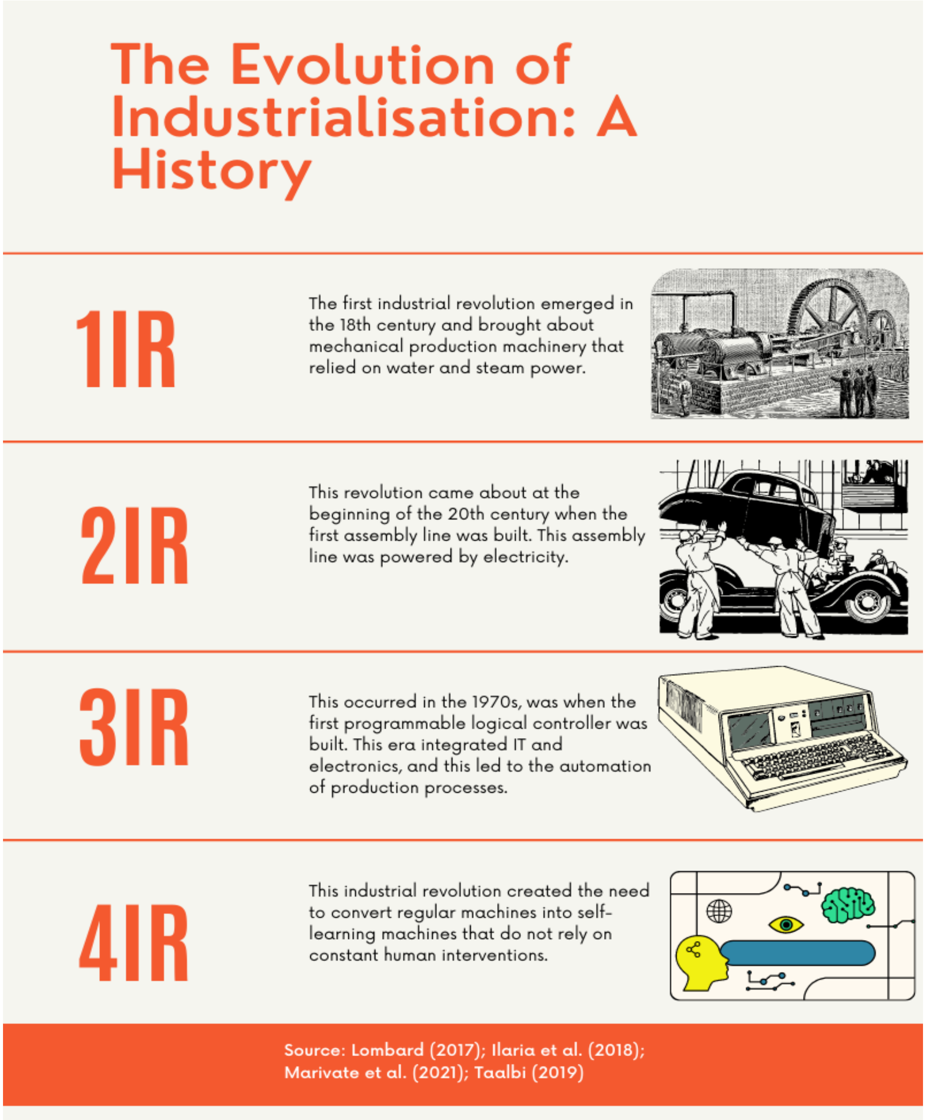
1IR emerged in the 18th century when English blacksmith Thomas Newcomen invented the steam engine, an “atmospheric engine” that burned coal to create motive force that could pump water out of coal mine shafts (Mohajan, 2019). James Watt, who is credited as the pioneer of the industrial revolution, upgraded Thomas Newcomen’s invention by harnessing coal-powered energy and revolutionising how goods were manufactured (Jacob, 1997). This invention made way for mechanical production machinery that allowed for commodities to be manufactured in larger quantities, as well as giving rise to the steam train, triggered by the construction of railroads that served as a means of transportation for the bulk manufactured goods (Lombard, 2017; Ilaria et al. 2018; Marivate, 2021; Mohajan, 2019). In conducting a study of the wages and prices in Britain during the 17th and 18th centuries, Robert Allen (2019) argues that Britain was a high-wage economy. He posits that:

1. Wages in Britain were among the highest relative to other countries in Europe and Asia.
2. The cost of consumer goods was lower than the wages, therefore workers in Britain were able to buy more, indicating a higher standard of living.
3. The price of capital was low relative to the higher wages.
4. The price of energy was lower relative to the wages at the time, which were among the highest in the world.
5. Consumerism and education were on the rise.
6. The economic growth of the period was spurred by the high wages which led to the invention of new technologies that saved Britain from the expansive English labour at the time.

Deane (1979), however, discusses how 1IR came at a time when 18th century Britain was characterised by poverty (although not without economic surplus), stagnation, a dependence on agriculture as its main economic activity, lack of occupational specialisation and most people living on the verge of economic calamity. Granato, Inglehart & Leblang (1996) furthermore stated that pre-industrial societies were characterised by zero to little economic growth which meant that transitioning into a different class came at the expense of another. 1IR began in South Africa in the late nineteenth century with the arrival of the first steam train in 1860, roughly 60 years after it was invented, and the discovery of diamonds in 1867 and gold twenty-one years later which attracted foreign capital investment (Sharife & Bond, 2011; Marwala, 2020). At the time, SA's colonisation by the Dutch and later the British meant that cheap labour was possible and profitable after the discovery of minerals attracted foreign investment and immigration (Marwala, 2020). The Second Industrial Revolution began in the late 19th and early 20th centuries as a consolidation of the 1IR, where the idea of electromagnetism resulted in electricity and the electric motor (Marwala, 2021; Marivate et al., 2021). This enabled mass production, as it was fostered by the invention of electricity and the assembly line, changing the scale and speed of manufacturing (Schwab, 2017). 2IR revolutionised homes and the transport and mass production industries by electrifying them. Other "general purpose technologies", as coined by Taalbi (2019), were the internal combustion engine, automobile, and airplane mass production (Taalbi, 2019).

In the South African context, industrialisation in the 1920s became dependent on the minerals-energy complex (MEC), where state-owned electricity, steel and transport corporations worked together with private mining companies to build an economy strengthened by mining through the use of cheap forms of energy (Sharife & Bond, 2011) and a perpetual supply of cheap black labour under apartheid. The third industrial revolution of the 1970s produced the first programmable logic controller. This era integrated IT and electronics, leading to the automation of production processes (Lombard, 2017; Ilaria et al., 2018). This era consisted of computer technologies, an expansion of the internet and an advancement in mechanical production using robots for mass manufacturing (Marivate et al., 2021). Globally, 3IR brought about digital technologies that are said to have had a positive impact on productivity, efficiency, and globalisation in terms of how the world became connected virtually (Marivate et al., 2021). South Africa, on the other hand, was affected by widespread and unequal access to these technologies despite its promise to eliminate inequality and create jobs (Presidential Commission for 4IR) which further exacerbated inequality and unemployment but also further hampered innovation (Marivate et al., 2021; Marwala, 2020). 4IR is the interaction of digital systems with physical production systems (Patil & Shekhawat, 2019). Some technological advancements that have characterised 4IR include 3D printing, artificial intelligence, robotics, the Internet of Things (IoT), and nanotechnology (Simbanegavi et al.,2018). Schwab (2017) asserts that 4IR technologies will overhaul the way the economy, our communities, and our identities have operated in the past. Figure 2 shows the evolution of the industry over the years (Lombard, 2017; Ilaria et al., 2018)

Figure 2: The Evolution of Industrialisation: A History



Vaidya et al. (2017) emphasise that 4IR aims to construct an open, smart manufacturing platform that allows for real-time data monitoring and tracking of the status of production. Business owners are thus able to coordinate and monitor all business activities in the supply chain because the systems are in constant communication with one another (Lee et al., 2015). Schwab (2017) continues to assert that 4IR will offer unending opportunities for the world to connect to one another and have increased access to information, offering unique and disruptive ways of conducting businesses and services with examples such as Uber, Airbnb, Instagram and WhatsApp. Businesses will enjoy the advantage of enhanced and informed decision-making processes due to how data is collected and analysed to drive intelligent action back into physical systems.

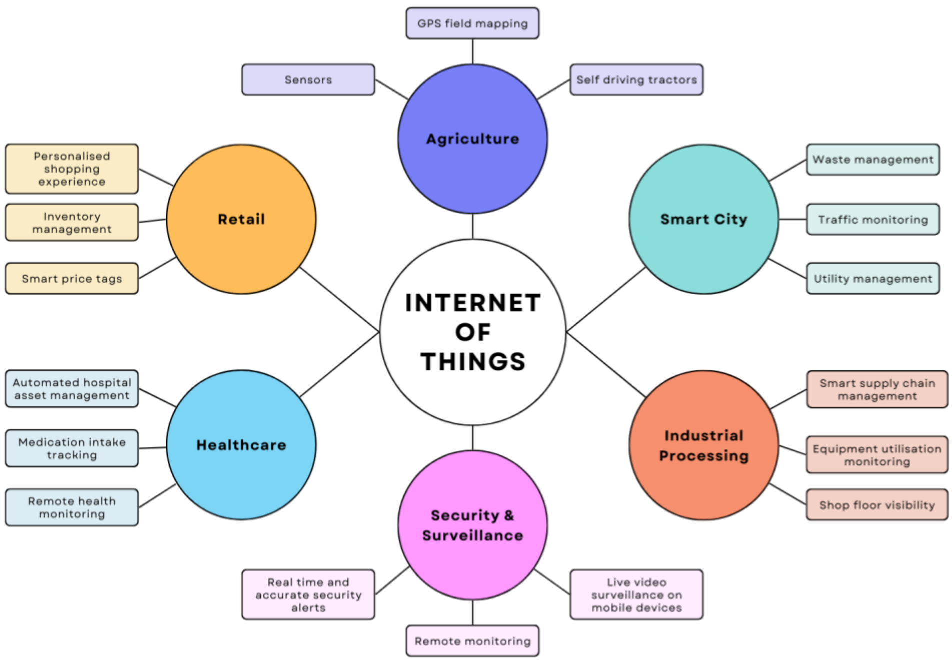
There is ample literature on the diffusion of technology from 1IR to what is now known as 4IR. Literature on 4IR in South Africa is limited due to continuing efforts to catch up on 3IR technology and skills.

2.2.2 The Internet of Things

The world is experiencing a societal and economic transformation due to the emergence of technological innovations (von Kutzchenbach & Daub, 2021) and one such innovation is IoT. IoT is a comprehensive open network characterised by and made up of worldwide data and web-associated things and other intelligent components that have the capacity for auto-organisation, adaptation to environmental changes, and data and resource sharing Madakam et al., 2015). Ashton (2009) coined the term at the beginning of the 2000s, which he described as a system where the Internet is connected to the physical world through sensor technology, which means that objects equipped with identifiers and wireless connection can communicate with other devices through a mobile device (Bucci et al., 2018). The Internet of Things theory does link objects of the physical world with the virtual world, enabling its users to connect at any point in time, anywhere, and for anything at any time (Patel & Patel, 2016). Information and communication technology (ICT) is the communication network that IoT uses to transmit information faster (Bucci et al., 2018), which Rouse (2005) described as any communication object or application in addition to computers, namely cellular phones, television, satellite systems, radio, and network hardware and software. ICT has been recognised over the years for playing a role in development, poverty eradication, and empowering the historically disadvantaged (Maier & Nair-Reicher, 2007). Basu & Ferald (2008) and Miller & Atkinson (2014) argue that IoT and ICT are widely prevalent in our society and are being used in businesses, resulting in higher production and revenue. IoT is an integral component of the future internet that focuses on the automation of processes such that they require less human intervention. During this process of automation, data is collected by sensors and processed through controllers, and then the process is completed by actuators (Madushanki et a. Al., 2019; Arvind et al., 2017).

IoT is considered a technological revolution that represents the future of computing and communications, where information and operational technologies converge. To understand IoT and its role in various economic and societal sectors, some of its key components must be discussed. IoT is applied across industries such as manufacturing, healthcare, smart cities, retail, industrial processing, security and surveillance, and agriculture as shown in figure 3 below. The development of IoT is dependent on dynamic technical innovation in several important fields, from wireless sensors to nanotechnology, and is largely driven by key sectors and large corporations in attempts to meet their needs for foresight and accurate prediction. Through the autonomous manufacturing and computer systems that emerge from IoT, these large corporations can code and track their objects through production and supply chains. Subsequently, they enjoy benefits such as protection from theft, increases in efficiency and accuracy, and reductions of monetary and time costs (Madakam et al., 2015).

Figure 3: Applications of IoT



IoT is characterised by and made up of worldwide data and web-associated things while being an integral component of the internet with a focus on the automation of processes by reducing human intervention. During this process of automation, data is collected by sensors and the data is processed using controllers and the process of automation is completed by actuators (Madushanki et al., 2019; Arvind et al., 2017). Large corporations and their need to benefit from the foresight and predictability that IoT offers have been the driving force behind its development. Through IoT, these large corporations have been able to code and track their objects resulting in benefits like cost reduction and faster processes (Madakam et al., 2015).

Cisco created an IoT reference model that defines the seven identified levels as shown in Figure 4 and summarised in Table 2.

Figure 4: Cisco IoT Reference Model

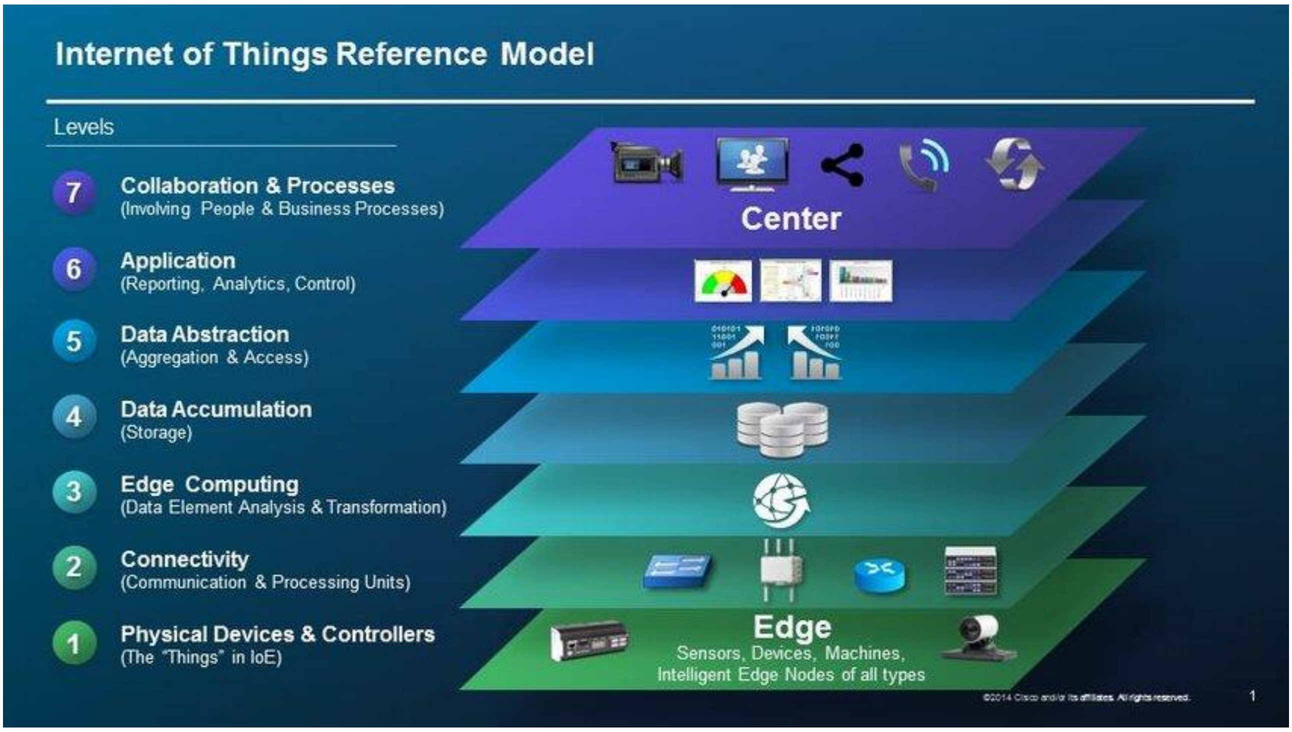


Table 2: Summary of Cisco IoT World Forum Reference Model (Source: Castrignano et al., 2020)

Level	
1. Physical devices and controllers	This level contains the "Things" in IoT. IoT objects are placed on this level and those objects include sensors with their hardware and/or application or the complete device.
2. Connectivity	This level is where the "Things" in IoT are connected to a network. This could either be a wired or wireless network.
3. Edge Computing	In this level, the full mapping of cloud computing services are available to implement the requirements of an IoT platform. This level receives the data packets and outputs

	data understandable to higher levels. It combines network and data-level analytics. Data is analysed, transformed, filtered, cleaned up, aggregated and inspected. Events are also generated on this level.
4. Data Accumulation	This level functions as a data warehouse of sorts where data is stored. This level also serves to convert data-in-motion to data-at-rest.
5. Data Abstraction	In this level, methodologies and technologies are found that create schemas and views of data are created in line with what the application wants.
6. Application	In this level, applications are controlled, and business intelligence and analytics is performed.
7. Collaboration & Processes	In this level, all the processes and people involved collaborate with IoT resources.

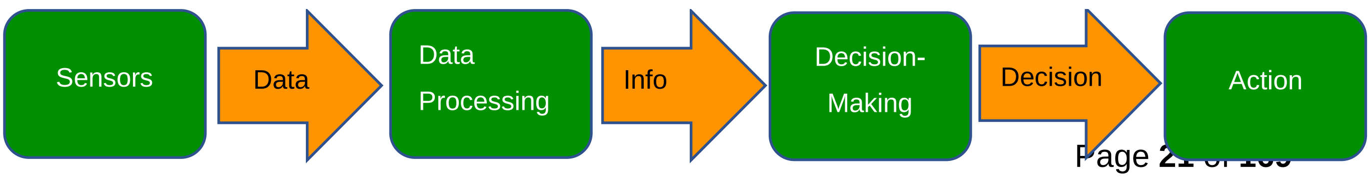
Users of IoT can either buy a system or product that has been developed as needed or with that specific user's industry in mind, or develop their own system through open-source IoT platforms (Castrignano et al., 2020). Platforms such OpenRemote, Arduino, ThingsBoard, Thinger.io, Mainflux and Record Evolution provide decentralised software development models that are free and accessible to everyone and provide users with the opportunity to collaborate with people around the world (Record Evolution, 2021). Whether through open source platforms or ad hoc systems, one of the significant applications of IoT is in agriculture, in areas such as precision farming and genomic prediction, which have the potential to significantly change and improve the sector (Braun et al., 2018).

2.2.3 IoT in agriculture

The term fourth agricultural revolution (4AR) was proposed by Lejon & Frankelius in 2015 in response to the changing industrial sector, which directly influenced the agricultural landscape. 4AR is characterised by the use of smart farming approaches where farmers can accurately select crops and predict their performance. 4AR, and its use of ICT, has been recognised over the years for their role in development, poverty eradication, and empowering the historically disadvantaged (Maier & Nair-Reicher, 2007). The European Union developed The Digital Agenda for Europe in 2010, as a strategy for addressing the challenges posed by ICTs, and to stimulate the digital economy. IoT has been identified as the main issue of the Digital Agenda, which attempts to boost the economies of several European economies by delivering sustainable economic benefits with the potential to contribute to the growth of rural areas and support innovation in European agriculture as one of its objectives.

The agricultural landscape is faced with the great challenge of meeting the food needs of the world as the population grows and climate change progresses while contributing to global economic development (FAO, 2017). Precision Agriculture (PA) has been identified as one of the solutions for these challenges currently facing the world. PA emerged in developed countries about 30 years ago and has been defined through the five R concept, which states that PA is a farming concept of applying the right inputs and the right time and place, in the right amount and in the right manner (Robert et al., 1995; Khosla, 2010). PA has been formally identified by the International Society of Precision Agriculture (ISPA) as "a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines it with other information to guide site, plant and animal specific management decisions to improve resource efficiency, productivity, quality, profitability and sustainability of agricultural productions" (ISPA, 2018). Over the three decades, PA has evolved from having a significant focus on global navigation satellite services and the ability to locate and quantify the spatial variability in soils in its first decade to focusing on the automation of tractors and the development of technologies that would enable the precise management of inputs like crop nutrients in its second decade. The third decade of PA is characterised by location-based agricultural data obtained through sensors to ensure precise management of farms and better decision-making (Castrignano et al., 2020). The advent of IoT has brought sensor technology that produces large amounts of data that are processed and translated into information that fosters better decision-making, as shown in Figure 5 (Castrignano et al., 2020).

Figure 5: Agricultural Internet of Things model (source: Castrignano et al., 2020)



IoT has a significant role in smart farming (Ronaghi & Forouharfar, 2020). It allows farmers to collect multiple types of data, in large volumes, from the crops themselves, the environment, and the supply chain, and facilitates analysis of the data to provide insight that is then used to make timely changes and adaptations to processes, ensuring that crops are successful (Ndzi et al., 2014). Examples include the use of robots such as drones to monitor the vegetative cycle, weather conditions and the state of the soil and autonomously adjust these factors to respond to any changes that may jeopardise the crops (Lopez & Corrales, 2018; Rose & Chilvers, 2018). Boursanis et al. (2022) identified elements of IoT technology such as cloud computing, big data analytics, embedded systems, and communication protocols. Wireless Sensor Networks (WSN) also play an important role in IoT as most applications rely on the wireless transmission of data to provide the necessary information to improve farm management (Boursianis et al., 2022; Nukala et al., 2016). The types of IoT sensors used in agriculture are classified optical, mechanical, electro-mechanical, dielectric soil moisture, airflow and location sensors (Li, Simonian & Chin, 2010). The hydroponic farming system has benefited from the emergence of IoT as farmers are now able to monitor and regulate water use, pH levels, water temperature and flow monitoring, and controlling these on a remote device through apps or LCD panels that are connected to the hydroponic microcontroller (Mehra et al., 2018; Gosavi, 2017; Peuchpanngarm et al., 2016). IoT technology contributes to livestock farming through smart ear tags and collar units that provide real-time descriptions of herd location, animal behaviour, grazing time, walking time, water consumption time, and resting time (Lee and Choudhury, 2017).

Table 3 summarises the elements of IoT, their application in agriculture and the benefits experienced in agriculture (Boursianis et al., 2022; Ronaghi & Forouharfar, 2020). Literature on IoT in agriculture is prevalent as it is being applied on a large scale and constantly developed. The next section considers the challenges of adopting such technologies.

Table 3: Elements of IoT and their applications in agriculture (Source: Boursianis et al., 2022; Ronaghi & Forouharfar, 2020)

Elements of IoT Technology	***Application in Agriculture***	***Benefit in Agriculture***

WSNs: Sensor nodes with radio communication Capabilities	Sensors integrated together to monitor various physical parameters	Easy collection and management of data gathered from sensors
Cloud Computing: A type of Internet-based computing	Provides shared processing resources and data to computers and other devices on demand	Easy collection and management of data gathered from cloud computing services like agriculture fields maps, cloud storage, etc.
Big Data Analytics: The process of studying and analysing large sets of data	Access to many forms of data types like water levels, soil moisture and animal grazing patterns	Uncover patterns, correlations, market trends, customer preferences, and other useful information
Embedded Systems: A computer system that consists of both hardware and software	System performs specific tasks, such as monitoring, controlling and efficient management of various activities	Productions costs can be reduced to a remarkable level which will increase profitability and sustainability
Communication Protocols: The pillar of IoT systems to enable connectivity	These protocols facilitate exchange of data over the network in various data exchange formats	Easy collection and management of tons of data gathered from sensors and cloud computing services, cloud storage, etc.

2.2.4 Challenges of the 4AR

The adoption of technology and the resulting benefits differ according to a society's ability to use the technologies (Lechman, 2015). Factors such as poor education, a lack of skilled individuals, cultural limitations, geography and an unfavourable legal environment are influencing factors (Lechman, 2015). In discussing the literature on the relevance of 4IR in technology, it is clear that some opportunities and benefits can be reaped, though this will not be the case for every role-player in the agricultural landscape. In the EU, where 4AR technologies are being implemented in farming systems, the adoption and use of new farming technologies continue to be below expectations and is unevenly spread, with small and medium-holder farmers accessing these technologies far less than larger corporations (Bucci et al. 2018). Regarding IoT implementation, infrastructural limitations are one of the challenges (Bucci et al. 2018). Ilaria et al. (2019) argued that these challenges are a result of the short-term strategies followed by most SMEs, which make it difficult to foot the costs required to keep up with the constant and rapid development in technology. SMEs typically have short-term strategies and cannot respond to continuous and rapid changes in innovation due to their high costs (Ilaria et al., 2019). One proposed solution to address this challenge is that policymakers create strategies that support SMEs and provide resources to support investment in these new technologies as they emerge (Zambon et al., 2019).

In Africa, Ayentimi & Burgess (2019) argue that readiness for 4AR technologies is context and country-specific. One of the components of 4IR and its emerging technologies is the requirement for highly skilled workers who replace lower-skilled workers (Naude, 2017). Sub-Saharan Africa is faced with a high concentration of low-skilled jobs, mainly in the agricultural sector, as reported in a Statistics South Africa 1st Quarter Labour Force survey which found that women make up only 7000 of the skilled labour force in agriculture, with men making up 40 000 (Ogundari & Awokuse, 2018; Statistics South Africa, 2019). Gunawan & Fakhruddin (2018) found that few women have access to technology, which excludes them from accessing information related to 4AR technology. A report by Deloitte found that among surveyed executives, only a few anticipated that 4IR would affect their organisations significantly, and many believe that they could rely solely on higher education institutions to ensure their employees are prepared and trained for the 4IR (Deloitte, 2017). The lack of skills and efforts to make training available poses a threat to smallholder farmers' participation in the 4AR (Ayentimi & Burgess, 2019), and in the context of the study, this includes urban farmers. Marivate et al. (2021) suggest that this can be tackled by investing in research, development and establishment of training opportunities such as internship programmes in the industrial sector, with universities creating a pipeline of skilled individuals (Marivate et al., 2021).

Inadequate infrastructure in most African countries is also a challenge, as it hinders the use of new technology. Adenle et al. (2018) state that the unavailability of well-constructed and equipped infrastructure has impacted extension services, credit, market data, and even healthcare. This is the case with technological advancements. IoT, as stated above, requires perpetual connectivity to a wireless network for information to be fed to ICTs. With only 26% of the world population of mobile internet users in SSA (in 2019), access to these advancements can be nearly impossible for farmers (Guliwe, 2019; Okeleke & Suardi, 2020). In South Africa, 3IR's promise to reduce income poverty and inequality and create jobs has not come to fruition due to the gap in digital skills (Marivate et al., 2021). These gaps are prevalent from the basic education level, where an estimated 48% of schools have no access to technological devices, to the higher education level with students and lecturers still catching up to 3IR without adequate access to smartphones, the internet and computers (Marivate et al., 2021; Van Wyk, 2012). As such, agricultural technology innovators must respond to these problems by developing inclusive technologies that can be described as responsible innovation (Rose & Chilvers, 2018).

Weersink et al. (2018) note that the inability to collect and interpret data in a way that informs positive decision-making for farmers is also a barrier to realising the potential of 4AR technologies such as big data. There is a need to train urban farmers on how to use these new tools, and policymakers and extension service providers have been encouraged to provide adequate training and information for farmers. Marivate et al. (2021) suggest that government should incentivise industries to invest in 4IR technology projects and invest in and encourage SMEs to advance technologically. The literature regarding the challenges farmers face as a result of the emergence of 4AR technologies is prevalent, although the gap identified is that the literature does not narrate the thoughts and feelings farmers may have regarding their inability to access these technologies or their feelings about the factors hindering them.

2.3 URBAN AGRICULTURE

2.3.1 Urban agriculture defined

The growth of the world's population, urbanisation, climate change and various other factors requires more sustainable ways of farming and feeding the growing urban population.

Solutions to this rising demand require the application of approaches that enable the cultivation, processing and distribution of agricultural produce in and around cities while aligning with global goals of sustainability, reduction of urban poverty, and increasing food security (FAO, 2017). These approaches also need to maintain the environmental integrity of urban landscapes and contribute to the economy. Some of the issues to address in overcoming this challenge include the decreased availability of arable land, food security, the effects of climate change and the inefficiency and unsustainability of current farming practices (Vadlamudi, 2020). Urban Agriculture (UA) is generally defined as farming where food, fuel and other products are produced from crops and livestock raised in and around urban areas, from sustainable, reusable and/or waste products to meet the needs of the local population (Drechsel and Kunze, 2001; Game & Primus, 2015). FAO defines UA as "a permanent and dynamic part of the urban socio-economic and ecological system, using typical urban resources, competing for land and water with other urban functions, influenced by urban policies and plans, and contributing to urban social and economic development" (FAO, 2007). The geographical area where UA takes place differentiates it from rural agriculture.

UA has thus emerged as a sustainable and efficient approach to addressing the increasing environmental, social and economic needs of growing urban populations and making them less vulnerable to global changes brought about by rapid urbanisation (Khatami, Hanaei & Daneshvar, 2020). UA can be divided into two subgroups; urban food gardening and professional UA, which both involve all major role players and are embedded in the culture and social life of the communities in which they are established (Skar et al., 2020). Both subgroups focus on specialisation, niche production, multifunctionality, food chain management, and the quality and embeddedness of food (Wästfelt & Zhang 2016). Professional UA refers to urban farming for commercial purposes with large-scale projects on large areas of land, while urban gardening refers to small-scale projects more associated with subsistence farming (Lohrberg, 2011). Agriculture is regarded as a required contributor to achieving higher levels of sustainability in cities with professional UA playing an increasing role in the agricultural supply chain (Pölling, Mergenthaler & Lorleberg, 2016).

The nature of agriculture is that it is bound to a place in a particular space of time, making land tenure of any kind a prerequisite for farming as plants and animals require space to grow (Skar et al., 2020). Urban farming spaces differ vastly, making its accessibility to a wide range of the urban population and its contribution to urban resilience even more crucial. Table 4 shows the type of urban farming spaces available (Skar et al., 2020; Santo et al., 2016; Simon-Rojo et al., 2015).

Table 4: Types of urban farming spaces (Adapted Skar et al., 2020; Santo et al., 2016; Simon-Rojo et al., 2015)

Typology of the city area	***Urban farming spaces***
Soil-bound spaces	Arable land
	Allotment gardens
	Private backyard gardens
	Squatter gardens
	Community gardens
	Parks
	Neglected land in cities
Mobile and soil-independent systems	Grow boxes and bags
	Mobile containers
Building bound spaces	Rooftops: open rooftops, covered rooftops, flat roof, roof with inclination.
	Façades: open facades, covered facades
	Building extensions: Balconies, window sills
	Indoor space without/with artificial lighting
Water bound spaces	Urban streams
	Ponds and lakes
	Floating islands

Urban agriculture has been identified as being more broad, existing within a dichotomy, and more multifaceted than any other form of agriculture (Zasada, 2011). As a result, despite the number of risks that urban farming systems can potentially pose, farmers can establish new structures that help them overcome barriers and ensure that they develop a new form of urban farming (Sanye-Mengual et al. 2015; Skar et al. 2020; Specht et al. 2015). Common strategies of urban agriculture focus on high-value production, product niches, short supply chains, and alternative food networks (AFNs) (Skar et al., 2020).

In the South African context, UA is linked to issues of food security, social welfare and local economic development, with Cape Town having the longest history of official awareness regarding the planning and development issues relating to UA and the urban poor due to its initiation of a UA policy document (Rogerson, 2003). Despite the awareness and policy support in Cape Town, UA appeared to be less of a significant coping strategy (for food security) for urban populations in comparison to other coping mechanisms such as income from wages and piece jobs, remittances, social welfare grants, stokvels and loans from community members (Battersby, 2011; Frayne et al., 2016; Frayne, McCordic & Shilomboleni, 2014).

2.3.2 Urban farms and their relevance in cities

The challenges plaguing cities are exacerbated by their high and growing dense populations and their limited resources. UA has already shown great potential for improving and solving a wide range of global challenges, including but not limited to food security, job creation, food resilience, and reduction of economic pressure on the poor (Armanda, Jeroen & Tukker, 2019). Food security is a significant global challenge as it impacts economic development, public health, social equity, land use and security – this necessitates that it is addressed efficiently (Saiker et al., 2019). UA is said to increase food security in cities by improving geographical access to food and increasing income to improve economic access to food. UA makes food more accessible by creating and improving local food markets – since food is produced in and around the city, it is consistently available to the local population.

Additionally, UA makes food more economically available as it relies on local labour, which results in job creation and increased income (Malan, 2020). It is assumed to create an opportunity cost where locals can save income by buying cheaper food produced by commercial urban farmers or generating additional income by selling these locally-produced goods. Therefore, even when households are unable to grow their own food, they can still participate in other UA activities that are economically beneficial and ensure their food security (Stewart et al., 2013). In South Africa, the agriculture sector has a higher employment share compared to its GDP contribution (Maluleke, 2021). UA can also help grow the tourism industry through green yards in spaces that attract tourists (Sutic, 2003). An example of this in South Africa is the rooftop farm at Constitutional Hill in Johannesburg, where tourists learn more about South Africa's history while also having the opportunity to see the rooftop greenhouse farms that have been set up. Another example is the farming space around Victoria Yards in inner-city Johannesburg, where its restaurants, local clothing shops and art galleries attract tourists from across the world.

UA also plays a key role in women's empowerment and particularly the economic empowerment of women who are considered responsible for providing meals in most cultures (Armanda et al., 2019). In Kenya, women play a significant role in UA (Mireri, 2002). A study by Mireri (2002) found that 56% of UA farmers were women, and the percentage was even higher for large towns and cities such as Nairobi where 62% of urban farmers were women. Women also tend to be more involved in urban gardening and using UA to produce food for household consumption, even though men tend to make up most of the commercial farming labour force (Korir, Rotich & Mining, 2015). In Botswana, women have been able to increase their social status through the income gained from their chicken farming businesses (Hovorka, 2006).

Environmental issues such as deforestation, depletion of natural resources such as water and soil and pollution are currently a global concern (Khatami, Hanaei & Daneshvar, 2020). Thus UA practices are exceedingly relevant in cities, as they take into account the maintenance and protection of the environment and the communities inhabiting them. UA practices help limit the land, water and other resources required to feed urban populations, as well as manage and recycle the waste produced by cities (Malan, 2020). UA practices can reduce pollution and clean areas that are already polluted (Bon, Parrot & Moustier, 2009). The environmental benefits of urban agriculture can include managing rainfall by absorbing rainfalls or collecting rainwater for irrigation, absorbing a significant percentage of air heat and modulating air, and increasing biodiversity by producing diverse products (Khatami, Hanaei & Daneshvar, 2020; Mazereeuw, 2005).

Olivier (2019) applied the sustainable livelihoods framework to UA in the Cape Flats and found that UA contributed to the livelihood of the community in more ways than just economically. The study found that social capital gains had direct links to economic benefit. Community members shared surplus goods, creating an environment of bartering amongst themselves during times of need. It also found that urban farmers benefitted from UA training and farming as it was a vehicle for educating people about healthy eating. The more the community members learned about the value of the natural resources around them, the more they were inclined to look after those resources and teach those around them. This ties into the benefit of creating recreational spaces that make cities more aesthetically pleasing and liveable and how these spaces can be used as vehicles for education (Khatami, Hanaei & Daneshvar, 2020).

There is a prevalence of papers that either focus on the advantages or the drawbacks of UA, and not many that consider factors other than economic benefits as critical success factors. It is worthwhile to consider urban agriculture holistically.

2.3.4 Issues faced in urban farming

The main hurdles for urban agriculture are land-related constraints, conflicts by improper behaviours of urban dwellers, and economic incentives within cities for activities outside of farming (Skar et. al., 2020). Despite UA's widely endorsed benefit of increasing food security and socio-economic livelihoods, Olivier (2019) found that the results are mixed in the South African context. The study found that urban farmers were limited by their adverse living conditions due to the prevalence of crime. Respondents recalled muggings that resulted in them no longer owning a cellular device that would allow them to communicate with customers as well as instances where urban farmers were limited in their choices of what to grow due to the likelihood of the produce being stolen (Olivier, 2019).

With more and more people living in cities, urban agriculture's role keeps growing in importance at a population and individual level, especially with women who are primary meal providers in low- and middle-income countries (Aberman, Meerman & van de Riet, 2022). In their working paper, Aberman, Meerman & van de Roet (2022) problematised the gender norms that exclude women from participating in income-generating urban farming opportunities that are offered by municipalities and therefore find themselves participating in informal channels such as food vending to reduce food insecurity for themselves and their families. These informal channels should not be overlooked by governments and municipalities as they tend to be the primary income generator for low- and middle-income households (Aberman, Meerman, van de Riet, 2022).

Access to land and land tenure are among the issues faced in urban agriculture as it determines how sustainable and efficient urban farming is (Sucha et al., 2020). Urban farmers rent out parts of their land with short-term leases to allow the owners to quickly revert to the land in case of a good opportunity to earn more profit (Polling, Mergenthaler & Lorleberg, 2016). Most farmers use the land they farm on under short-term arrangements or without any permission or title (FAO, 2012), potentially influencing their market behaviour (Sucha et al., 2020). Sucha and Duskova (2022) found that farmers' identity and ability to create and navigate through the complex web of social relations represents a vital formative force for land tenure and invites policymakers to enhance the agenda to allocate land for urban farming by preserving and fortifying the social networks and relationship.

The success of UA is typically measured in relation to profitability. This narrow view excludes those who may not have access to the resources to enable such profitability (Olivier, 2019). These resources include the level of education of farmers, their access to technology and their social status. Most of the existing literature focuses on and consequently overstates the economic benefits of UA while neglecting the holistic benefits that contribute to the sustainability of urban farmers and their communities.

2.4 SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

2.4.1 Defining Sustainability and Sustainable Development

Sustainability has not only been a challenge in terms of execution but also when it comes to defining it. The concept of sustainability is defined differently in different spheres and by different communities, which trickles over into how it is then applied in those unique contexts, muddying the definition even more (Harrington, 2016). Furthermore, Harrington (2016) emphasises how the goal of sustainability and sustainable development have become essential across science and society at large.

As discussed in Chapter 1, the Merriam-Webster definition of sustainability refers to sustainability as being capable of lasting without interruption or being depleted; “of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged” (Merriam-Webster, n.d). In a 1987 report titled Our Common Future, the United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987). As the UN Sustainability timeline in Figure 6 shows, this was followed by the United Nations Conference on Environment and Development in Rio de Janeiro, also known as the Earth Summit, where Agenda 21 was adopted. A major milestone that followed Earth Summit was the 2000 UN Millennium Summit in New York, where the Millennium Development Goals (MDGs) were set to run from 2000 to 2015. The eight MDGs were as follows:

Goal 1: Eradicate extreme poverty and hunger
Goal 2: Achieve universal primary education
Goal 3: Promote gender equality
Goal 4: Reduce child mortality
Goal 5: Improve maternal health
Goal 6: Combat HIV/AIDS, malaria and other diseases
Goal 7: Ensure environmental sustainability
Goal 7: Develop a global partnership for development

Figure 6: U.N sustainability timeline (Source: U.N., n.d)

2015 was considered an important year in the world of development as these SDGs were adopted. They are intended to be a guide for nations to follow and ensure that sustainable development challenges are addressed and the definition established in 1987 is achieved (Nhamo, Togo & Dube, 2021). The 17 SDGs are:

Goal 1: No Poverty
Goal 2: Zero Hunger
Goal 3: Good health and well-being
Goal 4: Quality education
Goal 5: Gender equality
Goal 6: Clean water and sanitation
Goal 7: Affordable and clean energy

Goal 8: Decent work and economic growth

Goal 9: Industry, infrastructure and innovation

Goal 10: Reduced inequalities

Goal 11: Sustainable cities and communities

Goal 12: Responsible consumption and production

Goal 13: Climate action

Goal 14: Life below water

Goal 15: Life on land

Goal 16: Peace, justice and strong institutions

Goal 17: Partnership for the goals

Von Kutzschenbach & Daub (2021) describe sustainability as a "wicked problem" because, despite the SDGs and their targets as illustrated in Table 1, there are no clear end goals or fixed deliverables to achieve. Table 5 below is a synthesis of the key ideas and definitions given in the literature.

Table 5: Definitions and key ideas around sustainability

Citation	***Definitions and key ideas***
Virtanen, Siragusa & Guttorm (2020)	A community's capacity to create and maintain existence for all by managing natural resources to ensure that members of the community and the environment survive and remain interconnected. Before we can go any further with the definitions, the history of the goal should be explored.
Harrington 2016	"Sustainability can be defined as the capacity to maintain or improve the state and availability of desirable materials or conditions over the long term."
Agyeman & Evans (2004)	Agyeman & Evans (2004) coined the term "just sustainability" to refer to "an equal concern with equity, justice, and ultimately governance on the one hand, and environment on the other."
Samuel (2006)	Samuel (2016) refers to 'the sustainability fix' which is aimed at addressing crises and attempts to fix the material, discursive, and political order of the city along the lines of green capitalism.

Pernille et al (2019)	Sustainability is becoming an integral part of business models in a drive to achieve long-term corporate growth and profitability and to fulfil environmental and social responsibilities, at the same time considering how sustainability services should impact people, profit, and the environment.
American Planning Association (2016)	Sustainable planning is expected to provide the following: • A plan for ensuring equality. • Communities that came about because of implementing the goal of sustainability must be diverse, resilient and self-sufficient . • Implementing sustainability should create a healthy environment for the use of natural resources and improve the socio-economic health of the system.
Culwick Fatti (2021)	The idea of 'just sustainability' is based on the premise that environmental and social challenges are interconnected, where efforts to stay within planetary boundaries are influenced by actions to improve quality of life for the poor and reduce inequality, and vice versa.
Rubin (2021)	Environmental sustainability is about maintaining ecological systems and processes into the future through protection, and by minimising resource consumption and waste production.

Literature exists on sustainability and defining sustainability. There is no way of defining sustainability considering how broad the concept is. In the context of the study, sustainability will be the ability to improve and maintain the status and availability of important materials and ideal conditions over a long period of time (Harrington, 2016). This is the definition that will be applied throughout the literature.

2.4.2 Sustainability in urban farming

The growth of the agricultural sector is essential to achieving development goals in developing countries. Urban agriculture is a way to reduce the vulnerability of urban populations of the world towards global environmental change**.** It is a sustainable and efficient system to respond to the environmental, social and economic needs of the city, which leads to urban sustainability (Khatami, Hanaei & Daneshvar, 2020). Gauteng is a hub for people from across the country, the continent and around the world due to the perception of abounding opportunities and services that may not necessarily be available. This has resulted in housing shortages, lack of access to basic services and living in adverse conditions. Gauteng's conditions magnify the relationship between urban living and sustainable development (Culwick Fatti, 2021). For urban farming to be sustainable it should bring in profit and contribute economically, be environmentally appropriate, inclusive and culturally acceptable (FAO, 2007). The sustainability of UA is known to encompass economic, environmental, and social parameters (Kumari, 2017) and focusing only on maximising profits creates even more of a gap for members of society who do not have profitable UA businesses (Olivier, 2019). A report by the IAASTD (2008) made a global call for the conversion to sustainable agriculture and that the decline in agricultural yields was due to farmers not working in tandem with the environment. They suggest that, if done well, smallholder farming can meet the challenges currently faced from a food production point of view.

Previously, policymakers considered UA as 'hangovers' of rural habits, a marginal activity of little economic importance, or as a health risk and a source of pollution. These biases can threaten a community's ability to benefit from UA when it is not formally recognised from a policy perspective (Haysom, 2010). In Cape Town, an urban agriculture policy was drafted to elevate the importance of UA in the city. The policy articulated that "in order to improve and make urban agriculture more sustainable, it is necessary to give it a formal status. This will be done through the inclusion of urban agriculture as a multifunctional component in municipal land planning and standard development processes concerning land use and environmental protection, i.e. land use plans, zoning schemes and site development plans should provide for urban agricultural activities." (City of Cape Town, 2007). UA is central to FAO's aim to support the transformation of food production to become more efficient, inclusive, resilient and sustainable through the use of green innovations and digitalisation (FAO, Rikolto & RUAF, 2022). Additionally, UA can be linked to SDGs 1, 2, 3, 8, 11, 12, 12 and 16 (FAO, Rikolto & RUAF, 2022). For this study, the focus is on SDGs 1,2 and 11. With the importance of becoming more sustainable in urban dwellings, UA should be encouraged and facilitated and not looked down upon but supported to contribute to sustainable cities (Arif, Janet & Dora, 2019).

Precision agriculture (PA) and sustainability are undoubtedly linked as PA aims to apply input in the right quantities at the rate that is measured and required (Oliver et al., 2018). Controlled environment agriculture (CEA) is considered a form of PA where the growing of plants, fish, insects or livestock takes place inside structures, whether a greenhouse or a building with controlled conditions (CGIAR Research Program on Water, Land and Ecosystems, 2021). It is acknowledged that CEA is not the ultimate fix for food security or a sustainable UA system as it is unlikely that it could replace traditional farming systems but it can complement traditional farming systems in ensuring that fresh produce and niche products are supplied to customers across social statuses (CGIAR Research Program on Water, Land and Ecosystems, 2021). Technology developers are therefore encouraged to develop these innovations with urban farmers from adverse backgrounds in mind, offering better access to systems that can benefit their communities. Policymakers should continue to formalise policies that encourage participation in sustainable UA while making training and resources available to those who are interested. In Johannesburg, programs such as the Johannesburg Inner City Project (JICP), Wouldn't It Be Cool (WIBC), Urban Agriculture Initiative (UAI) and Izinda Zokudla take on a multi-stakeholder engagement method to help achieve food security and drive job creation (Malan, 2015; Malan, 2020).

2.4.3 The relationship between IoT and sustainability

Over the years, technological advancement has had adverse side effects such as carbon emissions contributing to global warming, water pollution, and an increase in deteriorating mental health due to the use of smartphones (Arias, Lasse Lueth & Rastogi, 2018). With the emergence of IoT in many industries, it is being discovered that IoT could have the means to address socio-economic challenges in ways not seen before. Green innovation and digitisation are considered central to the practice of UA and ensuring that it creates better production, better nutrition, a better environment, and a better life (FAO, Rikolto & RUAF, 2022). The concepts of Industry 4.0 and sustainability have emerged recently as technological trends that are influenced by the goal of improving productivity while being sustainable (Bai et al., 2020). In 2017, Geneva hosted the IoT Week where stakeholders such as IoT researchers and industry members expressed their support of working to research, develop, and leverage IoT technology for sustainable development for all (IoTWeek, 2017). Table 6 lists the key activities that were declared regarding SDGs 1, 2 and 11.

Table 6: Key activities from IoT Week 2017's International Declaration on the Internet of Things for Sustainability and their relationship with SDGs 1, 2 & 11 (Source: IoTWeek, 2017)

SDG	***International Declaration on the IoT for Sustainable Development activities***
1: No Poverty	• Promoting the development and adoption of IoT technologies for the benefit of humanity, the environment and sustainable development. • Galvanizing interest in the use of IoT for risk reduction and climate change mitigation. • Identifying and supporting the growing trend of using IoT technologies for education. • Contributing to global research and discussions on IoT for smart and sustainable cities through global initiatives.
2: Zero Hunger	• Promoting the development and adoption of IoT technologies for the benefit of humanity, the environment and sustainable development. • Adopting new and innovative IoT applications to deal with challenges associated with hunger, water supply, and food security. • Embracing the application and use of IoT for biodiversity conservation and ecological monitoring.
11: Sustainable Cities and Communities	• Promoting the development and adoption of IoT technologies for the benefit of humanity, the environment and sustainable development. • Supporting the implementation of the IoT in urban and rural contexts to foster the application of ICTs in providing services to build smarter and more sustainable cities and communities. • Promoting a broad, vibrant and secure ecosystem for IoT, including support for start-ups and incubators. • Encouraging the development and implementation of standards that facilitate interoperability among IoT technologies and solutions in order to pave the way to an open and interoperable IoT ecosystem,

- Adopting new and innovative IoT applications to deal with challenges associated with hunger, water supply, and food security.
- Contributing to global research and discussions on IoT for smart and sustainable cities through global initiatives.
- Promoting international dialogue and cooperation on the IoT for sustainable development.

In terms of SDGs, Bai et al. (2020) define the different ways in which IoT technology relates to each SDG. Table 7 focuses on three SDGs, namely no poverty, zero hunger and sustainable cities and communities, which is what the research focuses on.

Table 7: SDGs and their relationship with IoT adapted from Bai et al., (2020)

SDG	***Definition***	***Relationship with IoT***
(1) No Poverty	Putting an end to poverty in all its forms, everywhere.	Industry 4.0 technologies can bring access to information, education, health care and greater economic opportunity that provide more basic resources and services to the poor people and bring them out of poverty. Industry 4.0 technologies also can alleviate the unexpected economic losses during disasters.
(2) Zero Hunger	End hunger by promoting sustainable agriculture to achieve food security and improved nutrition.	Industry 4.0 technologies can promote sustainable agriculture and fair distribution systems to make

		sure that nobody will ever suffer from hunger again. Industry 4.0 technologies also help to achieve food security and improved nutrition.
(11) Sustainable Cities and Communities	Making cities and human settlements safe, resilient, and sustainable.	Industry 4.0 technologies can help build modern, sustainable, intelligent, public order, safety, and security cities with green and culturally inspiring living conditions.

In Kenya, Safaricom introduced the NB-IoT network in 2017, which has implemented a remote water monitoring system for Kenya's utility EWASCO to enable the utility to identify optimal water flow and match supply with demand. Hospitals and other health facilities were able to track their water consumption during the COVID-19 pandemic, which was considered a critical period (Okeleke & Suardi, 2020). Additionally, Safaricom partnered with M-Gas using M-Pesa to launch a prepaid gas service that allows households to control their usage and replenish the gas once finished (Okeleke & Suardi, 2020). There needs to be a prevalence of literature that examines how IoT has contributed to sustainability and vice versa in South Africa, as a gap has been identified.

2.5 CONCLUSION

In this chapter, relevant literature was discussed to provide context on IoT by discussing how technology evolved over the years, IoT in agriculture, and the challenges faced. Urban agriculture is defined, including its relevance in cities, as well as the issues experienced. Finally, sustainability and sustainable development are defined in relation to UA and IoT. Chapter 3 discusses the theory that underpinned the study.

3 THEORETICAL UNDERPINNING

3.1 INTRODUCTION

The purpose of this chapter is to discuss and compare different adoption models and theories. In this chapter, the author will also discuss how the evolution of technology and its adoption hinges on several factors which directly intersects with the adoption theoretical frameworks. The theories discussed will be TRA, TAM, TPB, DOI and finally, UTAUT.

3.2 THEORY OF REASONED ACTION

The theory of reasoned action (TRA) has been deemed one of the most paramount and game-changing theories of human behaviour due to how other theories have been enriched by having derived or updated TRA. The TRA model has its roots in social psychology where it was initially proposed by Fishbein and Azjen (1975) under two constructs:

- "Attitudes defined as a positive or negative feeling in relation to the achievement of an objective" (Attitude towards behaviour)
- "Subjective norms, which are the very representations of individuals' perception in relation to the ability of reaching those goals with the product" (Subjective norm)

TRA emphasises the importance of intention more than usage and posits that people who buy products do so based on what they feel and not so much because of the actual need. The TRA model that Fishbein & Azjen (1975) proposed states that beliefs, attitudes, and intentions create a casual chain where beliefs lead to attitudes, and attitudes lead to intentions which then lead to behaviours as shown in Figure 10 below.

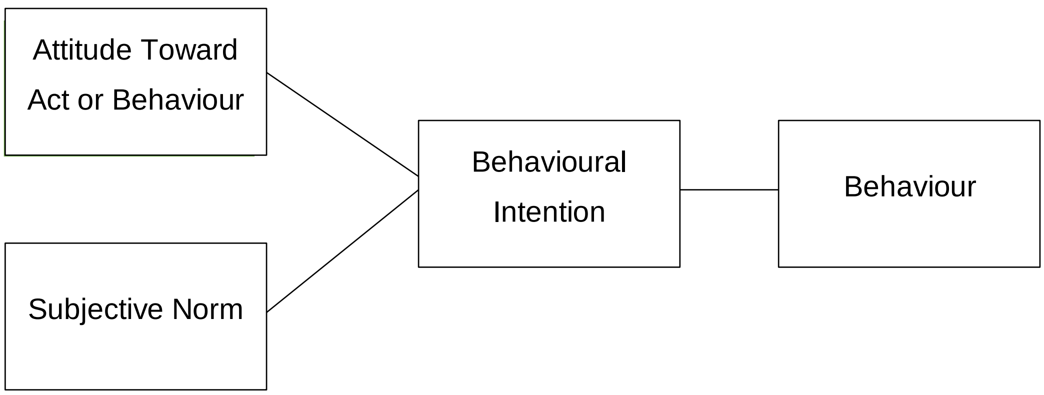


Figure 7: Theory of Reasoned Action. Source Fishbein and Azjen (1975)

The efficacy of the TRA in research was investigated and supported by various studies, including a notable review by Sheppard, Hartwick and Warshaw (1988), who sought to determine the empirical implications observed when studies that used the model failed to meet its parameters. Sheppard, Hartwick and Warshaw (1988) conducted two meta-analyses to assess the degree to which the studies surpassed the intended conditions of the TRA, subsequently falling within one or more of the three limiting conditions. The review found strong evidence of the model's good predictive ability, across studies in a wide range of fields, even when used in research that fell outside the bounds of the intended conditions specified for the model.

As a general and well-researched model with a successful record in predicting and explaining behaviour across various fields, the TRA appears as a good candidate for a model for predicting intention, use, acceptance and rejection of technology in information systems. Early applications of the TRA in information systems include its use in a study which sought to address the ability to predict computer acceptance from intentions and explain user intentions in terms of attitude, subjective norms, perceived use of ease, and perceived usefulness (Davis, Bagozzi & Warshaw,1989). The study compared the prediction ability of TRA and TAM for user acceptance and rejection of computer-based technology and identified that combined use of TRA and TAM produces a more parsimonious causal model with better explanations and predicts user behaviour based on behavioural intention, perceived usefulness and perceived ease of use. The study had three main conclusions: intentions are a reasonable predictor for computer use, perceived usefulness is a significant determinant of intentions to use computers, and perceived ease of use is a significant secondary determinant of intentions to use computers (Davis, Bagozzi & Warshaw, 1989). Critics have, however, suggested that TRA does not clearly differentiate between normative and informational influences on behaviour or measures of attitude and subjective norm are correlated (Warshaw, 1980).

In a study by Hartwick and Barki (1994), TRA was employed as the theoretical framework to help determine the relationship and effects between user participation and the use of systems. The use of TRA resulted in the discovery of two findings related to the determinants of a user's system. The first was that although TRA provided strong predictions of compulsory and voluntary user intentions and behaviours, their attitudes and subjective norm components differed. These components differed in that voluntary users used a system frequently because they believed it was helpful and valuable to them, whereas users who were compelled to use the systems did so because they believed that somebody of higher influence expected them to (Hartwick & Barki, 1994).

Previous studies related to technology adoption and usage have compared the precursors of initial technology usage behaviours and attitudes right after adoption with the precursors of the use of technology by users who are more experienced. This means that the dependent variables were 'intention to use' or 'current level of usage' for inexperienced users and the continued use of these technologies (Rogers, 1983). Karahanna, Straub & Chervany (1999) applied TRA in their study examining the adoption and usage of IT, attitude towards the adoption and continued use of IT and the subjective norm towards the adoption and continued use of IT. The researchers, however, captured the user's attitude towards adopting IT before the users adopted the technology, so the dependent variable was 'intention to adopt' instead of 'intention to use'. The study concluded that social norms alone result in initial adoption, while the sustained usage of technology is influenced only by attitudinal considerations. Therefore, where a user does not have concrete knowledge of the technology, both instrumentality and non-instrumentality beliefs can influence their attitude towards adopting the technology. With post-adoption, when users have concrete knowledge, beliefs around usefulness and the perceptions of image enhancement can influence attitudes.

3.3 THEORY OF PLANNED BEHAVIOUR

The theory of planned behaviour (TPB) is an extension of TRA by Ajzen (1991) which aims to address some of the shortcomings of the TRA (Ajzen, 1991). The TPB expands TRA such that it accounts for constraints perceived by individuals and allows for application in instances where behaviours are under non-volitional control. (Ajzen, 1985). As such, TPB expands the constructs seen as determinants of behaviour and intention by the TRA to include perceived behavioural control, making the theory's focus the user's behaviour. In

TPB, perceived behavioural control, which is defined as an individual's perception of the ease or difficulty of performing a behaviour, is viewed as a spectrum that ranges from behaviours that are easy to perform, to behaviours that require substantial expansion of effort and resources. Figure 11 is an illustration of the model.

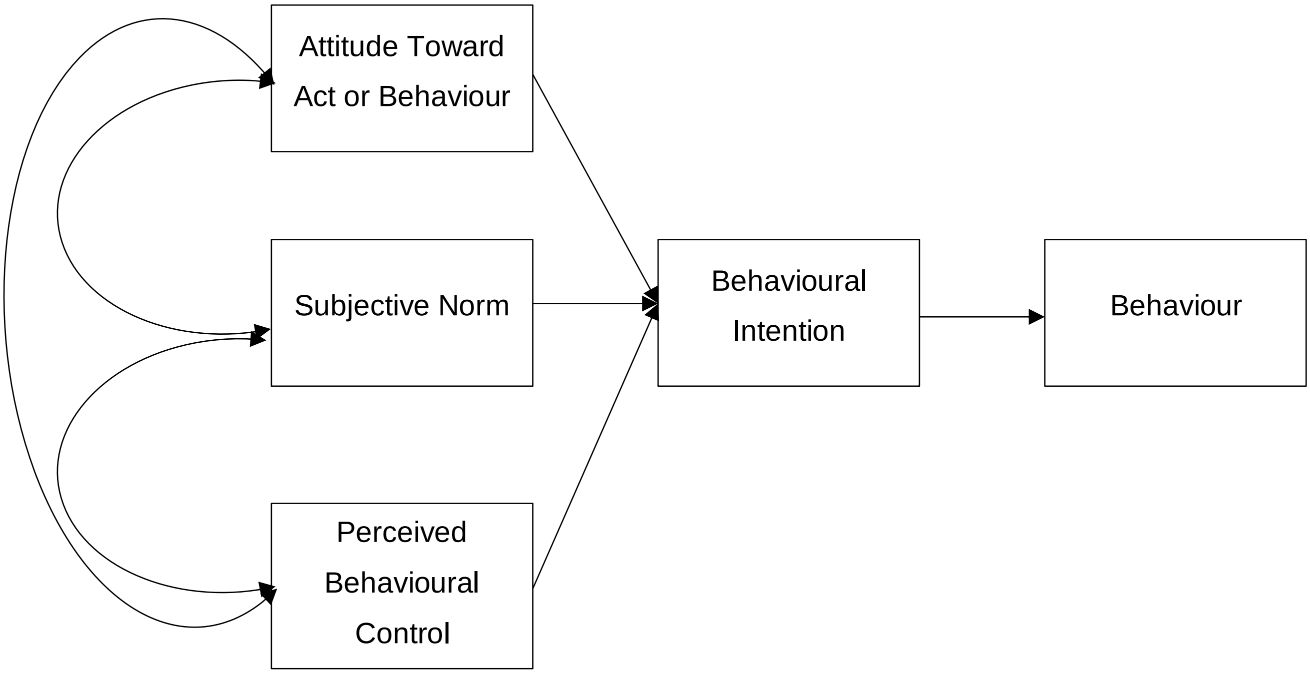


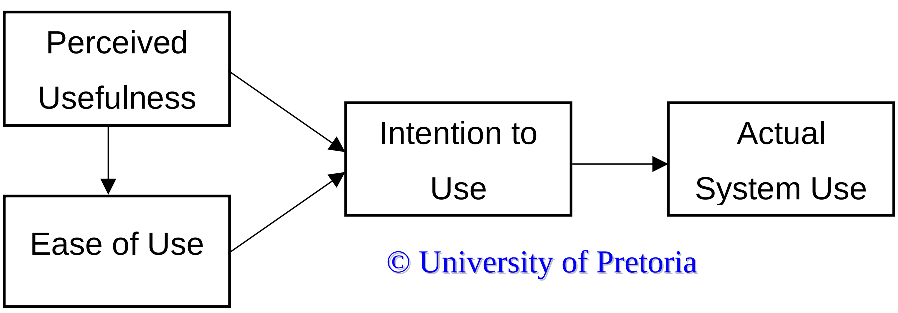
Figure 8: Theory of Planned Behaviour Diagram Source: Ajzen (1991)

Like the theory it was derived from, the TPB is a general model that can and has been applied across a wide range of fields to predict behaviour and explain intentions across various behaviour categories. Many reviews have assessed the effectiveness of TPB in research across a range of fields, with most supporting TPB and finding it to have good predictive ability for behaviour and intention. Notable reviews include Ajzen (1991) and Godin & Kok (1996). A more recent meta-analysis by Armitage & Conner (2001) found that previous reviews had analytic weaknesses such as failure to report reliability statistics, treatment of all studies and data as equivalent, and analysing data from the same participants in the same study more than once. The review by Armitage & Conner (2001) tested the efficacy of TPB while accounting for factors neglected in previous reviews, such as predictive validity relative to observed and self-reported behaviour. The findings of the meta-analysis corroborated previous findings confirming the efficacy of TPB for predicting behaviour and intentions across fields (Armitage & Conner, 2001).

3.4 TECHNOLOGY ACCEPTANCE MODEL (TAM)

The technology acceptance model (TAM) is an adaptation of TRA proposed by Davis (1986). It is a theory for modelling user acceptance of information systems which asserts that the primary determinant of an individual's use of a system is their attitude towards that system (Davis, 1986). In TAM, attitude towards use is the function of two beliefs, perceived usefulness and perceived ease of use, which are influenced by the system's design features, as these seek to enhance usability. TAM adopts the definitions of perceived usefulness and perceived ease of use that are used in TRA and TPB, i.e. perceived usefulness as "the degree to which an individual believes that using a particular system would enhance his or her job performance" and perceived ease of use as "the degree to which the user expects the system to be free of effort." (Davis, Bagozzi & Warshaw, 1989). The model, originated by Davis (1986), hypothesises that a user's intention to use a system is determined by perceived usefulness and ease of use, with the 'intention to use' being the moderator of actual system use. Davis (1986) initially developed TAM as an adaptation of the theory of reasoned action (TRA) with the objective that it should, firstly, improve the way we understand the process of user acceptance, which will give us new theoretical insights into how successful Information Systems are designed and implemented. The second objective is that the theory should provide us with a methodology for developers to test a proposed IS before implementing it.

Figure 9: TAM Model



While TAM uses some elements of TRA, it diverges the Fishbein model in a few ways, such as completely excluding subjective norms in its view of behaviour intention, to account for technology-specific conditions (Davis, 1986), as seen in Figure 12. Another significant difference between the two is that in TRA, salient beliefs are elicited anew for each new instance, therefore, considering the specific context, while in TAM, perceived usefulness and perceived ease are postulated a priori as general determinants of acceptance to generalise computer systems and user populations (Ajzen & Fishbein, 1980).

3.5 UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY

The unified theory of acceptance and use of technology (UTAUT) intends to explain the objective behind why users use a certain IS, as well as the usage behaviour (Venkatesh et al., 2003). Venkatesh et al. (2003) formulated UTAUT by reviewing eight prominent models, comparing their similarities and differences and conducting an analytical comparison of the models using data from four different businesses to produce a baseline assessment of the relative explanatory power of each model against which UTAUT can be compared. The eight theories were the theory of reasoned action (TRA), technology acceptance model (TAM), motivational model (MM), theory of planned behaviour (TPB), combined TAM and TPB (C-TAM-TPB), model of PC utilisation (MPCU), innovation diffusion theory (IDT) and social cognitive theory (SCT). Of the eight theories reviewed and consolidated, performance expectancy, effort expectancy, social influence, and facilitating conditions were identified as four key constructs that act as direct determinants of usage intention and behaviour. Gender, age, experience, and voluntariness of use are posited to moderate the impact of these constructs on usage intention and behaviour.

Venkatesh et al. (2003) conducted research by reviewing the user acceptance literature and discussing and comparing the eight models and their extensions over the years, then unifying them to create one model. They then tested the model by studying data from four organisations over a six-month period where they aimed to determine user intentions to use new technologies (Venkatesh et al., 2003). This validation of the UTAUT model identified four key areas, which are performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC), as well as four moderators, these being age, gender, experience and voluntariness, to contribute to ways in which organisations can predict behavioural intention to use a new technology and actual use of the technologies as pictured below in Figure 13. The test revealed that PE, EE and SI were influencers of Behavioural Intention (BI), whereas BI and FC determined the Actual Use of the technologies (Venkatesh et al., 2003). UTAUT is considered a theory that currently provides a more BI-centric understanding of IT use (Venkatesh et al., 2003).

Table 8: UTAUT Key Constructs and their moderators. Adapted from Venkatesh et al., (2003), Maruping et al. (2017)

Key Constructs	***Definition***	***Construct***	***Moderators/Determinants***
Performance Expectancy	The extent to which an individual believes that using the IS will help them better perform their job. PE has the strongest relationship to behavioural intention and is significant in non-compulsory and compulsory settings.	Perceived usefulness Extrinsic Motivation Job-fit Relative Advantage Outcome Expectations	Gender Age
Effort Expectancy	The level of ease linked to the use of the system.	Perceived ease of use Complexity Ease of Use	Gender Age Experience
Social Influence	Social influence has been defined as the level to which an individual believes that	Subjective Norm Social Factors Image	Gender Age Voluntariness Experience

	people who are vital to them think that they should use the new system. This construct is significant in settings when use is mandatory. Where it is compulsory, the social influence seems to be substantial in the early stages of individual experience with the technology, with its role eroding over time and eventually becoming insignificant with sustained usage.		
Facilitating Conditions	How much an individual believes that an organisational and technical support system exists to support using the IS Structures being in place that will remove barriers to use. This construct does not have a significant influence on behavioural intention.	Perceived behavioural control Facilitating conditions Compatibility	Age Experience

Performance Expectancy

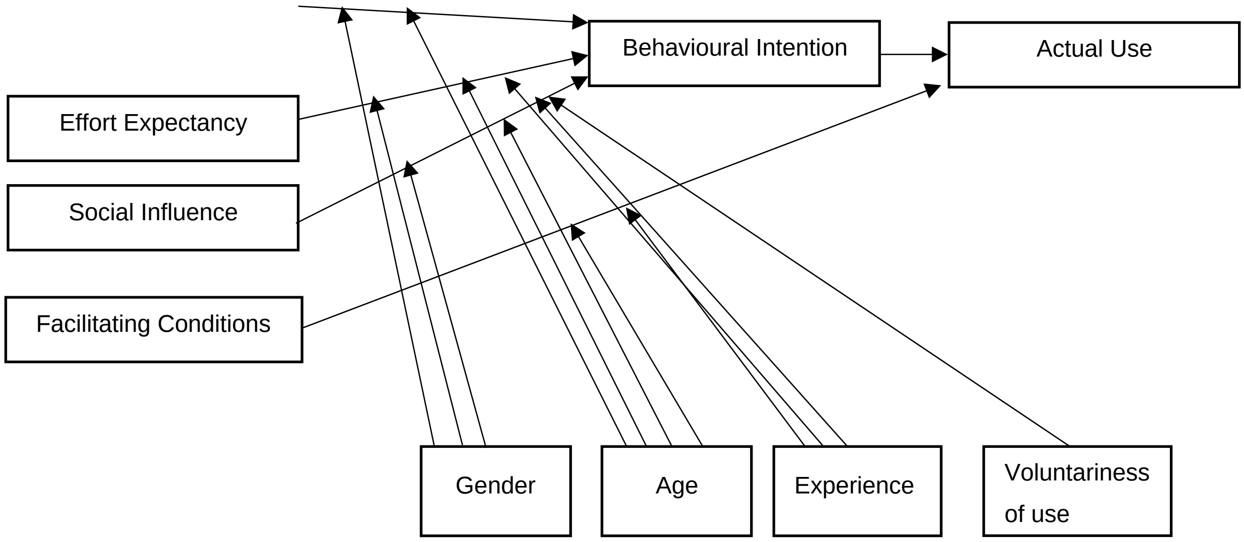


Figure 10: UTAUT Model by Venkatesh et al. (2003)

In their assessment and comparison of the eight models that were unified to create UTAUT, Venkatesh et al. (2003) highlighted the following limitations illustrated in Table 9.

Table 9: Limitations of unified models

Limitation	***Description***
Type of technology	Venkatesh et al. (2003) noted that the type of information technologies that were observed in the other models were simple and focused on the individual instead of more "complex" and "sophisticated" technology for the more organisational context.
Respondents	Venkatesh et al. (2003) noted that for the other models, the respondents were students and they overcame these limitations by looking at respondents in settings other than academic ones.
Timing	Venkatesh observed that the other models tested respondents' acceptance or rejection of technologies instead of the decision-making process as it is happening. UTAUT observed adoption through the different adoption stages.
Nature of measurement	It was noted by Venkatesh et al. (2003) that the other models tracked different samples at a single point in time whereas

	UTAUT was more longitudinal, samples would change and different stages of technology acceptance and adoption were studied.
Compulsory vs non-compulsory settings	The other models besides TRA and TAM2 studied respondents in non-compulsory settings whereas UTAUT examines respondents in both compulsory and non-compulsory settings.

Studies in numerous fields have applied UTAUT to determine behavioural intention to adopt or actual use. Table 10 is a synthesis of some studies that have applied UTAUT, whether as it was or by adding or removing constructs. This synthesis serves to further justify the researcher's decision to contribute to the existing research that aims to make the theory more robust by applying it in different settings. Based on location, the researcher did not find many studies that applied UTAUT in the agricultural field in South Africa.

Table 10: A synthesis of studies that applied UTAUT

Study	***System***	***Field***
(Pynoo et al., 2011)	Digital Learn Environment	Education
(Or et al., 2011)	Web-based interactive self-management technology	Healthcare
(Ronaghi & Forouharfar, 2020)	IoT	Agriculture
(Wu, 2012)	Information technology services	Agriculture
(Dulle & Minishi-Majanja, 2011)	Open access	Higher education
(An, Han & Tong, 2016)	Online shopping	Agriculture
(He, Zhang & Zeng, 2020)	Energy utilisation of crop straw	Straw management
(Chang, Chiu & Lai, 2020)	Cloud-based e-learning	Agriculture
(Mzomwe et al., 2021)	Mobile phone	Agriculture
(Wei et al., 2021)	Mobile payment system	E-commerce
(Rübcke von Veltheim, Theuvsen & Heise, 2021)	Autonomous field robots	Agriculture
(Molina-Maturano et al., 2021)	Agricultural apps	Agriculture

(Chen et al., 2021)	E-commerce platform	E-commerce
(Eweoya et al., 2021)	E-agriculture	Agriculture
(Awotunde et al., (2021)	Social media	Higher education
(Michels, Bonke & Musshoff, 2020)	Smartphone apps	Agriculture
(Han et al., 2021)	Social media	Agriculture
(Garfield, 2005)	Tablet PCs	Human Resources
(Rusere et al., 2020)	Ecological intensification	Agriculture

Over time, behavioural intention (BI) has become the predominant determinant of IT usage on an individual level in IT adoption and use models and studies (Maruping et al., 2017). BI has been defined as an individual's personally thought-out behavioural commitment to perform a desired behaviour (Maruping et al., 2017) which can be determined by performance expectancy, effort expectancy, and social influence (Han et al., 2021). Since IoT systems are not prevalent in the Gauteng UA market, this study focuses on behavioural intention to use IoT instead of actual use behaviour (the modified UTAUT model in Chapter 4 illustrates this). This is validated by how UTAUT is considered a theory that provides a behavioural intention-centric understanding of the use of technologies and in this case, IoT (Venkatesh et al., 2003).

The UTAUT model is used in information systems to assist management and decision-makers in better understanding the constructs influencing users' behaviour where acceptance or behavioural intention to accept are involved while also guiding decision-making. The researcher adopted UTAUT as the suitable research model to understand the influences so that the outcomes of the research can be implemented by urban farmers, policymakers, IoT system developers and other decision-makers regarding IoT adoption in the urban farming landscape. Research by Venkatesh et al. (2003) has shown that UTAUT explains up to 70% of the variance in behavioural intention, which is the predominant indicator of acceptance. It makes the UTAUT model even more suitable, as the research aims to measure the constructs (particularly sustainability) and their influence on behavioural intention. The modified version of the UTAUT model will retain all but two of the main constructs of the original model and introduces a new construct, namely "sustainability". This is in line with the future research recommendations of Venkatesh et al.

(2003) that researchers should identify constructs that can add to the prediction of intention and behaviour over and above what has already been studied and understood. This recommendation influenced the researcher's choice of research theory, as it felt like a real contribution would be made, not only to IS, but specifically to technology adoption studies in agriculture. The modified UTAUT model is discussed in more detail in Chapter 4.

3.6 CONCLUSION

In this chapter, the theories of reasoned action, planned behaviour, the technology acceptance model, and unified technology acceptance and use of technology were discussed. UTAUT was discussed in greater detail as it is behavioural intention-centric, making it suitable as a holistic approach to the study of behavioural intention to adopt IoT. One of the limitations of the study, the actual use of IoT, is not considered due to the limited number of urban farmers that have adopted IoT.

4 METHODOLOGY

4.1 INTRODUCTION

The chapter begins by justifying the research philosophy and theory undertaken in the research, namely pragmatism and UTAUT. It then goes into the chosen research design and why it is being used and describes the data collection and analysis methods. The reliability and validity of the data collection methods are analysed and then ethical considerations are discussed.

4.2 RESEARCH PHILOSOPHY AND THEORY

4.2.1 Research philosophy

The research philosophy, or paradigm, is described as a researcher's assumptions about parts of the world which influence how knowledge is studied and interpreted (Oates, 2006; Mackenzie & Knipe, 2006). These philosophies or worldviews, as described by Creswell & Creswell (2017), vary depending on discipline orientations, the inclinations of students' advisors or mentors, and past research experience. The choice of paradigm sets the intent, motivation, and expectations for the research and whether the researcher will apply a qualitative, quantitative, or mixed-method research approach (Creswell & Creswell, 2017; Mackenzie & Knipe 2006). In the information systems field, there are three main research philosophies namely, interpretivism, positivism and pragmatism. In this section, the different paradigms will be discussed from an ontological, epistemological, and methodological point of view. Ontology refers to the assumptions and beliefs we hold about reality and, more specifically, the reality that is the object of the research (Biesta, 2010). Epistemology poses questions such as: How does the researcher interact with what is known? How did the researcher come to know what they now know? What is knowledge? (Krauss, 2015). Methodology refers to the research methods that are employed.

Early academics defined pragmatism as a means to "relieve and benefit the condition of man – to make mankind happier by enabling them to cope more successfully with the physical environment and with each other" (Rorty, 1991). The purpose of pragmatic research in practice, according to Cronen (2001), is to improve the human condition by adaptation and accommodation in the world. The pragmatic researcher is interested in what is potentially yet to be and, therefore, aims to create a world that has not yet been realised

(Goldkuhl, 2012). Blumer (1969) believes that to be understood, a society must be observed and grasped in terms of the action that characterises the society, while Braa and Vidgen (1999) refer to the belief that human action and knowledge are inseparable, and the researcher must intervene to achieve change. Goldkuhl (2012) described it as 'taking part in the world' instead of observing. This ties in with the epistemology of pragmatism because to produce practical knowledge that is applicable to the real world, the researcher must then take on the role of an intermediary (Dewey, 1998). Valid knowledge, to a pragmatic researcher, is meant to make a purposeful difference when put into practice. A pragmatic researcher centres the research question to apply different approaches to understand what and how the research problem will be addressed (Creswell & Creswell, 2017). The researcher typically uses the "what" and "how" format to formulate a research question. This format enables the researcher to answer the research question practically and to construct a solution that translates into action. Pragmatic researchers typically use mixed methods, but Goldkuhl (2012) suggests that action research and design research are the methods pragmatic researchers should employ because they are concerned with action and solutions, as they must act as a participant instead of an observer. The purpose of mixing methodologies is to adopt the most practical approach to addressing the research question at hand (Creswell & Creswell, 2017).

Table 11: Summary of various research philosophies

	Interpretivism	***Positivism***	***Pragmatism***
Ontology	There is a belief that the social world is produced and reinforced by humans through their action and interaction (Orlikowski & Baroudi, 1991)	Reality exists objectively and separately from human experiences and social factors (Chen & Hirschheim, 2004). The researcher and the phenomena they are studying are separate from one	Pragmatists do not see the world as an absolute unity (Creswell & Creswell, 2017)

		another (Weber, 2004)	
Epistemology	Aware that in their attempt at making sense of the world, the acts of sense-making exist within the framework of their lived experiences and the goals they have for their work (Weber, 2004)	The researcher is neutral and objective and acts as an impartial party who can discover truths about the world independent from their personal values and beliefs (Oates, 2006)	Truth is what works at the time. It is not based in a duality between reality independent of the mind or within the mind (Creswell & Creswell, 2017)
Methodology	Qualitative research methods	Quantitative research methods	Mixed methods research

The paradigm best suited for this research is the pragmatism philosophy. From an ontological perspective, pragmatism is suitable because pragmatists believe that the truth is observable as well as subjective, which allows the researcher to use more than one form of data as the aim is to provide the best understanding of a research problem (Creswell & Creswell, 2017). The worldview of a pragmatic researcher is that the world is not an absolute unity which opens the opportunity to look at multiple approaches for collecting and analysing data instead of one type of method (Creswell & Creswell, 2017). This makes the pragmatic philosophy suitable as the researcher has determined that to best understand the influence of sustainability on urban farmers' behavioural intention to use IoT, more than one approach must be applied. The advantages of the mono-method research choices will help to gain a deeper understanding of the social world and aid in theory building and contributing to the robustness of theories (Onweugbuzie & Leech, 2005; Wu, 2012). The distinctions between positivism and interpretivism are not clear-cut from a research method perspective, as some researchers might collect large amounts of data to support certain inferences (Weber, 2004), though numeric or scientific data alone will not assist in addressing the research questions. Pragmatism is a practical philosophy because pragmatists believe there are many ways to interpret the truth, which is suitable in this study as 'truth' can be understood from several dimensions – such as the constructs that the research theory explained below provides – and analysed and interpreted based on the respondents' views. To determine the full extent to which urban farmers understand sustainability and their role in it, the researcher had to engage them on what works and use diverse methods of inquiry to answer the research question as best as possible. Interpretivism and positivism were rejected primarily due to prescription of mono-method research design.

4.3 RESEARCH DESIGN

4.3.1 Mixed methods design

This study aims to understand the influence of sustainability on urban farmers' behavioural intention to use IoT. An explanatory sequential mixed-methods design was used, and it involved collecting qualitative data and then quantitative data. In this phase, the plan was to explore and unpack urban farmers' perceptions and thoughts on sustainability, their role and contributions to creating a more sustainable society, the influence of sustainability considerations on their behavioural intention to use IoT, their thoughts and perceptions on IoT technology and how the COVID pandemic may have affected their intention to use IoT. The quantitative phase of the study involved a survey questionnaire data was collected from urban farmers in the Johannesburg area to measure UTAUT and assess the significance of the constructs to behavioural intention, particularly the new construct sustainability.

Mixed methods research design is an approach that uses both quantitative and qualitative research methods in one research study. The merging of research methods results in rich insights into several phenomena of interest that would not necessarily be fully understood by only using a quantitative and qualitative method (Venkatesh, Brown & Bala, 2013). Diversity in research methods is considered a particular strength of IS research (Venkatesh, Brown & Bala, 2013) with Mingers (2001) advocating for diversity in the IS discipline by suggesting that a pluralist methodology approach would provide richer and more reliable results. A definition of mixed methods that aligns with the researcher's aim, is that of an inquiry which looks at the social world and actively invites participation through dialogue regarding the multiple ways of seeing and hearing, and making sense of the social world and its views on what is important and to be valued and cherished (Greene, 2007). The mixed-method approach has the potential to facilitate theory building (Wu, 2012) which aligns with the researcher aiming to enrich the UTAUT model by adding sustainability as a construct. There are three major types of mixed-method designs as defined by Creswell and Clark (2017): triangulation, embedded, explanatory and exploratory (as defined in Table 12). The researcher applied an explanatory mixed methods design by using qualitative data to elaborate on the quantitative data. For example, the survey results may show that social influence is key to the behavioural intention but the interview gives the idea of who influences them outside of the prescribed definition provided in the theory.

Table 12: Types of mixed methods designs (Source: Creswell & Clark (2017))

Type of mixed methods design	***Definition***
Triangulation	Merges qualitative and quantitative data to understand a research problem.
Embedded	Uses either qualitative or quantitative data to answer a research question within a largely quantitative or qualitative study.
Explanatory	Uses qualitative data to help explain or elaborate quantitative results.
Exploratory	Collects quantitative data to test and explain a relationship found in qualitative data.

The researcher's intention for applying a mixed method design is tied to how the differing conclusions from the quantitative and qualitative methods may result in the re-examination of the conceptual framework and the assumptions underlying these methods (Venkatesh et al., 2013). Venkatesh et al. (2013) deem it important for researchers to understand when it is appropriate to apply mixed methods, which can be for the following reasons. Firstly, explicitly describing the reason for applying mixed methods research can help the readers understand the goals and outcomes of such a research paper. Understanding the purpose will also help researchers make informed decisions about the design and analysis of the research. Table 13 lists and describes the purposes of mixed methods research as adapted from Venkatesh (2013). The researcher chose this design to gain complementary views about urban farmers, their perceptions of IoT, and the influence sustainability has on their intention to use the technology. The researcher gained complementary views by ensuring that the interview questions also touched on what was asked in the survey questionnaire to support the results from the survey questionnaire.

Table 13: Purposes of mixed methods research adapted from Venkatesh (2013)

Purposes	***Description***
Complementarity	Mixed methods are used to gain complementary views about the same phenomena or relationships.
Completeness	Mixed methods designs are used to sketch a complete picture of a phenomenon.
Developmental	Questions for one strand emerge from the inferences of a previous one (sequential mixed methods), or one strand provides hypotheses to be tested in the next.
Expansion	Mixed methods are used to explain or expand upon the understanding obtained in a previous strand of a study.
Corroboration/Confirmation	Mixed methods are used to assess the credibility of inferences obtained from one approach (strand).
Compensation	Mixed methods enable compensating for the weaknesses of one approach by using the other.
Diversity	Mixed methods are used with the hope of obtaining divergent views of the same phenomenon.

Survey research design is defined as the systematic collection of information from individuals to provide a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population (Creswell & Creswell, 2017; Stockemer, 2019). It includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection, with the intent of generalising from a sample to a population (Babbie, 1990). The idea of a survey is that you will obtain the same kinds of data from a large group of people (or events) in a standardised and systematic way. You then look for patterns in the data that you can generalize to a larger population than the group you targeted (Oates, 2006). Surveys can bring breadth to a study by helping researchers gather data about different aspects of a phenomenon from several participants (Venkatesh et al., 2013) by asking the participants one or several questions about attitudes, perceptions, or behaviours (Stockemer, 2019). Considering that UTAUT is estimated through the standardised items that Venkatesh et al. (2003) developed, the survey design is the suitable research design for this study. These items are defined in the next section.

Williams et al. (2015) conducted a systematic review of research articles that applied UTAUT as their research theory and their analysis of 174 existing articles found that survey methodology was the most explored methodology.

Interpretive case studies were developed in response to increasing social issues related to the use of information systems being identified over time, as their focus was mainly on human interpretations and meaning (Myers & Avison, 2002). The qualitative nature of the case study research plays a crucial role in the IS academic landscape (Merriam & Tisdell, 2016) and yields rich data through interactions with the research subject in its natural setting. It can focus on describing processes, individual or group behaviour in its overall environment, or the sequence of events in which the behaviour occurs (Stake, 2005). Merriam & Tisdell (2016) further state that the value of qualitative case studies lies in how it makes it possible to view the examined problem through the research participant's lived experiences and understanding in their natural setting.

Some of the characteristics of case studies listed by Benbasat, Goldstein and Mead (1987) are that:

- The study is examined in its natural setting.
- More than one data collection source is used which makes the research more credible and adds to the richness of the data.
- To complete the research study in the given time, one or at most a few respondents can be examined.

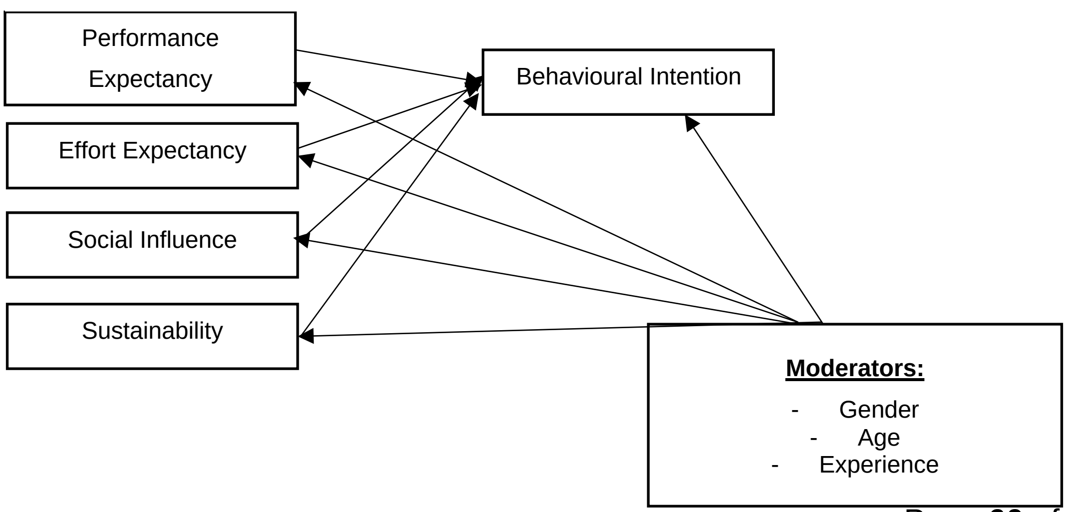
Case study research fits this study as it aims to understand the extent to which sustainability influences urban farmers' behavioural intention to use IoT, and their thoughts and perceptions on IoT technology as well as explain the quantitative data collected in the first phase by expanding on some of the questionnaire items that were used to measure UTAUT. The researcher also sought an immersive experience, which meant going to the farms, speaking to the farmers, and taking photos to collect rich data to build case studies. Case studies often illuminate the specific intricacies between cause and effect instead of only revealing the influence of a factor that causes an effect (Yin, 2017). The case study method will provide deeper analysis and insights into, for example, how urban farmers maintained their goal of sustainable development during the COVID-19 lockdown. The study applied the case study method through three urban farms in the Johannesburg area to answer the research questions.

4.3.2 Adapted UTAUT and construct definition

The UTAUT model has been used widely across the Information Systems field. It is crucial to extend existing theory by proposing and validating new variables that reflect various research contexts, especially where researchers identify a gap in the application of UTAUT in specific contexts (Venkatesh et al., 2016). In the longitudinal study by Venkatesh et al. (2003), validation of the UTAUT model in that context revealed that it accounted for 70% of the variance in behavioural intention and approximately 50% of the variance was accounted for by actual use of technology.

In the context of this study, the independent variables in the adapted research model are performance expectancy, effort expectancy, and social influence. The dependent variable used in the study is behavioural intention. Gender, age, education level and experience will be the moderators of the constructs. This research contributes to the UTAUT model by introducing a new construct, namely sustainability, which is an independent variable. This study will seek to understand how the constructs (particularly the new construct sustainability) and the moderators affect the dependent variable, behavioural intention. Figure 14 presents the Adapted UTAUT model.

Figure 11: Adapted UTAUT Model



The definitions of the key constructs, as proposed and defined by Venkatesh et al. (2003), are discussed in Table 8 in the theory underpinning chapter. Table 14 below discusses the constructs and their definitions in relation and application to the study and the variable types.

Table 14: Constructs, their definition in the context of the study and their variable types

Constructs	***Definition in relation to the study***	***Variable type***
Performance Expectancy	The degree to which urban farmers believe IoT improve their farm management.	Independent
Effort Expectancy	The level of ease that urban farmers associate with the use of IoT.	Independent
Social Influence	The degree to which urban farmers believe that the people who are important to them think that they should use IoT. This can be governments, training programs, fellow farmers or global calls to action like the SDGs.	Independent
Sustainability	The ability to improve and maintain the status and availability of important materials and ideal conditions over a long period of time.	Independent
Behavioural Intention	The degree to which the Urban Farmers have	Dependent

	actively and consciously considered (or planned) to use or not use IoT technology.	
Gender	Male, female, prefer not to say	Moderator
Age	18-24 years old 25-34 years old 35-44 years old 45-54 years old 55-64 years old 65-74 years old 75 and older years old	Moderator
Education level	Primary school Secondary school High school University undergraduate Postgraduate Not applicable	Moderator
Experience	Never Less than 6 months 6 months – 1 year 1-2 years More than 2 years	Moderator

4.3.3 Research hypothesis

Below are the research hypotheses the researcher formulated based on the adapted UTAUT model, as summarised.

Performance Expectancy is the degree to which IoT technology will benefit urban farmers' management of their farms. Performance expectancy is considered the strongest predictor of intention, with gender and age being notable moderator variables (Venkatesh et al., 2003). If a farmer stands to gain more from using IoT technology to manage their farm, their intention to use these technologies will increase. Therefore, the research hypothesises that *urban farmers' behavioural intention to use IoT technology will be influenced if they feel it will improve their current operations (H1).*

Effort expectancy is the degree to which the IoT technology is easy to use for urban farmers. People hesitate to adopt new technology if they do not feel confident to do so (Han, Xiong & Zhao, 2021). Therefore, if urban farmers perceive IoT technology as easy to use to manage their farms, they will likely adopt it. Contrarily, if they feel as though the technology is complex and difficult to use, they will continue with their current farm management methods. We, therefore, hypothesise that *urban farmers' behavioural intention to use IoT technology will be positively influenced if they feel that the technologies are not difficult to use (H2).*

Social influence is the degree to which urban farmers believe that the people they 'look up to' believe that they should use IoT technology. Urban farmers in Johannesburg often work in teams or cooperatives, attend the same training programs, or may have mentors in the same field. They likely share methods and advice, and the farmers may find their opinions on farm management valuable. If those who are influential to urban farmers feel they should be using IoT technology, the farmers are likely to do so. Therefore, *urban farmers' behavioural intention to use IoT technology is impacted by social influence (H3).*

Sustainability: a new construct. We propose the sustainability construct to assess urban farmers' behavioural intention to use IoT farming technology. In the research context, sustainability is defined as the ability to improve and maintain the status and availability of important materials and ideal conditions in the long term. If the technology can lead to a more sustainable farm by ensuring that urban farmers contribute towards the goal of sustainability or the SDGs, then they are more likely to use them. Therefore, *urban farmers' behavioural intention to use IoT is influenced by Sustainability (H4).*

Moderator: age. The age of the urban farmers may affect their behavioural intention to use IoT. Therefore, *age plays a moderating role in urban farmers' behavioural intention to use IoT (H5)*

Moderator: gender. It is assumed that gender plays a moderating role on the relationships between the key constructs and behavioural intention. Therefore, *gender plays a moderating role in urban farmers' behavioural intention to use IoT (H6)*

Moderator: experience. The amount of experience that urban farmers may have had with IoT systems could have a moderating effect on the key constructs and behavioural intention, as they may hold different views about IoT systems than inexperienced users. Therefore, *experience plays a moderating role in urban farmers' behavioural intention to use IoT (H7).*

Moderator: education level. It is assumed that the level of education of the urban farmers could have a moderating effect on the constructs and behavioural intention. Therefore, *education level plays a moderating role in urban farmers' behavioural intention to use IoT (H8).*

Table 15: Summary of proposed hypotheses

Hypothesis number	***Hypothesis***
H1	*Urban farmers' behavioural intention to use IoT technology will be influenced if they feel it will improve their current operations.*
H2	*Urban farmers' behavioural intention to use IoT technology will be influenced if they feel that the technologies are not difficult to use.*
H3	*Urban farmers' behavioural intention to use IoT technology is influenced by social influence.*
H4	*Urban farmers' behavioural intention to use IoT is influenced by sustainability.*
H5	*Age plays a moderating role in urban farmers' behavioural intention to use IoT.*
H6	*Gender plays a moderating role in urban farmers' behavioural intention to use IoT.*
H7	*Experience plays a moderating role in urban farmers' behavioural intention to use IoT.*
H8	*Education level plays a moderating role in urban farmers' behavioural intention to use IoT.*

4.4 DATA COLLECTION AND ANALYSIS

4.4.1 Data Collection

4.4.1.1 Questionnaire survey

The questionnaire survey method is a set of questions or items a researcher prepares in a pre-determined order before distributing to respondents (Oates, 2006). This method allows a researcher to collect large amounts of information, making it possible to compare the habits of different groups of respondents (Bryman, 2012). The purpose of conducting questionnaires is for the researcher to analyse all responses, identify patterns, and make generalisations about the larger populations and their actions and behavioural patterns (Oates, 2008).

Questionnaire surveys allow multiple or large numbers of questionnaires to be managed simultaneously due to the standardised questions. They may also be easier for the respondents to complete and easier for the researcher to process since the researcher and the respondents are not expected to write long-form questions and answers, but instead tick or circle an option in the case of paper-based questionnaires (Bryman, 2012). Online or web-based surveys are posted on a website or sent to respondents through email for them to complete online. Online surveys are cost-effective as a researcher can access free survey platforms such as Google Sheets. They also hold an important advantage over paper-based or email surveys as researchers can customise the appearance of the questionnaires. Furthermore, they can be designed to filter out questions that do not apply to the respondent, thus skipping automatically to the next question; as well as ensuring that respondents do not skip compulsory questions. Completed surveys are automatically downloaded into a database and exported in an appropriate format such as an Excel spreadsheet, which makes coding less intimidating (Bryman, 2012).

One of the downfalls of questionnaire surveys, however, is that response rates can be lower due to the following reasons (Bryman, 2012):

- The respondents in question may have limited access to the internet which restricts them from participating in the survey. This is likely in South Africa as 38.1 million of the population are active internet users (Galal, 2021).

- Respondents must be motivated to participate in the survey or believe that they will receive some form of incentive for participating.
- Respondents may doubt whether their information will remain confidential and anonymous especially when contacted through email. Respondents may be wary about how their information was obtained (especially considering the POPI Act).
- Respondents may complete the questionnaire more than once, potentially compromising the quality of the data collected.

A questionnaire survey that contains quantitative measures (such as the Likert scale) and a few open-ended questions does not produce an in-depth or rigorous database (Creswell & Clark, 2017). This created the necessity for another form of data collection that would allow the researcher to ask open-ended questions in the form of case study interviews.

The study used the purposive sampling technique to obtain respondents for the questionnaire survey. Purposive sampling is a non-probability method that samples respondents strategically so that the questions posed are relevant to them. This sampling method requires the researcher to have specific criteria for their respondents to ensure that their questionnaire is relevant and is answered adequately. The downside is that it does not allow the researcher to generalise findings to the greater population (Bryman, 2012). The researcher's initial sample consisted of urban farmers operating in the Johannesburg area, who have gone through the WIBC incubation program that trains and equips them with hydroponic technology and a tunnel or greenhouse structure. The researcher selected this sample who, to a certain extent, are privy to agricultural technology and use technology that is considered modern, while the structure of their farms allowed for the installation of IoT systems. This initial sample would not be suitable, as urban farming businesses were already a niche in Johannesburg and the sample size would be limited. The research was then expanded to include urban farmers in the province of Gauteng with businesses currently in operation that use tunnels or greenhouse structures and plant their crops through hydroponic or aquaponic farming methods. In August 2020, a standardised online survey was distributed across social media and directly to farmers via email to measure their behavioural intention to use IoT and establish to what extent sustainability influences the said intention. The farmers' emails were sourced through a Google search of urban farmers in Gauteng which led the researcher to either finding their websites (where applicable), Facebook business pages or LinkedIn. Additionally, the researcher looked through WIBC's Twitter feed and was able to obtain some email addresses as they use the platform to showcase the farmers they have trained. The questionnaire survey was hosted on Google Sheets, a free and effective platform. The questionnaire consisted of a section that informed respondents of the researcher's information, an explanation of the research study and a purpose statement for the questionnaire survey so that the respondents understand why they are requested to participate in the survey. Additionally, the researcher included two links to YouTube videos that explained IoT systems in case the respondents did not know what was being referred to when referring to IoT. Finally, the respondents were informed that their participation would be voluntary, and all information would be kept anonymous.

The questionnaire design was divided into three parts. The first consisted of one question requesting informed consent from the participants. This question required a "yes" or "no" answer, with those answering "no" being free to abandon the questionnaire. The second part of the survey collected demographic characteristics that are considered moderators of the key constructs in UTAUT. Gender, age, education level and level of experience were the demographic characteristics considered. The third part of the questionnaire consisted of questions based on the UTAUT model and the measurement items included questions on the newly-added construct, sustainability. To measure UTAUT, using the items listed in the tables below, a five-point Likert scale was applied, with 1 indicating 'strong disagreement' and 5 'strong agreement' at the opposite extremes. Points 2, 3 and 4 were labelled 'disagree', 'neutral' and 'agree'. These items are shown below (Tables 16 to 21).

Table 16: Questionnaire item design for Performance Expectancy

Item reference	***Item***
PE1	I would find IoT useful in my job
PE2	Using IoT would enable me to accomplish tasks more quickly
PE3	Using IoT would increase my productivity
PE4	If I were to use IoT, I will increase my chances of making more money
PE5	If I were to use IoT, my farm would be more sustainable

Table 17: Questionnaire item design for Effort Expectancy

Item reference	*Item*
EE1	My interaction with the IoT system in my farm would be clear and understandable
EE2	It would be easy for me to become skilful at using IoT
EE3	I would find the IoT system easy to use
EE4	Learning to operate the IoT system on my farm would be easy

Table 18: Questionnaire item design for Social Influence

Item reference	*Item*
SI1	People who influence my behaviour and decisions think that I should use IoT so my farm can be more sustainable
SI2	People who are important to me think that I should use the IoT system for a more sustainable farm
SI3	The senior management of this business would be helpful in the use of IoT
SI4	In general, the people in my business would support the use of IoT for a more sustainable farm

Table 19: Questionnaire item design for Facilitating Conditions

Item reference	*Item*
FC1	If an IoT system were to be implemented, I would have the resources necessary to use it
FC2	I have the knowledge necessary to use IoT
FC3	A specific person (or group) would be available for assistance with the IoT system difficulties

Table 20: Questionnaire item design for Behavioural Intention

Item reference	*Item*
BI1	I intend to use IoT technology for my farming operations in the next 3 months

BI2	I predict that I would use IoT in the next three months
BI3	I plan to use IoT technology in the next three months

Table 21: Questionnaire item design for Sustainability

Item reference	***Item***
SUS1	As a farmer, sustainability is important to me
SUS2	I believe that I contribute to the collective goal towards being more sustainable
SUS3	I am willing to do what I can to ensure that my farm is sustainable
SUS4	I believe that my farm can be more sustainable through the use of IoT

4.4.1.2 Semi-structured interviews

The interview method is the most widely applied data collection method in qualitative research (Bryman, 2012) as it provides a level of depth that allows the researcher to obtain rich narratives by exploring how their respondents describe the phenomenon (Venkatesh et al., 2013) and consist of structured, semi-structured and unstructured interviews.

The researcher's sample selection process involved researching urban farms in Gauteng. Purposive sampling was applied to select urban farmers considered advanced from an agricultural tech perspective. Three farms were identified, and the researcher sent each one a letter explaining the research and its purpose and how the participants fit into the study. The purpose of the letter was to request permission to conduct face-to-face interviews, in line with the ethical considerations required by the University of Pretoria, and to explore their farms with them while adhering to COVID-19 guidelines.

The researcher set out to yield rich data by using the case study research approach, where participants take part in semi-structured interviews. This study's use of semi-structured interviews is so the researcher can extract richer information by establishing a more personal connection with the participants and getting more of an insight into their lived experiences. Due to the nature of the case study approach that requires direct interaction with the participants, the researcher will conduct the interviews face-to-face, allowing them to immerse themselves in the participants' environment. Semi-structured interviews also let the researcher ask probing questions based on the participants' tone to obtain clarity. During the interview, the interviewer used a digital audio recording device to record the participants' responses and make handwritten notes, as well as a research journal to detail the process and experience of building the different case studies. It is also a tool for reflecting on the process. The interview questions are partly formulated on the constructs and their hypotheses used to measure UTAUT, and some are formulated by the researcher.

Table 22: Research Phases and Research Collection Methods

Research Phases	***Research Collection Methods***
Phase 1: Qualitative Interview *Conducting semi-structured interviews with Urban Farmers*	Individual face-to-face and online interviews
Phase 2: Quantitative Survey *Collecting quantitative data with Urban Farmers*	Online questionnaire survey

Sample interview questions

- How long have you been a farmer for?
- What made you choose urban farming?
- Did you always intend on farming within the city?
- What type of technology do you currently use in your farming operations?
- When you started farming, was the plan always to use IoT technology (depending on the farm and the type of technology, the researcher will specify)?
- If yes, what influenced you to build an urban farm that uses IoT technology?
- If no, what made you switch to a smart farm?
- Were you influenced by anyone to make use of these technologies in your farm? If so, who and who are they in relation to you?

- When considering using these technologies on your farm, what factors did you considering in your decision-making?
- Did you consider sustainability/sustainable development in your decision-making?
- Are you aware of the UN SDGs and/or the NDP 2030?
- Did you consider the collective goal of sustainability?
- Did the collective goal of sustainability make it easier for you to decide on using these technologies?
- Does the collective goal of sustainability influence you to continue using these technologies? Is it a factor in your continued use?
- Who do you consider important/influential to you as an urban farmer or in the urban farming/farming space?
- Do they influence how you manage your farm?
- How was your experience of lockdown?
- Did lockdown affect your initial decision to use these technologies?
- Did lockdown affect your perception of sustainability? Did lockdown affect your goal of being a sustainable farm?
- In terms of how you market the farm, do you specifically mention your sustainability efforts? Do you mention that you are part of the collective goal towards achieving sustainable development goals?
- Do you think that mentioning sustainability/sustainable development goals in your marketing helps with your image or how people perceive your farm? Is this positive or negative?
- Are you regarded highly as a result of your sustainability efforts/marketing that mentions your sustainability efforts?

Data collection began in July 2021, when the researcher identified urban farmers who were farming in the city and had operational businesses. The researcher sent the farmers emails with a consent form, requesting an interview and explaining what the process entailed. Two of the interviews were conducted through Microsoft Teams as the most convenient times for the respondents were before heading out to their farms, or upon returning. Their office spaces were at home and as such, was where they had a stable internet connection. The third interview was an in-person interview where COVID-19 regulations were adhered to. This allowed the researcher to visit the rooftop farm and become familiar with the infrastructure and take various photographs (with consent). Informal interviews were conducted in 2022 during the second phase of the quantitative data collection process as the researcher had to make phone calls to ask farmers to complete the questionnaire survey and request permission to see them in person. These informal interviews were not recorded but notes were made. Respondents were more interested in the informal interviews and completing the surveys as some had time constraints, while others were weary of important company information being revealed despite the assurance of anonymity and confidentiality. Table 23 is a summary of the semi-structured case study interview respondents' profiles.

Table 23: Summary of case study respondents' profiles

	CASE 1	**CASE 2**	**CASE 3**
SECTOR	Hydroponic rooftop farming: Hops	Hydroponic farming: Vegetable seedlings inputs	Hydroponic rooftop farming: lettuce, tomatoes, peppers, herbs
LOCATION	Johannesburg CBD	Johannesburg CBD	Sandton
TECHNOLOGY USAGE CATEGORY	Adopter of hydroponic technique and control environment technology. No IoT	Adopter of hydroponic technique. User of data collection apps. No IoT	Adopter of hydroponic technique. No other technology besides timers. No IoT

4.4.2 Data analysis

Quantitative statistical analysis was performed using R Software (version 4.1.3; http://www.Rproject.org). The analysis began with the descriptive statistics for the questionnaire responses from the 32 respondents. The demographic information and UTAUT construct questions were calculated using the following metrics:

1. Frequency

The count frequencies for each category/response are calculated.

2. Proportions

The proportions are obtained from the frequencies of each category/response.

Graphically, the categorical variables are shown using pie charts or Likert scale graphs.

When the variable consisted of numerical values, the following metrics are calculated:

1. Number of Missing Values
The number of missing values present in the variable.
2. Minimum
The minimum numerical value of the variable.
3. Maximum
The maximum numerical value of the variable.
4. Mean (SD)
The mean is given first and followed by the standard deviation of the variable.
5. Median (IQR)
The median is given first and followed by the interquartile range of the variable.
6. Mean (CI)
The mean is given first and followed by the 95% confidence interval of the variable.

Based on an examination of the literature and studies that had previously applied UTAUT, as well as the fact that the sample size of the study population of urban farmers is considered niche, further analysis of the quantitative data was selected alongside the Statistics Department. Based on a systematic review of 174 articles performed by Williams et al. (2015), it was established that the most used analysis method was structural equation modelling (SEM), closely followed by regression analysis and partial least squares (PLS) analysis. SEM is a statistical method used to analyse the structural theory bearing on a phenomenon through a confirmatory approach (Byrne, 2016). Of the UTAUT papers that used SEM, most had sample sizes of 50 and above (Williams et. al., 2015), so due to the sample constraints, the researcher and statisticians believed that it would not be a suitable analysis method. A confirmatory factor analysis (CFA), which is used when there are preconceived constructs (Byrne, 2016), was performed on each construct. This factor analysis was performed to confirm the constructs to open more doors for analysis. Since the responses are categorical (contain words, not numbers) and have no values assigned to them, the following key was assigned to the question responses to contain only numeric responses as displayed in Table 23.

Table 24: Numerical values assigned to questionnaire responses

Question	***Values***
Question 2	• 1: Male • 2: Female
Question 3	• 1: 18-24

	• 2: 25-34 • 3: 35-44 • 4: 45-54 • 5: 55-64
Question 4	• 1: High School • 2: University Undergraduate • 3: Postgraduate
Question 5	• 1: Less than 6 months • 2: 6months-1year • 3: 1-2 years • 4: More than 2 years
Question 6-28 (Likert scale items)	• 1: Strongly Disagree • 2: Disagree • 3: Neutral • 4: Agree • 5: Strongly Agree

The modified UTAUT model consists of 6 constructs, namely:

• Performance Expectancy (PE 1-5)
• Effort Expectancy (EE 1-4)
• Social Influence (SI 1-4)
• Sustainability (SUS 1-4)
• Behavioural Intention (BI 1- 3)

The researcher checked whether these constructs formed their factors, which gave us factor scores, enabling us to perform further exploratory analysis and evaluate and estimate the relationships between different constructs and demographic variables. Since the overall model is a work in progress, some fine-tuning would be needed within each construct. The researcher went through each construct and double-checked their performance before combining them. Table 24 illustrates PE, EE, SI and BI as well as their variable definitions. Sustainability is discussed separately after the abovementioned constructs.

Table 25: Constructs PE, EE, SI & BI and their variable definitions

Construct	*Variable Definitions*
Performance Expectancy	V1 - 10. I would find IoT useful in my job at the farm PE1 V2 - 11. Using IoT would enable me to accomplish tasks more quickly PE2 V3 - 12. Using IoT would increase my productivity PE 3 V4 - 13. If I were to use IoT, I would increase my chances of making more money PE4 V5 - 14. If I were to use IoT, my farm would be more sustainable PE5
Effort Expectancy	V1 - 15. My interaction with the IoT system in my farm would be clear and understandable EE1 V2 - 16. It would be easy for me to become skilful at using IoT EE2 V3 - 17. I would find the IoT system easy to use EE3 V4 - 18. Learning to operate the IoT system in the farm would be easy for me EE4
Social Influence	V1 - 19. People who influence my behaviour and decisions think that I should use IoT so my farm can be more sustainable SI1 V2 - 20. People who are important to me think that I should use the IoT system for a more sustainable farm SI2 V3 - 21. The senior management of this business would be helpful in the use of IoT SI3 V4 - 22. In general, the people in my business would support the use of IoT for a more sustainable farm SI4
Behavioural Intention	V1 - 23. I intend to use IoT technology for my farming operations in the next 3 months BI1 V2 - 24. I predict that I would use IoT in the next three months BI2 V3 - 25. I plan to use IoT technology in the next three months BI3

The initial tests that helped determine whether factor analysis is appropriate consisted of Spearman correlation, Kaiser-Meyer-Olkin measure, Barlett's test, a calculation of the determinant of the correlation matrix, Cronbach's alpha and finally, a parallel analysis.

The Spearman correlation was preferable in this case since the researcher used Likert scale data rather than continuous data. To determine the factorability of the data, the Kaiser-Meyer-Olkin helped to measure sampling adequacy. Guidelines on how to interpret the measure are illustrated below.

Table 26: KMO interpretation guidelines

KMO measure	***Interpretation***
$KMO \geq 0.90$	Marvellous
$0.80 \leq KMO < 0.90$	Meritorious
$0.70 \leq KMO < 0.80$	Average
$0.60 \leq KMO < 0.70$	Mediocre
$0.50 \leq KMO < 0.60$	Terrible
$KMO < 0.50$	Unacceptable

Thereafter, the Barlett test was performed to determine if a factor analysis of the data was appropriate. The p-value from Barlett's test would help to conclude whether a factor analysis would be useful, in which case the p-value needed to be approximately zero. Thereafter, the determinant of the correlation matrix was calculated to determine whether a factor analysis was likely to run. If the determinant is positive, the factor analysis will likely run. The Cronbach alpha value was also computed to determine the validity of the questionnaire and scale reliability as it is a measure of internal consistency, that is, how closely related a set of items are.

Table 27: Cronbach's alpha guidelines for interpretation

Cronbach's alpha	***Internal consistency***
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

A parallel analysis was also run to double-check whether a factor is suggested, which is ideal since we have one construct which we ideally wanted to group. The factor loadings would be an indication of whether a construct is strong or weak, where a factor loading of greater than 0.5 is typically indicative of a strong loading, indicating a strong link to the factor construct.

The Spearman correlation matrices for constructs PE, EE, SI and BI are illustrated below in Tables 27-19.

Table 28: Correlation matrix for PE

	V1	***V2***	***V3***	***V4***	***V5***
V1	1	0.6321	0.677	0.625	0.5962
V2	0.6321	1	0.8596	0.7444	0.5839
V3	0.677	0.8596	1	0.7559	0.6983
V4	0.625	0.7444	0.7559	1	0.7412
V5	0.5962	0.5839	0.6983	0.7412	1

Table 29: Correlation matrix for EE

	V1	***V2***	***V3***	***V4***
V1	1	0.587	0.6133	0.3915
V2	0.587	1	0.5809	0.3432
V3	0.6133	0.5809	1	0.5757
V4	0.3915	0.3432	0.5757	1

Table 30: Correlation matrix for SI

	V1	***V2***	***V3***	***V4***
V1	1	0.6716	0.561	0.4771
V2	0.6716	1	0.7135	0.5525
V3	0.561	0.7135	1	0.794
V4	0.4771	0.5525	0.794	1

Table 31: Correlation matrix for BI

	V1	***V2***	***V3***

V1	1	0.8297	0.8425
V2	0.8297	1	0.8824
V3	0.8425	0.8824	1

The KMO measures for constructs PE, EE, SI and BI are illustrated in Table 31. These measures indicated that a factor analysis could be performed for constructs PE, EE, SI and BI, as follows:

Table 32: KMO measures for PE, EE, SI and BI

Construct	***KMO Measure***	***Interpretation***
PE	0.8302	Meritorious
EE	0.7533	Average
SI	0.7307	Average
BI	0.7662	Average

The Bartlett test results for PE, EE, SI and BI are illustrated in Table 32 below. Since we had a p-value so small it was approximately zero, we concluded that factor analysis would be useful.

Table 33: Barlett's test results for PE, EE, SI and BI

Construct	***Result***
PE	
Chi-Square Test Statistic	121.2876
P-Value	0.0000
Df	10
EE	
Chi-Square Test Statistic	48.34987
P-Value	0.0000
Df	6.0000
SI	
Chi-Square Test Statistic	56.96661
P-Value	0.00000
Df	6.00000
BI	

Chi-Square Test Statistic	91.32815
P-Value	0.00000
Df	3.00000

Following the Bartlett test, the researcher calculated the determinant of the correlation matrix. As Table 33 illustrates, the results were small but positive nonetheless, so a factor analysis would likely run.

Table 34: Results of the determinant of the correlation matrix for PE, EE, SI and BI

Construct	*Determinant*	*Result*
PE	0.0198537253809536	Extremely small but positive
EE	0.239875388230126	Small but positive
SI	0.0962441346147903	Small but positive
BI	0.0568116328766647	Extremely small but positive

The Cronbach alpha results for PE, EE, SI and BI were computed and Table 34 illustrates that there was strong consistency in the data, meaning that the questionnaire items were valid.

Table 35: Cronbach's alpha results for PE, EE and SI

Construct	*Cronbach's Alpha value*	*Internal Consistency*
PE	0.9206	Excellent
EE	0.8405	Good
SI	0.8446	Good
BI	0.9527	Excellent

The parallel analysis that was run to double-check whether one factor is suggested revealed that for PE, EE, SI and BI the number of factors = 1 and the number of components = 1.

This finally led to factor analysis. PE, EE, SI and BI had strong factor loadings of greater than 0.5 which indicated a strong belonging to the factor construct. Figures 12 to 15 illustrate the results.

Figure 13: PE Factor Analysis

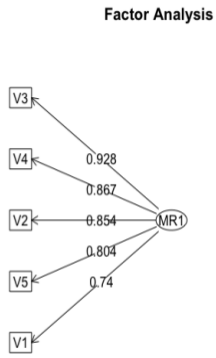


Figure 12: EE Factor Analysis

Figure 15: SI Factor Analysis

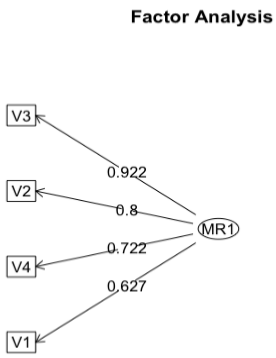
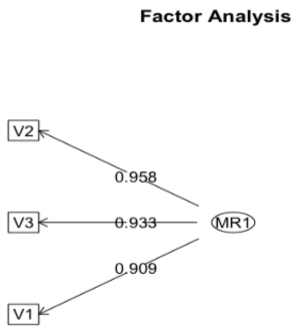


Figure 14: BI Factor Analysis



The Sustainability construct has the following variable definitions illustrated in Table 35.

Table 36: Sustainability and its variable definitions

Construct	***Variable Definitions***
Sustainability	V1 - 6. As a farmer, sustainability is important to me SUS1 V2 - 7. I believe that I contribute to the collective goal towards being more sustainable SUS2 V3 - 8. I am willing to do what I can to ensure my farm is sustainable SUS3 V4 - 9. I believe that my farm can be more sustainable through the use of IoT SUS4

Table 37: Sustainability correlation matrix

	V1	*V2*	*V3*	*V4*
V1	1	0.405	0.2901	0.276
V2	0.405	1	0.6123	0.3329
V3	0.2901	0.6123	1	0.5703
V4	0.276	0.3329	0.5703	1

Table 38: Sustainability Barlett's test results

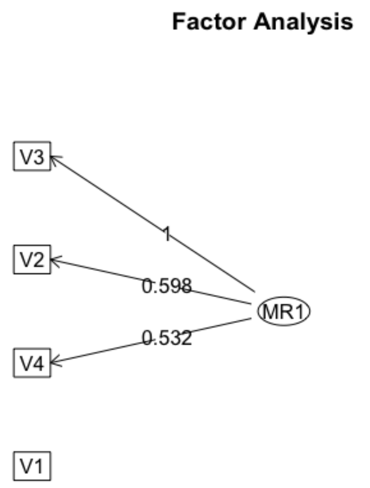
Chi-Square Test Statistic	26.91
P-Value	0.0001
Df	6

Table 39: Determinant of correlation matrix for sustainability

Construct	*Determinant*	*Result*
SUS	0.342683412896178	Small but positive

Sustainability underwent the same initial tests before the factor analysis was performed. The Spearman correlation results are illustrated in Table 36. The KMO measure was calculated to be 0.639, meaning the measure was mediocre but we could still perform factor analysis. The p-value was approximately zero, therefore the researcher concluded that factor analysis would be useful. The determinant of the correlation matrix was calculated for SUS as illustrated in Table 32 and despite it being small, a factor analysis would likely run. A Cronbach alpha value of 0.5014 indicated that we have a weak and unacceptable consistency in our data. The parallel analysis suggested that the number of factors = 1 and the number of components = 1. We had strong factor loadings as illustrated in Figure 14, which indicates a strong construction, except for V1, which had a very weak loading. V1 speaks to SUS1 - 6: “As a farmer, sustainability is important to me”, which is weakly loaded and therefore had to be removed.

Figure 16: SUS factor analysis



The initial tests were reperformed after the removal of V1.

Table 40: Correlation matrix for sustainability after removal of V1

	V2	*V3*	*V4*
V2	1	0.6123	0.3329
V3	0.6123	1	0.5703
V4	0.3329	0.5703	1

Table 41: Barlett's test result after removal of V1

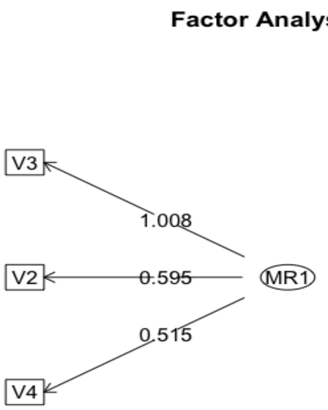
Chi-Square Test Statistic	24.41
P-Value	< 0.0001
Df	3

Table 42: Determinant of correlation matrix after removal of V1

Construct	*Determinant*	*Result*
SUS	0.421490357066464	Small but positive

The KMO measure was recalculated to be 0.6004 which was still mediocre but allowed for factor analysis. The p-value of approximately zero meant that factor analysis would be useful. A Cronbach alpha value of 0.6668 indicated that we have a moderate consistency in our data. The parallel analysis again suggested that the number of factors = 1 and the number of components = 1. We had strong factor loadings as illustrated in Figure 15, which is a good indication of strong construction, except for V1, which had a very weak loading.

Figure 17: Factor analysis after removal of V1



Though it was noted that the factor loadings were not very high, the fact that we have Likert scale data meant that loadings above 0.5 were adequate.

Due to the limited sample size, the researcher performed the qualitative data analysis manually. The researcher began the data analysis process by transcribing the recordings verbatim and cleaning the interview data up by removing repetitive and unnecessary words. Themes were extracted from the transcription and the different responses were arranged according to the themes identified, which were attitudes on IoT, inaccessibility of IoT, the role of sustainability and SDGs and the effect of lockdowns on urban farms.

4.5 ETHICAL CONSIDERATIONS

Prior to data collection, the respondents were provided with an informed consent form to sign if they agreed to participate in the study. The form clearly stated that they were not obligated to sign, and should they not feel comfortable signing, the interview would be abandoned. The form explained the study objectives and stated the respondents' role, and they were assured of total anonymity, as no identifying information such as their ages or names would be disclosed. The consent letter included the contact details of the research supervisor in case a respondent had any concerns or needed any further clarification regarding the research. The sample semi-structured interview questions and the questionnaire survey underwent an approval process with the University of Pretoria Ethical Committee before data collection started. UTAUT posits that gender, age, experience, and voluntariness of use moderate the impact of the four key constructs of usage intention and behaviour. Due to the nature of ethical considerations at the University of Pretoria, age and gender information was requested in a manner that ensured the respondents would not be identifiable. For example, instead of asking for the respondent's exact age, the questionnaire only offers age ranges. The participants were informed that they would be provided with the research results on request, once these had been finalised. Additionally, the survey's first question explicitly requested the respondents' consent and made sure to mention that should they select 'no', they were not obliged to continue with the survey.

4.6 CONCLUSION

This chapter detailed the research methodologies used to collect data. The choice of research philosophy and design were explained along with the adapted UTAUT model and the hypotheses that will be calculated in Chapter 5. Reasons for the choice of theory, philosophy, design, and methodology were provided. The data collection and analysis methods were described in detail, as were the identified themes. Finally, the ethical considerations were discussed.

5 FINDINGS AND ANALYSIS

5.1 INTRODUCTION

This chapter discusses the qualitative and quantitative findings from the data collection and analysis process detailed in Chapter 4. The quantitative section will present the descriptive statistics for the respondent demographics and the UTAUT construct responses. This is followed by the hypothesis testing results based on the questionnaire survey responses. The qualitative section will profile the interviewees and then present and analyse the responses from the interviews. The researcher will thereafter discuss both the quantitative and qualitative findings to answer the research questions and establish if the objectives were met.

5.2 QUANTITATIVE FINDINGS AND ANALYSIS

The quantitative findings consist of responses from the questionnaire survey that was initially distributed across social media platforms such as LinkedIn, Twitter as well as some Facebook forums. The researcher had already been acquainted with some urban farmers in the Johannesburg inner city who were graduates of the WIBC incubator program so the questionnaire survey was distributed then. This was during the time COVID-19 lockdown restrictions were still in place. This initial distribution yielded about 18 responses, which was too low for any viable data analysis of UTAUT outside of the descriptive statistics, to answer the research questions. The researcher then cast the data collection sample net wider to include more urban areas in Gauteng Province including the City of Tshwane and Ekurhuleni. To increase the number of respondents, the researcher spent a week travelling through Gauteng to connect with more urban farmers and get them to complete the survey questionnaire and distribute it to their communities. The process involved looking up urban farms in Gauteng through Google and getting leads, which were contacted to establish whether they would be willing to have the researcher visit their farm to complete the survey questionnaire. The researcher believed that seeing the urban farmers in-person would show a level of care and closeness that we were all deprived of during the COVID-19 era. The questionnaire was still being distributed across social media platforms and the researcher was granted access to the Khula! App WhatsApp support group that consisted of farmers around South Africa who used the Khula app. Khula! is a startup that provides software solutions for farmers, and also markets their input products through the mobile app. Most urban farmers contacted were either too busy, they had closed their businesses or were weary of divulging any information that would reveal their competitive edge (particularly the ones using IoT systems already). This process resulted in a total of 32 responses, which was still too low for “typical” data analysis methods such as SEM, PLS, and AMOS (Williams et al., 2015). The researcher looked for other UTAUT studies that had small study samples to study the data analysis methods that were applied. This was an enriching data collection process nonetheless for the researcher as it allowed the researcher to speak to the Urban Farmers and ask questions related to their farms as well as any struggles that were faced although it was done off the record. The descriptive statistical analysis was obtained by calculating the following metrics: mean, standard deviation, counts and proportions.

5.2.1 Demographic information

The demographic information of the respondents in the study were obtained through the 32 survey participants. The information includes gender, age group, educational background, and experience level with IoT. These characteristics are moderators of the behavioural intention of urban farmers to adopt IoT in the modified UTAUT model.

Table 43: Demographic Information Proportions

	DEMOGRAPHIC_INFORMATION (N = 32)
Gender	
Missing Values	0
Male	17 (53.1%)
Female	15 (46.9%)
Age	
Missing Values	0
Age 18-24	2 (6.2%)
Age 25-34	18 (56.2%)
Age 35-44	9 (28.1%)
Age 45-54	2 (6.2%)
Age 55-64	1 (3.1%)
Education Level	
Missing Values	0

High School	3 (9.4%)
University Undergraduate	16 (50.0%)
Postgraduate	13 (40.6%)
Experience with IoT systems	
Missing Values	0
Never	8 (25.0%)
Less than 6 months	7 (21.9%)
6 months - 1 year	4 (12.5%)
1-2 years	3 (9.4%)
More than 2 years	10 (31.3%)

The gender statistics are shown in Table 43. Of the 32 samples, female respondents accounted for 46.88%, whereas men were the majority at 53.12%. In Q1 of 2022, the agricultural sector's male workers were 70.9% and females were 29.1% which is a significant shift from 2021's Q1 percentage of 72.5% male workers and 27.5% female workers (Stats SA, 2021; Stats SA, 2022). This may be a reflection of UA's increasing ability to empower women to participate in agriculture beyond the purpose of sustaining their households.

From the age descriptive statistics, most participants were between the ages of 25 and 34, making up 56.25% of the sample. This proportion is close to the 35-44 age group, which accounts for 28.12% of the respondents. The 18-24 and 45-54 age groups only had two respondents each and the 55-64 age group accounts for 3.12%.

The education level descriptive statistics show that university undergraduates totalled 16, making them the majority of the respondents and accounting for 50.00% of the total number of respondents. There were 13 respondents at the postgraduate level, accounting for 40.62% of the sample, which is close to the university undergraduate proportion. Three of the urban farmers had only reached the high school level, accounting for 9.38%. No respondents were below the high school level (primary and secondary school).

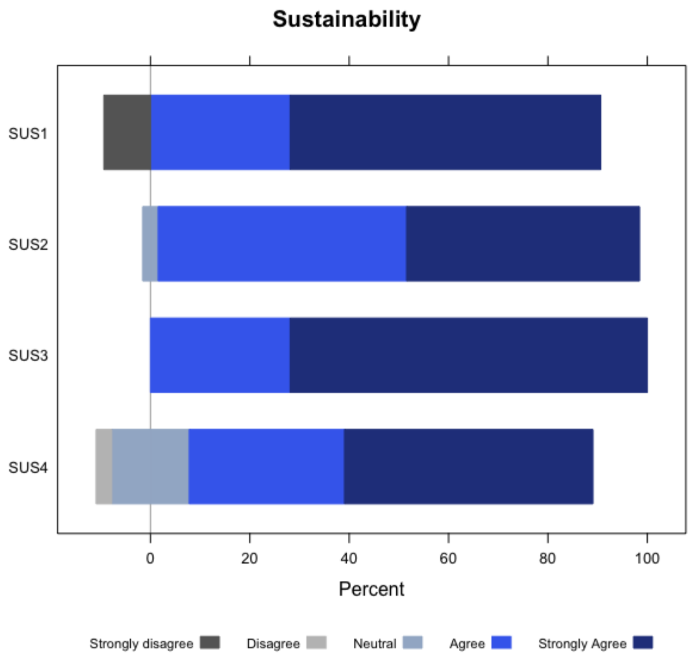
The IoT system experience descriptive statistics show that at 31.25%, the majority of the participants have more than two years of IoT system experience. It should be noted that most participants have some form of IoT experience ranging from less than six months of experience to greater than two years, which altogether makes up 17 of the total number of respondents and accounts for 53.13%. The second-largest group had less than 6 months of experience, accounting for 15 of the total number of respondents, or 46.88%.

5.2.2 UTAUT construct descriptive analysis

The following section aims to present the descriptive statistics of the responses to the questionnaire portion related to the constructs which will act as means to answer the RQ.

a) Sustainability

Figure 18: Visual Summary of Sustainability Responses

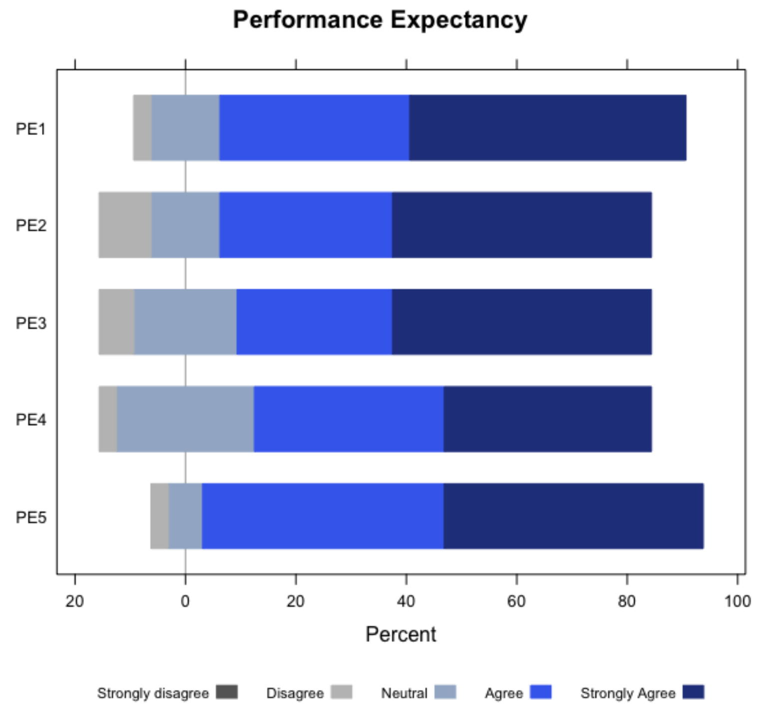


In the study context, sustainability is the ability to improve and maintain the status and availability of important materials and ideal conditions over a long period. The majority of the respondents strongly agree that as farmers, sustainability matters, as shown in the 20 responses accounting for 62.50%. This is followed by nine respondents who agree, accounting for 28.12%, whereas only three respondents, or 9.38% of the sample, strongly disagree with the importance of sustainability. 50% of the urban farmers agreed that they can contribute to the collective goal of being more sustainable, while 46.88% strongly agreed

– which indicates an overwhelmingly clear belief in their perceived ability and commitment. The majority of the participants strongly agree they are willing to do what they can to ensure that their farm is sustainable, as indicated by the proportion of 71.88 %. This is a promising finding in helping to answer the RQs. Half (or 50%) of the participants strongly agree that their farm can be more sustainable by using IoT. It should be noted that the responses in this section are more evenly spread across the other options, with the minority being in disagreement.

b) Performance Expectancy

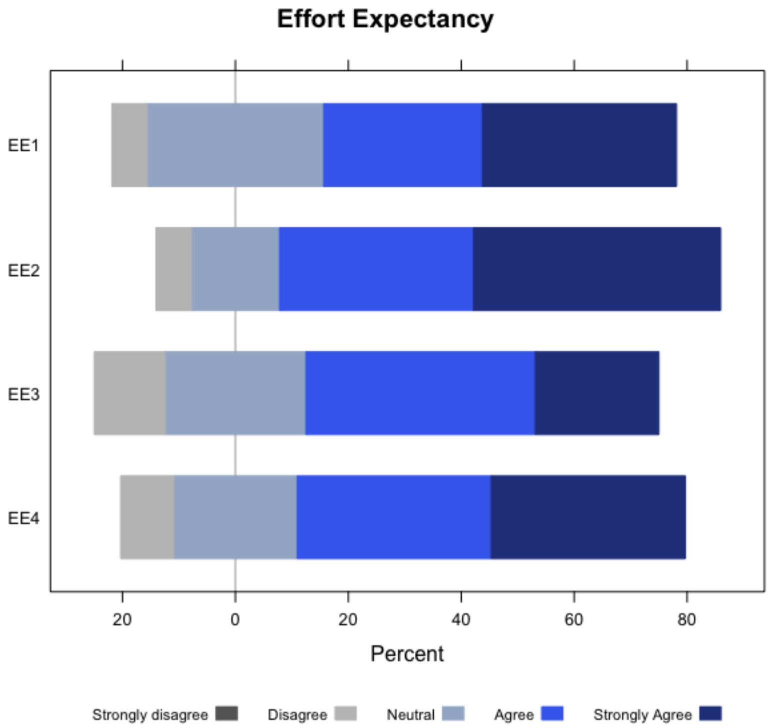
Figure 19: Visual Summary of Performance Expectancy Responses



Most of the participants (50%) strongly agree that they would find IoT useful in their job at the farm. The responses in the performance expectancy section are more spread across the other options, with the minority being in disagreement. The majority of the respondents strongly agreed that the use of IoT on their farm would enable them to accomplish tasks quicker, and that it would increase productivity, as indicated by the percentage of 46.88% in both cases. Most of the participants (37.5%) strongly agree that the usage of IoT on their farm would increase their chances of making more money; and that it would make their farm more sustainable, as indicated by the proportion of 46.88%.

c) Effort Expectancy

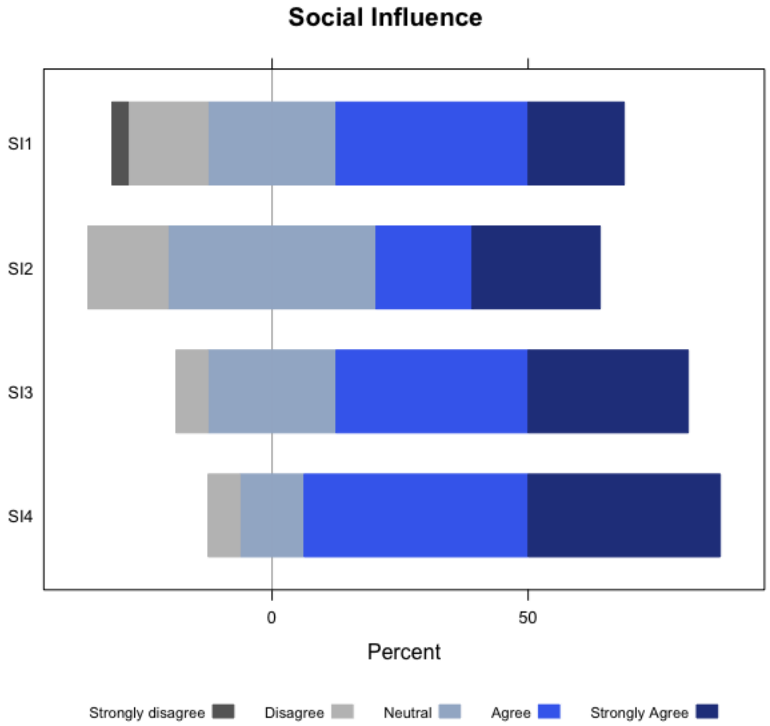
Figure 20: Visual Summary of Effort Expectancy Responses



Most participants strongly agree that their interaction with the IoT system is clear and understandable (34.38%). As in some other sections, the minority of responses are in disagreement. Most strongly agree with the statement that it would be easy for them to become skilful at using IoT (43.75%); and that the IoT system is easy to use (40.62%), as per Table 30 and Figure 26. There were fairly mixed responses here, as many of the participants felt neutral or disagreed. The majority, or 34.38% of the participants, agreed or strongly agreed that learning to operate the IoT system on the farm.

D) Social Influence

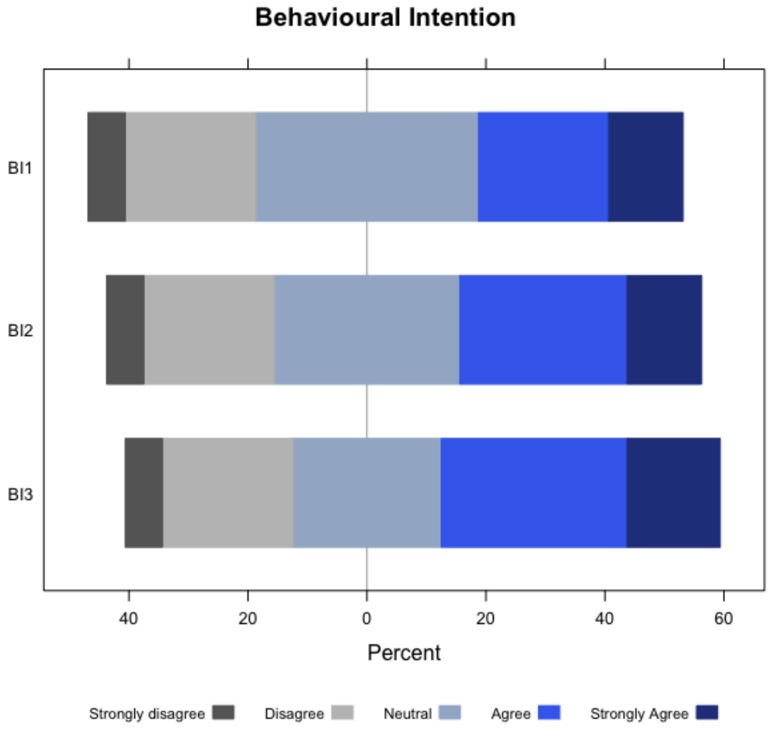
Figure 21: Visual Summary of Social Influence Responses



Regarding social influence, 37.5% of farmers agreed that people (such as mentors) who influence their behaviour and decisions think that they should use IoT for the sustainability of the farm. The majority, or 40.62% of the respondents, were neutral regarding this statement. A total of 43.75% agreed that people in their business would support the use of IoT for a more sustainable farm; and that senior management would help guide and explain the use of IoT (37.5%). A total of 43.75% of the respondents agreed that people in their business would support the use of IoT for a more sustainable business, closely followed by the respondents who strongly agreed.

e) Behavioural Intention

Figure 22: Visual Summary of Behavioural Intention Responses



When asked whether or not they intend to use IoT technology for their farming operations in the next three months, 37.5% were neutral, while a small number of the urban farmers agreed. Once again, large variations in responses are noted, with 21.88 % of participants disagreeing. Most the participants (31.25%) agreed that they intended to use IoT technology on their farms in the next three months.

5.2.3 Hypothesis testing

Various hypothesis tests were formulated to achieve the aims and objectives of the study. These hypotheses are labelled H1 through H8, as shown in Table 15.

a) Hypothesis 1-4

To test hypotheses H1 to H4, we used correlation analysis on the factor scores obtained by the confirmatory factor analysis (CFA) to understand the various relationships, quantify them and test for significance between them. Traditionally, Pearson's correlations are computed, which is the parametric approach to correlation analysis. However, certain assumptions must be accepted before performing analysis using this method. To check the validity of these assumptions, we plotted the various constructs against each other to ensure that they have a linear relationship and performed a Shapiro-Wilk test to test for normality. A normality assumption was done for each construct. The general hypothesis being tested was:

H_0:The variable is normally distributed

$vs.$

H_a:The variable is not normally distributed

In this case, a resultant p-value greater than 5% was ideal, as it led us to not reject the null hypothesis and conclude that the variable is normally distributed.

Table 44: Normality Test results

BI	0.1281
PE	0.0022
EE	0.0695
SI	0.1397
SUS	0

Based on the normality test results, we noted that SUS and PE both violated the normality assumption. Therefore, a nonparametric approach was applied across all tests for consistency. The generalised hypothesis test was as follows:

H_0:There is no significant correlation i.e. $\rho = 0$

$vs.$

H_a:There is significant correlation i.e. $\rho \neq 0$

Here, we tested for significance using 5%. Therefore, if our resultant p-value is less than 0.05, we would reject the null hypothesis above and conclude that we have a significant correlation between the two variables. Spearman's correlation test computes the correlation between the rank of the X and Y variables and is useful in cases where we have a violation in the normality assumption of the variables (Bain & Engelhardt, 1992). This will be tested throughout this report.

Table 45: Correlation Test Results Summary

	Correlation Coefficient	*P-value*
BI vs PE	0.1411	0.4406
BI vs EE	0.301	0.094
BI vs SI	0.5465	0.0012
BI vs SUS	0.0477	0.7949

For the moderating variables (H5-H8), we performed correlation analysis between groups split by gender, age, experience, and education.

b) Hypothesis 5

For the age moderator (H5) the various age groups were merged into two broader categories due to sample size constraints, being 18-34 years and 35-64 years.

Using a t-test, these two groups were compared to determine whether significant differences existed between the means of the two age groups. A pre-requisite for the computation of a t-test is that both variables need to be normally distributed, which was confirmed using a Shapiro-Wilk test. As illustrated in Table 46, the test shows that the normality assumptions were adhered to by both groups, allowing us to proceed with the t-test to check the significance in the means of both groups.

Table 46: Age (H5) Normality Test

BI: 18-34 years old	0.0579
BI: 35-64 years old	0.2279

Table 47: Age (H5) t-test

	VALUES
Test Statistic	-0.3966
P-value	0.6967

c) Hypothesis 6

For Gender vs BI (H6), a normality test was also performed and as illustrated in Table 48, both groups adhered to the normality assumptions, meaning that a t-test was appropriate.

Table 48: Gender (H6) Normality Test

BI: Females	0.7154
BI: Males	0.5816

Table 49: Gender (H6) t-test

	VALUES
Test Statistic	0.1007
P-value	0.9204

d) Hypothesis 7

In the case of the Experience vs BI (H7), since we had at least three individuals in each experience group, we used the Kruskal-Wallis test, the nonparametric alternative to ANOVA, to compute the differences in means. This test can perform multiple comparisons across more than two groups to test for significant differences. This nonparametric approach was used over the parametric method (ANOVA) due to the sample size requirement of at least five per group not being met. Note that even when the groups were merged, the same conclusion was reached (non-significance).

Table 50: Experience vs BI (H7) Kruskal Willis Test

	VALUES
Test Statistic	7.513
P-value	0.1112

The p-value for this Kruskal-Wallis test was 0.1112, which indicated that we would not reject the null hypothesis and that there was no significant difference between experience levels for BI at a 5% level.

e) Hypothesis 8

The Kruskal-Wallis test approach was used here to compare the multiple groups. Note that there were no participants with primary or secondary school education only.

Table 51: Education Level (H8) Kruskal-Wallis Test

	VALUES
Test Statistic	1.152
P-value	0.5621

The p-value for this Kruskal-Wallis test was 0.5621 which indicated that we would not reject the null hypothesis and conclude that there is no significant difference between education levels for BI at a 5% level.

f) Summary of hypothesis test results

Table 52: Summary of hypothesis test results

HYPOTHESIS NUMBER	HYPOTHESIS	RESULT
H1	*Urban farmer's behavioural intention to use IoT technology will be influenced if they feel it will improve their current operations (BI vs PE)*	***Not Supported***
H2	*Urban farmers' behavioural intention to use IoT technology will be influenced if they feel that the technologies are not difficult to use (BI vs EE)*	***Supported***
H3	*Urban farmers' behavioural intention to use IoT technology is influenced by social influence (BI vs SI)*	***Supported***
H4	*Urban farmers' behavioural intention to use IoT is influenced by sustainability (BI vs SUS)*	***Not Supported***
H5	*Age plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Age)*	***Not Supported***

H6	*Gender plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Gender)*	***Not supported***
H7	*Experience plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Experience)*	***Not supported***
H8	*Education level plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Education)*	***Not supported***

We noted significant relationships between BI and EE & SI at a 10% level, which indicated that urban farmers' behavioural intention to use IOT will be influenced if they feel that technologies are easy to use, and their behavioural intention is also influenced by social influence. We noted no significant relationships between BI and the moderators.

5.3 QUALITATIVE FINDINGS AND ANALYSIS

For the qualitative data collection, three semi-structured case study interviews were conducted to help explain the quantitative data. The interviews will be discussed under three themes: infrastructure constraints, thoughts on IoT, inaccessibility, the role of sustainability and SDGs in technology, and lockdown's effect on urban farm operations and IoT adoption.

Theme 1: Infrastructure constraints

Respondents were asked about the type of technology they were currently using in their operations. Excerpts from their responses were:

"Well, I will be brutally honest and say I did not know about those things. I knew that those things existed in isolation, but not in so far as they pertain to agriculture. So, I went, and I learned how do you improve systems. That is where I learned about precision farming. That is when I learned about precision farming, even though hydroponics is a form of precision farming, I wanted to go deeper."

- *Respondent 1*

"…just a normal tunnel with a basic pump and a normal timer for irrigation. You know, it can cost well over 250,000 and I mean you have not even done anything yet, so that is just the NFT system..."

- *Respondent 2*

"For now, I have no technology. Everything is done manually. I do not have anything that is technically programmed besides timers, but honestly speaking, I really love the technology in the agritech space. I want it desperately, where everything can be controlled, because technology will assist you to the level of you understanding the data."

- *Respondent 3*

"I was shocked when I read a book [from] 1985 and I was shocked by how backwards we are. A hydroponic book from 1985! And yet in our technical training, we are not told about that. [I mean it is only coming into fashion now] and it comes in small-scale [sic]. When you look at people growing tomatoes, it is not a 300 square meter tunnel, it is a hectare and you are like, "a hectare of hydroponics?". I have spent so much to get this tunnel, I cannot imagine a hectare. And it is glass, mind you. You know what? We are honestly, honestly behind and yet they still say we do not support hydroponic farming."

- *Respondent 3*

Based on these responses and feedback in the informal discussions, the respondents use a hydroponic system for their farms. They revealed a barrier to entry, which was how load-shedding was already affecting their hydroponic farm systems. IoT systems would suffer the same fate with crucial information getting lost at certain points in time. When the researcher mentioned IoT in relation to their current technologies the urban farmers seemed to regard their current setups as not being technological, except for one who acknowledged that hydroponic farming is a form of precision agriculture. Hydroponic systems are farming technology, but it seems they are not considered a technological advancement.

Figure 23: Rooftop farm in Sandton

Theme 2: Thoughts on IoT

The researcher wanted to understand the urban farmers' perceptions and thoughts on IoT to determine if its adoption is important to them, as well as a general assessment of how much they regard IoT in relation to their operations. Some of the insights were:

"And that is when I learned about AI and sensors and all the things, all the innovation around agriculture and that sparked the interest too. Because I had a bit of an identity crisis, I had things in fintech and crypto currency, still within the innovation spectrum but on the financial side, going … and agriculture as well… Yes, I did not know how to position the company to either go fintech or agriculture, but developments have led more to agriculture, so I focused on that and it is brought about information or access to information on sensors on lasers and all these things that help in precision farming, AI and machine learning."

- *Respondent 1*

"So, I would say from where I am standing, in the past three years that I have been supplying, there's WIBC, which was the [initial] institute that we worked with from 2018 and 2019, and then in 2020 we were working with the Urban Agriculture Initiative and these are basically [sponsors and] major role players in urban agriculture within the CBD, and the technology packages offered within those support programs do not go that far. And I did say that we are starting on a premise that the farmer owns a farm and I'm saying that most farmers do not own farms, and even those ones that do get the hydro urban rooftop farms have got so many problems that it is hard for them to even get to a point [where] they buy their own farm. The understanding then is that you have support systems that help you farm easier, farm better, farm faster, farm smarter and I'm saying now that the only way they have access to that is through research institutions. So, when an institution has a new app or [another small] company, it has another new app they can [test the app on]. So that is the only time they would have access to that type of technology. But they would never be able to then go on an acquisition. And I am talking about people that are doing rooftop farming on less than half a hectare going down. Obviously, if we are talking about one hectare going up to five hectares, it is a different type of farmer, because [that is] an investment they have made on their own to some extent. So, maybe they would have then that that that muscle to then bring in technology so, the idea why the idea when we started was to hopefully get the full suite of an urban farm. To say that, you know, it is got all these sensors, you are basically managing the farm with the sensors that that was the idea, but then the reality is that you know it is probably something that you cannot afford, and you must work towards. But through strategic engagements and strategic partnerships, it is something that you could acquire within two or three years of your operation. So, I do not know if it makes sense to start … but as you are going through the journey, you find that it is a different journey."

- *Respondent 2*

" I see a problem solver to any farmer [sic]. I see a guide to better, smarter ways of doing things. I do not want to say I see an easy way of doing things, because then it would look like I'm lazy, but it is a simpler way of understanding what we are practically doing, and a much quicker turnaround in terms of understanding [sic]. I see a helping hand in understanding, more deep knowledge, and data capturing of the information that would feed you as a human being. Without data, we do not have knowledge, without knowledge we do

not know what we are doing … there is no execution and no further innovation. Innovation comes with time – If you are spending so much time on the farm, creativity does not come. It is like a child who is being told to clean, how will they be creative at school? … a child who is sitting at home and is told not to worry about the dishes or there's someone else responsible for that, or is hired to do that, they are able to read further than what they are told, and even read business books that you do not get to read at school … You do not get to focus on what you need to do; you do not live for the present; you do not get to live within what you would like to do. I believe if we are to use technology, I feel like there would be a lot of innovation from us farmers and people who live in that spectrum on a daily basis. Innovation would grow vastly in that."

- *Respondent 3*

Based on these responses, it is evident that these urban farmers regard IoT and its ability to create interconnectedness quite highly. They seem keen to adopt it to improve their current operations, though they are aware of the constraints and barriers to implementation. It appears that in the initial stages of their businesses, they were not well aware of IoT and were learning about it as they went along, studying the research and attending training programs and workshops.

Figure 24: Rooftop farm in Sandton

Theme 3: Inaccessibility

The researcher asked the respondents whether anyone had guided or influenced them to make use of the technologies they were using or intended to use in the future. Excerpts from the responses are shared below:

"For myself, specifically, hydroponic hops are not something that is generally done by anybody, [it is just me] innovating and testing from the ground [sic] and a lot of good things have come from that. My influence would be from outside of agriculture, because it is a very traditional industry now, especially in South Africa. So, there's nobody I can look to as a mentor to say, you have been an expert in AI farming or tech or machine learning farming … [it always comes] from external industries, people that innovate within their own industries that have inspired me to look within the agricultural sector and be like, 'how can I be this guy of this sector … like an Elon Musk, or [one of those] technical guys...' "

- *Respondent 1*

"So, I think what made us want that for our farm… and I mean it is interesting because, where do you find those ideas and how do those ideas come to you? And I mean, the way it is then presented, or the way you see it… You know it is because for us it was never something that we grew up around … You saw it in companies that you would like to work for, you saw it in in other organisations, you saw it in publications. It was never tangible until we got into the market, so I guess your surroundings feed into you wanting to achieve such or wanting to be part of that … and from a youth perspective, the technology and looking at that type of setup is interesting. You know, it is something you would like to be part of and that is the pull factor."

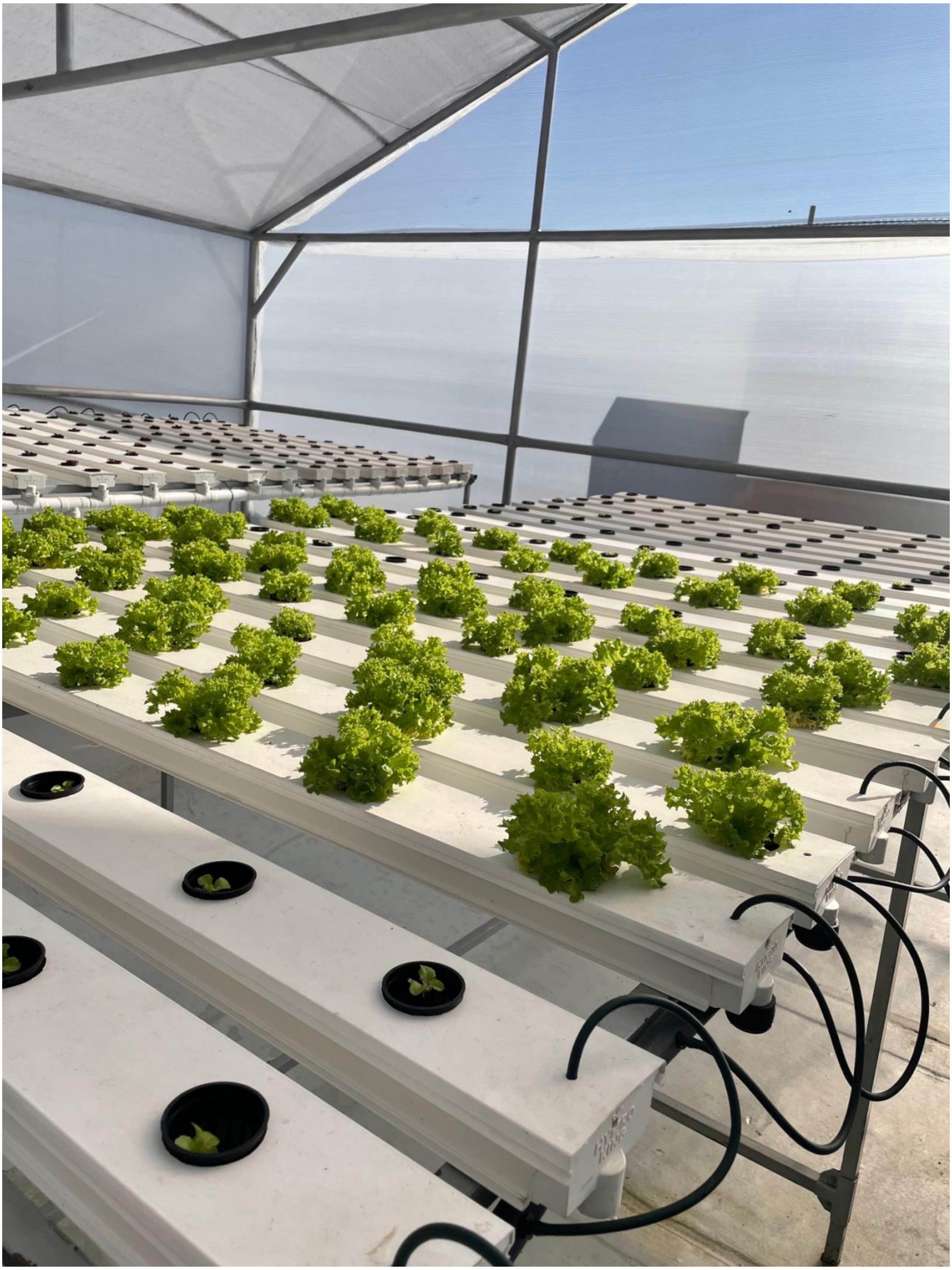
- *Respondent 2*

"It was Rotterdam in the Netherlands. They are the ones that showed me [what] hydroponics is … [and it is] actually possible to get a community to work using technology. If only one can get there…"

- *Respondent 3*

Two of the respondents seemed to be influenced more by nation-states such as the United States, Netherlands, Israel and the UAE, rather than by an individual or a business. This rhetoric was mirrored in the informal interviews, where urban farmers did not have local influences; rather, they were exposed to examples from nation-states or through training programs or by doing their own research. One of the respondents mentions how, for most urban farmers, exposure to innovations happens through research institutions wanting to test out the efficacy of their technological developments and advancements on urban farmers rather than urban farmers embarking on adopting these advancements on their own. This highlights the inaccessibility of IoT and how, in South Africa, larger businesses can access these IoT technologies as they have the capital to do so.

Figure 25: Hydroponic rooftop farm



Theme 4: The role of sustainability and SDGs in technology

The respondents were asked if they had been aware of the United Nations SDGs or the local NDP 2030 goals and if that knowledge informed their decision-making.

"So, I will be honest – no, I did not even know the UN had things like that. I do not even know what the UN does today. So, as I said, for me it was purely business I had no knowledge of agriculture and even know there was a food shortage or farming. From what I knew, everything green gives off oxygen and that is good for the environment, so I did not know it was beneficial for that. Growing and learning and failing and trying and reverse engineering everything. It led me [to] various competitions, and I happened to win the UN Sustainability challenge competition with Indalo Inclusive. I was [in the top three] of their competition for climate action of an industry [sic]. I had to go through an entire incubation program in agriculture, and I think those are beneficial if you know nothing … that is where I learned about sustainability and eco inclusivity, as well as the economic factors that come with agriculture. And I have since built the model of my business around those three pillars of [environmentally] friendly, social responsibility, and economically … empowering [of the] society …"

- *Respondent 1*

"So, we were very, very much aware of the UN sustainability goals. We mostly [align] ourselves to SDG2, which is Zero Hunger. I mean it also goes on to food security [sic]. We essentially fall under supporting food systems within the CBD. So for us, our definition of a food system [starts with] inputs that are needed by the producer and then it is producer and then it is the customer [sic]. So we are saying that we are the backbone of the producer. Which is the smallholder because we support the smallholder and then the smallholder takes to market and that cycle that that system is a full loop. Because after the customer then there's waste and then you know there so. So we see the system as from the producers of seed up until the how the waste is managed and that is the food system in our definition. And we have a specific role to play there."

- *Respondent 2*

"I do not know what you are talking about. If you could explain … Are they on the internet? I have seen the picture, but I never went deep into it. I think I saw it when we were in one of the programs in WIBC."

- *Respondent 3*

After explaining the SDGs to respondent 3, he replied:

"Now that I know, I feel that I am participating, because with my project, I am reducing hunger and poverty, I am bringing sustainability [sic]. I am supplying vegetables to restaurants and they can supply food to their customers and sell directly to households. I would also say that I am energy-efficient in terms of my energy consumption. I do not know if there's water efficiency… No, I could say Climate action maybe? I participate in climate action. I make sure that we do not excrete any harmful (substances) in the runoff that could damage water and other issues we have. And I make sure that whatever I use keeps the water recyclable and that I take care of my environment, basically with the practices that I do here. And I do not use any chemicals on my produce. Lately I have been planting insect retractable crops, like superficial plants like basil and edible flowers to attract bees to pollinate my tomatoes and I try to be as natural as possible, I believe I'm contributing to the world in that manner."

Respondents were asked whether sustainability or sustainable development was considered in the decision-making process, not only to start farming but the technologies that they would use and intend to use in the future:

"I think technology makes it inevitable to start thinking of the efficiencies of traditional whatever it is, whatever aspect you are doing [sic], so [there's an underlying awareness of sustainability]. How do you make it sustainable, cheaper, faster? I do believe in principles, that if you can save time, save money and save resources and still make money, I think technology enables that to happen. And that is the only reason you use technology. You do not do it because it is cool to press things, you just make it easier. So in that sense, I also would not take on a technological product [that] pollutes the environment or makes it worse just because it makes it easier for me … so in the back of my mind, I would say I did choose it because of the sustainability only to learn how unsustainable or desperate of innovation is needed in particular crop growing."

- *Respondent 1*

"So I have to start from a point of access to information and access to the global economy. I mean at that time I do not think we knew a lot. We were coming from these bubbles … from those institutions … but I mean, the full scope of where we were going was never there. But as we constantly engaged and chipped [away] at the idea, things started to come out … then you have to have a mantra, a sustainability mantra, and then you [have to] find ways to say [where your business fits] within the food system … and then trying to articulate yourself to the market [sic]. That is why I'm saying, the education happened [while] we were doing the business."

- *Respondent 2*

"Yes, every farmer wants to be sustainable in what they do. When you go into traditional farming and [understand] why it is not sustainable … the biggest factor is the yield, the amount of water they use, the amount of input that it takes for them to just bring that one crop [sic] and the number of days it takes to get it out, that output. Hence you need so much land. Being sustainable for me, I'm still in my 20s and land is an issue to get now, and with it being an issue, I sat and thought "If I go with hydroponics, what could be the sustainable factor if I do it?". It is quite difficult to be sustainable with one farm. It is difficult because we compete with open-field farmers and the pricing itself, we are still seen the same, hence you find out that most hydroponic farmers are [expensive] because they [have] one tunnel and it does not balance most of the time with your return on your investment or the investment you have put in to see quicker returns on it [sic]. But the advantage of it is that you are yielding better than an open-field farmer. But imagine if you were yielding like that with the same amount of land as a farmer, your return on investment would move to four years instead of 20 to 30 years … and it would make your life much better, much easier. Sometimes, honestly speaking, your market plays a role, and you find that it is one of the issues that we got when we got to the township where we were starting to sell into the market and we saw that this type of lettuce, it is not easily responsive [sic]. There is a lot of teaching that you have got to do. We suffered for months before we could even see a thousand rands [sic] and we were happy. [A lot of teaching had] to happen, but in that teaching, when it happens, the business is running … that is when you find the glitches of urban farming and hydroponics. In the end, you do want to be sustainable. [But we] do not quit because we

know you can be sustainable [if say] you get an angel investor that believes in you and says, “ten tunnels, go for it” … and you just put in your tomatoes and you are gone. Or “five tunnels, there you are”. But because you are starting small, even though you are yielding better, but sustainability, we are breaking even [more often] than a person who has the same square meters in an open field. That is what you can compare it to, but we are still far from sustainability with one tunnel because it is so difficult to hire someone you can pay just three thousand, seven hundred rands … just [an average] salary … It is hard, very hard, but we try to strive though those things and we break even in some other points [sic], and we hope that in the long run, we can become sustainable like commercial farmers. We will get there, but with growth.”

- *Respondent 3*

Only one respondent was fully aware of the UN SDGs and their operations were underpinned by SDG 2. The others were not aware of the SDGs or the local NDP 2030 but were in tune with the concepts of sustainability and sustainable development, and their operations and initial business ideas were led by these concepts.

Figure 26: Hops rooftop farm

Theme 5: Lockdown's effect on urban farm operations and IoT adoption

South Africa's lockdown was considered one of the most restrictive in the world, with its citizens only allowed to leave their houses for grocery shopping and essential medical care (Stiegler & Bouchard, 2020). This created a set of challenges for urban farmers and their operations. The respondents were asked how the lockdown measures affected the operations of their businesses, and these are quotes from the responses:

"During lockdown, I was very fortunate because my farm was still being built up, so it had not been up [sic]. I was not losing money; it was still being built [using] grant funding and sponsored and won funding … As we came out of it, I managed to harvest within that year and send it off. And like I said, it was a commercial test, I used it for PR to prove that this thing is possible and was viable and [it has] brought a lot of good attention because with everybody being at home, they could see what was happening. People were not rushing around and just like seeing it by chance, everybody saw it and applauded me for it. But one thing that came from the lockdown, I think that was serendipitous, was that where I have always focused [exclusively on] microbrewing the specific crops that I grow, which is hops … I did research outside of the brewery because, [due to] lockdown, there was the alcohol ban as well. So, I could not supply my ideal client because [no one was] ordering. I had already started doing research on other uses of hops, since I could grow it outside of where it is traditionally grown, I looked at who I could supply and essential oils and hops had incredible benefits, so people that use oil extraction [as well as] chefs reached out to me because they learned about the taste that hops give, when you sear it on steaks, [it gives] a nice buttery flavour that people like. So, I got the orders from different people, but [during the] hard lockdown there was generally no movement. Nobody was ordering. But it allowed me to research other clients and not focus primarily on brewing."

- *Respondent 1*

So, lockdown was a challenge and still is. To some extent it was good, because we actually got a full view of the underlying socio-economic challenges within the fabric of society. It just highlighted why we need such businesses or small to medium enterprises that focus on these issues. So that was the plus because before it was just, you know, it was just behind under the surface to some extent more like not really partaking in the formal economy. So right now, it has been brought to light, and you have had instead initiatives by solidarity fund *me to support homestead farmers and things like that, whereby they give out money to maintain the food security within the country. But also, it destroyed and pulled the market back. Agriculture was the highest performer from a GDP perspective up. But this is because it was also an essential service. But then, a lot of people got out of business also, so you know it was. It was up and down. It was not the easiest environment to [operate in].*

- *Respondent 2*

"[It was] hard because we depend on restaurants, and we depend on them because of their willingness to buy at the price that we want. When lockdown happens, you crumble because you wonder where you were going to sell your vegetables. Produces wilts. Mine did not wilt, but other farmers were complaining that their produce is wilting on the system and now you are adding to the food waste issue that you are trying to mitigate because of how the economy is going. I found a way to try to sell to the public, but it did not meet those quantities because when you see to the public, instead of taking two hours harvesting 4kgs, I take 32 hours for 400 grams or 200 grams. We got hit hard. I got hit hard by the first lockdown that happened, my first business ate into my savings because I had to maintain paying for electricity [sic]. We were closed for four months, the first level 5. That is the issue with why we cannot go to the DC, we cannot meet the volume. The first one hit hard, the second one got better. When it came, I was prepared, I sold to households which made it better to survive. But to pay up for water, you cannot even get one resource to come and assist, you cannot even go and deliver in Krugersdorp because you are limited to a radius [within] Sandton. It is hard when COVID comes, very hard."

- *Respondent 3*

Based on the above responses, respondents experienced challenges in their operations during the lockdown and particularly hard lockdown, which was to be expected as the impact was felt across South Africa and the rest of the world. The respondents were, however, able to come up with innovative ways to reach their markets during subsequent lockdown adjustments, having learned from the initial hard lockdown. Some urban farmers did not experience the same fate. During the informal interviews, the researcher noted a few businesses were forced to close. Farms that supplied produce such as microgreens seemed to be hit quite hard. Some businesses had to take part in agro-processing as their produce could not reach their main clientele which were restaurants, especially fine dining restaurants. This farmer then made products such as passata from the heirloom tomatoes they were growing to supply households.

Figure 27: Hops rooftop farm

When asked whether lockdown affected their intention to take on IoT or more agritech, the respondents said the following:

"I'm still going to go for it regardless because it is something I have been pursuing [since 2016]. So, it was something I was always going to do … as I said, the innovation company and I are trying to innovate the hop industry [sic] only to stumble onto other things, which I think are working out amazing as we speak. But regardless, I think lockdown was not going to deter me. I think once you put a hard lock on everything or you say no operations. I do not think there's a business that can survive that level 5 lockdown. Nobody leaves the house. I do not think a hop innovation changes any of that. Yeah, but if businesses are operational, it is open to a lot of industries."

- *Respondent 1*

"From an operational logistics point of view, the uptake [went up considerably] because we had to now find ways to deliver to the customer and access channels … From a cost perspective it went down because now we had to cut things that we could not afford in operations. So yeah, the uptake went up, but some of the barriers were costs."

- *Respondent 2*

The farmers felt that innovation had become the norm and that, looking to the future, it was required for their businesses to remain operational. Respondent three's operations were manual, and they had no technologically programmed devices besides timers for irrigation, so IoT was not going to be a consideration even during the lockdown, seeing that they faced several struggles during that period.

5.4 CONCLUSION

In this chapter looked at the quantitative findings from 32 survey questionnaire responses. The hypothesis testing was discussed, and it was found that there are only significant relationships between EE and BI and SI and BI. The qualitative findings from the semi-structured interviews and the informal discussion were also presented. The next chapter concludes the study.

6 CONCLUSION

6.1 INTRODUCTION

This chapter summarises the key findings and discusses the findings in relation to answering the research questions posed in Chapter 1. The theoretical, methodological, and practical contributions are summarised. Finally, further research recommendations are identified.

6.2 SUMMARY OF FINDINGS

Based on the quantitative findings, these were the results of the hypothesis tests.

HYPOTHESIS NUMBER	HYPOTHESIS	RESULT
H1	*Urban farmer's behavioural intention to use IoT technology will be influenced if they feel it will improve their current operations (BI vs PE)*	***Not Supported***
H2	*Urban farmers' behavioural intention to use IoT technology will be influenced if they feel that the technologies are not difficult to use (BI vs EE)*	***Supported***
H3	*Urban farmers' behavioural intention to use IoT technology is influenced by social influence (BI vs SI)*	***Supported***
H4	*Urban farmers' behavioural intention to use IoT is influenced by sustainability (BI vs SUS)*	***Not Supported***
H5	*Age plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Age)*	***Not Supported***
H6	*Gender plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Gender)*	***Not supported***

H7	*Experience plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Experience)*	***Not supported***
H8	*Education level plays a moderating role in urban farmers' behavioural intention to use IoT (BI vs Education)*	***Not supported***

6.3 FINDINGS IN RELATION TO EACH RESEARCH QUESTION

6.3.1 SUB RESEARCH QUESTIONS

How do farmers perceive themselves and their farms concerning sustainability and the Sustainable Development Goals?

Most farmers were fully aware of the UN SDGs and their operations were underpinned by SDG2. The respondents who were not aware of the SDGs or the local NDP 2030 were, however, in tune with the concepts of sustainability and sustainable development and their operations and initial business ideas were led by these concepts.

What are the factors that influence urban farmers' intention to use IoT?

Ease of use and social influence. If farmers believe that IoT is not difficult to use and becoming skilful at using it would be easy, then that would influence their behavioural intention. Additionally, if senior management and the people in their business were helpful and supportive of their use of IoT then that would influence their behavioural intention.

How do urban farmers assess their readiness to integrate IoT into their farm management?

This question was not answered.

What are urban farmers' thoughts and perceptions on IoT technology amid growing demands by the urban population?

Urban farmers regard IoT and how it brings interconnectedness quite highly and they expressed interest in eventually adopting it to improve their operations. It appears that in the initial stages of their businesses, they were not aware of IoT and were learning about it through research and various training programs.

How were urban farmers' intentions to adopt IoT affected by lockdown?

Farmers experienced challenges in their operations during lockdown, particularly the 'hard' lockdown, which was to be expected as the impact was felt across South Africa and the rest of the world. Since the farmers were not using IoT, it cannot be said with utmost certainty that their behavioural intention was affected, as priorities shifted during COVID. Farmers were aware of the costs involved and wanted to meet immediate needs. They had to come up with innovative ways to sell to their markets after learning from the initial hard lockdown. Some urban farmers did not experience the same fate, as many businesses were forced to close. The uncertainty, coupled with the loss of income undoubtedly affected the behavioural intention of many. Farms that supplied produce such as microgreens were seemingly hit quite hard. Some businesses had to take part in agro-processing as their produce could not reach their regular clientele which were restaurants, especially fine dining restaurants. One farmer innovated by making products such as passata from the heirloom tomatoes they were growing to supply households.

6.3.2 MAIN RESEARCH QUESTION

Main research question: How influential is sustainability urban farmers' intention to use IoT?

Based on the findings, urban farmers who agreed and strongly agreed with the sustainability-related questions were in the majority. Most urban farmers who strongly agreed were farmers who said they are willing to do what they can to ensure that their farm is sustainable; accounting for almost 72% of the sample. As well as how 50% of the urban farmers believed that their farms can be more sustainable using IoT. The hypothesis test, however, revealed that there is a non-significant relationship between sustainability and behavioural intention. The qualitative results show that respondents are aware of IoT but there are certain limitations to accessing them, including infrastructure constraints such as load-shedding and a lack of representation, which then limits access to IoT technology – partly due to cost constraints. The farmers are aware of the concept of sustainability and have embedded sustainable development practices and mantras into their operations. This shows that despite their awareness of sustainability and how they deem it important, their behavioural intention to use IoT is not determined by sustainability. Based on the results, sustainability is therefore not very influential in comparison to how easy adopting and using IoT and the influence of people they deem important to them.

6.4 SUMMARY OF CONTRIBUTIONS

The research made theoretical, methodological, and practical contributions which are discussed below.

6.4.1 Theoretical Contributions

The following theoretical contributions were made:

- The study contributed to UTAUT through the addition of sustainability as a key construct which is in line with recommendations made by Venkatesh et al. (2003). Doing this contributes to making the theory more robust.
- The study also contributed theoretically by applying it to a sample that has not been evaluated before.
- The final contribution is that the adapted UTAUT model can be used again in studying the same or a similar sample, with the limitations taken into consideration.

6.4.2 Methodological

The following methodological contributions were made:

- The data collection process took place virtually and in-person, adding to the level of detail that was captured. Semi-structured interviews were held, but during the in-person and telephonic questionnaire survey process the researcher was also able to have informal interviews with urban farmers who were unable to take part in the semi-structured interviews due to time constraints or were apprehensive to share information.
- During the questionnaire process, the researcher was able to browse through the farms to see the technologies that were used, if any. This enriched the process and the data as it provided the researcher with more detail and understanding to better inform the findings.

6.4.3 Practical

The following practical contributions were made:

- The researcher visited a few of the farms during the data collection process and was able to see their operations. This happened after the virtual process did not yield enough questionnaire survey results to allow for statistical analysis of the constructs and the moderators. Not only did the in-person visits increase the sample, but they allowed the researcher to connect with the respondents in a way that was not possible under the stricter COVID-19 restrictions. The in-person visits showed a level of care and compassion that enriched the collection process.

- The researcher was given access to a Khula! app WhatsApp support group where farmers across the country support one another and share research and opportunities with each other. This helped the researcher understand that there is a growing community of farmers, despite some being competitors, who support one another. The researcher was able to see how developers of 4AR systems and technologies can contribute to creating this community of farmers.

6.5 FUTURE RESEARCH

Urban farmers in Gauteng have not adopted IoT technology as the adoption of greenhouse, vertical, hydroponic and aquaponic farming systems and technologies currently take priority in the innovative urban agriculture space. The researcher recommends that the adoption and use of these technologies should be studied in relation to UTAUT as they reach the maturity stage. The researchers can have the option to use the UTAUT model in its entirety without having to focus only on behavioural intention. The fact that the sample was limited to one province is one of the reasons the sample size was so small, as urban farming via greenhouse tunnels and hydroponic systems is extremely niche at present. As such, it is recommended that researchers focus on urban farming throughout South Africa, as larger samples will enable statistical analytical methods like PLS and SEM. Although IoT technology is not being adopted at the moment, this should not dissuade researchers from conducting a round of data collection in the next few years as, based on the descriptive findings, a majority of the participants intend to start using IoT technology within three months from when the data was collected.

7 REFERENCES

Aberman, N. L., Meerman, J., & van de Riet, A. (2022). Gender-Inclusive Governance of Urban Food Systems For Improved Food Security and Nutrition. GAIN Working Paper. 25. Geneva, Switzerland. https://doi.org/10.36072/wp.25

Adams, J. S. (1963). Toward an understanding of inequity–Journal of abnormal and social psychology. Washington: American Psychological Association. (67), pp. 422-436.

Addicott, J. E. (2020). The precision farming revolution: global drivers of local agricultural methods. Palgrave Macmillan, Springer Nature Singapore Pte. https://doi.org/10.1007/978-981-13-9686-1

Adenle, A., Azadi, H., & Manning, L. (2018). The era of sustainable agricultural development in africa: Understanding the benefits and constraints. *Food Reviews International, 34*(5), 411-433. doi:10.1080/87559129.2017.1300913

Agyeman, J., & Evans, B. (2004). 'Just sustainability': the emerging discourse of environmental justice in Britain?. *Geographical Journal*, *170*(2), 155-164.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In *Action control* (pp. 11-39). Springer, Berlin, Heidelberg.

Ajzen, I. (1991). The theory of planned behavior. Organizational behavior and human decision processes, 50(2), 179-211.

Amankwah-Amoah, J., Osabutey, E., & Egbetokun, A. (2018). Contemporary challenges and opportunities of doing business in Africa: The emerging roles and effects of technologies. Technological Forecasting & Social Change, 131, 171-174. doi:10.1016/j.techfore.2018.01.003

American Planning Association. (2016). The Sustainability Policy Framework. Accessed 20 October 2022 from https://planning- org-uploaded-media.s3.amazonaws.com/document/Sustainability-Policy-Framework.pdf.

An, L., Han, Y., & Tong, L. (2016, May). Study on the factors of online shopping intention for fresh agricultural products based on UTAUT2. In The 2nd Information technology and mechatronics engineering conference (ITOEC 2016) (pp. 303-306). Atlantis Press.

Arias, R., Lasse Lueth, K., & Rastogi, A. (2018). The Effect of the Internet of Things on Sustainability. World Economic Forum. Accessed 06 June 2021 from https://www.weforum.org/agenda/2018/01/effect-technology-sustainability-sdgs-internet-things-iot/

Arif, H. S., Janet, F. B., & Dora, M. (2019). A framework for integrating agriculture in urban sustainability in Australia. Urban Science, 3(2). https://doi.org/10.3390/urbansci3020050

Armanda, D. T., Guinée Jeroen B, & Tukker, A. (2019). The second green revolution: innovative urban agriculture's contribution to food security and sustainability - a review. Global Food Security, 22, 13–24. https://doi.org/10.1016/j.gfs.2019.08.002

Armitage, C. J., & Conner, M. (2001). Efficacy of the theory of planned behaviour: A meta-analytic review. British journal of social psychology, 40(4), 471-499.

Awotunde, J. B., Ogundokun, R. O., Ayo, F. E., Ajamu, G. J., & Ogundokun, O. E. (2021). UTAUT model: integrating social media for learning purposes among university students in Nigeria. SN Social Sciences, 1(9), 1-27. https://doi.org/10.1007/s43545-021-00232-4

Ayentimi, D., & Burgess, J. (2019). Is the fourth industrial revolution relevant to sub-Sahara Africa? Technology Analysis & Strategic Management, 31(6), 641-652. doi:10.1080/09537325.2018.1542129

Babbie, E. (1990). The essential wisdom of sociology. Teaching Sociology, 18(4), 526–30.

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: a sustainability perspective. International Journal of Production Economics, 229. https://doi.org/10.1016/j.ijpe.2020.107776

Bain, L. J., & Engelhardt, M. (1992). Introduction to probability and mathematical statistics (2nd ed., Ser. The duxbury advanced series in statistics and decision sciences). Duxbury Press.

Basu, S., & Fernald, J. (2009). What do we know (and not know) about potential output? Review (00149187), 91(4).

Battersby, J. (2011). Urban food insecurity in Cape Town, South Africa: an alternative approach to food access. Development Southern Africa, 28(4), 545–561. https://doi.org/10.1080/0376835X.2011.605572

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. Qualitative Report, 13(4), 544-559.

Benbasat, I., Goldstein, D. K., & Mead, M. (1987). The case research strategy in studies of information systems. MIS Quarterly, 11(3), 369–369.

Bhattacherjee, A. (2012). Social science research: Principles, methods, and practices.

Biesta, G. (2010). Pragmatism and the philosophical foundations of mixed methods research. Sage handbook of mixed methods in social and behavioral research, 2, 95-118

Bisaga, I., Parikh, P., & Loggia, C. (2019). Challenges and opportunities for sustainable urban farming in South African low-income settlements: A case study in Durban. Sustainability, 11(20), 5660–5660. https://doi.org/10.3390/su11205660

Blumer, H. (1986). Symbolic interactionism: perspective and method. University of California Press.

Bonabana-Wabbi, J. (2002). Assessing factors affecting adoption of agricultural technologies: The case of Integrated Pest Management (IPM) in Kumi District, Eastern Uganda (Doctoral dissertation, Virginia Tech).

Boursianis, A. D., Papadopoulou, M. S., Diamantoulakis, P., Liopa-Tsakalidi, A., Barouchas, P., Salahas, G., Karagiannidis, G., Wan, S., & Goudos, S. K. (2022). Internet of things (IoT) and agricultural unmanned aerial vehicles (UAVs) in smart farming: a comprehensive review. Internet of Things, 18. https://doi.org/10.1016/j.iot.2020.100187

Braa, K., & Vidgen, R. (1999). Interpretation, intervention, and reduction in the organizational laboratory: a framework for in-context information system research. Accounting, Management and Information Technologies, 9(1), 25-47.

Bryman, A. (2012). Social research methods (4th ed.). Oxford University Press.

Brent, A., Drimie, S., Musango, J. & von Loeper, W. (2016). Analysing challenges facing smallholder farmers and conservation agriculture in South Africa: A system dynamics approach. South African Journal of Economic and Management Sciences , 19(5), 747-773. https://dx.doi.org/10.17159/2222-3436/2016/v19n5a5

Brooke, C. (2002). What does it mean to be `critical' in is research? Journal of Information Technology : Jit, 17, 49-58.

Bryman, A. (2016). Social research methods. Oxford university press.

Bucci, G., Bentivoglio, D., & Finco, A. (2018). Precision agriculture as a driver for sustainable farming systems: state of art in literature and research. Calitatea, 19(S1), 114-121.

Byrne, B. M. (2016). Structural equation modeling with AMOS : basic concepts, applications, and programming (Third, Ser. Multivariate applications series). Routledge, Taylor & Francis Group.

Carrion, G., Huerta, M., Barzallo, B., & 2018 IEEE 6th International Conference on Future Internet of Things and Cloud (FiCloud) Barcelona, Spain 2018 Aug. 6 - 2018 Aug. 8. (2018). 2018 IEEE 6th international conference on future internet of things and cloud (ficloud). In Internet of Things (IoT) applied to an urban garden (pp. 155-161). IEEE. doi:10.1109/FiCloud.2018.00030

Castrignanò, A., Buttafuoco, G., Khosla, R., Mouazen, A. M., Moshou, D., & Naud, O. (Eds.). (2020). Agricultural Internet of Things and decision support for precision smart farming. Academic Press.

CGIAR Research Program on Water, Land and Ecosystems (WLE). (2021).Controlled Environment Agriculture for sustainable development: A call for investment and innovation. Colombo, Sri Lanka: CGIAR Research Program on Water, Land and Ecosystems (WLE). 4p. [POLICY BRIEF #9]. Accessed 25 October 2022 from https://ruaf.org/document/controlled-environment-agriculture-for-sustainable-development-a-call-for-investment-and-innovation/

Chaminuka, N., & Dube, E. (2017). Urban agriculture as a food security strategy for urban dwellers: A case study of Mkoba residents in the city of Gweru, Zimbabwe. People: International Journal of Social Sciences, 3(2), 26–45. https://doi.org/10.20319/pijss.2017.32.2645

Chaminuka, N., Dube, E., Kabonga, I., & Mhembwe, S. (2021). Enhancing Urban Farming for Sustainable Development Through Sustainable Development Goals. In Sustainable Development Goals for Society Vol. 2 (pp. 63-77). Springer, Cham.

Chang, J.-H., Chiu, P.-S., & Lai, C.-F. (2020). Implementation and evaluation of cloud-based e-learning in agricultural course. Interactive Learning Environments, (2020). https://doi.org/10.1080/10494820.2020.1815217

Chen, W., & Hirschheim, R. (2004). A paradigmatic and methodological examination of information systems research from 1991 to 2001. Information systems journal, 14(3), 197-235. https://doi.org/10.1111/j.1365-2575.2004.00173.x

Chen, L., Rashidin, M. S., Song, F., Wang, Y., Javed, S., & Wang, J. (2021). Determinants of consumer's purchase intention on fresh e-commerce platform: Perspective of UTAUT model. Sage Open, 11(2), 215824402110278–215824402110278. https://doi.org/10.1177/21582440211027875

City of Cape Town. (2007). Urban Agriculture Policy for the City of Cape Town. Accessed 10 June 2021 from www.capetown.gov.za/en/ehd/Documents/EHD_Urban_Agricultural_Policy_2007_8102007113120.pdf.

Cobbinah, P. B., Erdiaw-Kwasie, M. O., & Amoateng, P. (2015). Rethinking sustainable development within the framework of poverty and urbanisation in developing countries. Environmental Development, 13, 18–32. https://doi.org/10.1016/j.envdev.2014.11.001

Creswell, J. W., & Clark, V. L. P. (2017). Designing and conducting mixed methods research. Sage publications.

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Cronen, V. E. (2001). Practical theory, practical art, and the pragmatic-systemic account of inquiry. Communication theory, 11(1), 14-35.

Culwick Fatti, C. (2021). Just sustainability in cities. In C. Culwick Fatti (Ed.), In pursuit of just sustainability (pp. 13–23). GCRO Research Report No. 12. Johannesburg: Gauteng City-Region Observatory. https://doi.org/10.36634/UIAB1074

Davis, F. D. (1986). A technology acceptance model for empirically testing new end-user information systems : theory and results (dissertation).

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. https://doi.org/10.1287/mnsc.35.8.982

Deane, P. (1979). The first industrial revolution (2d ed.). Cambridge University Press.

Deloitte. (2017). The Fourth Industrial Revolution is here – are you ready?. Accessed 20 October 2022 from https://www2.deloitte.com/cn/en/pages/consumer-industrial-products/articles/industry-4-0-technology-manufacturing-revolution.html

Department of Agriculture, Forestry and Fisheries. (2012). A framework for the development of smallholder farmers through cooperatives development. Pretoria: Directorate Cooperative and Enterprise Development Department of Agriculture, Forestry and Fisheries.

Dewey, J. (1998). The essential Dewey: Pragmatism, education, democracy (Vol. 1): Indiana University Press.

Doss, C. (2001). Designing Agricultural Technology for African Women Farmers: Lessons from 25 Years of Experience. World Development 29(12): 2075- 2092.

Doss, C., & Raney, T. (2011). The role of women in agriculture (Esa working paper, 11-02). Rome: FAO, Agricultural Development Economics Div. (2011). Retrieved June 21, 2019, from AgEconSearch.

Drechsel, P., Keraita, B., Cofie, O. O., & Nikiema, J. (2015). Productive and safe use of urban organic wastes and wastewater in urban food production systems in low-income countries. Cities and Agriculture–Developing Resilient Urban Food Systems, 162-191.

Dulle, F., & Minishi-Majanja, M. K. (2011). The suitability of the unified theory of acceptance and use of technology (UTAUT) model in open access adoption studies. Information Development, 27(1), 32–45.

Eastwood, R., Lipton, M., & Newell, A. (2010). Handbook of agricultural economics. In *Chapter 65 farm size* (pp. 3323-3397). Elsevier B.V. doi:10.1016/S1574-0072(09)04065-1

Eweoya, I., Okuboyejo, S. R., Odetunmibi, O. A., & Odusote, B. O. (2021). An empirical investigation of acceptance, adoption and the use of e-agriculture in Nigeria. Heliyon, 7(7), 07588. https://doi.org/10.1016/j.heliyon.2021.e07588

FAO. (2007). The State of Food and Agriculture: Paying Farmers for Environmental Services. Food and Agriculture Organisation of the United Nations. Accessed 20 June 2021 from https://www.fao.org/3/a1200e/a1200e.pdf

FAO (2017). France and FAO renew partnership on sustainable agriculture and climate change, Food and Agriculture Organization of the United Nations. Accessed on 5 September 2022 from https://www.fao.org/newsroom/detail/France-and-FAO-renew-partnership-on-sustainable-agriculture-and-climate-change/en

FAO. (2017). Soil Organic Carbon: The Hidden Potential. Food and Agriculture Organisation of the United Nations. Accessed on 13 August 2022 from http://www.fao.org/3/a-i6937e.pdf%20

FAO, Rikolto and RUAF. (2022). Urban and peri-urban agriculture sourcebook – From production to food systems. Accessed 25 October 2022 from https://www.fao.org/3/cb9722en/cb9722en.pdf

Fishbein, M., & Ajzen, I. (1975). Belief, attitude, intention, and behavior : an introduction to theory and research (Ser. Addison-wesley series in social psychology). Addison-Wesley Pub.

Frayne, B., McCordic, C., & Shilomboleni, H. (2014). Growing out of poverty: Does urban agriculture contribute to household food security in Southern African cities?. In Urban forum (Vol. 25, No. 2, pp. 177-189). Springer Netherlands.

Frayne, B., McCordic, C., & Shilomboleni, H. (2016). The mythology of urban agriculture. In Rapid urbanisation, urban food deserts and food security in Africa (pp. 19-31). Springer, Cham.

Galal, S. (2022). South Africa: Digital population as of January 2022. Statista. Accessed 20 September 2022 from https://www.statista.com/statistics/685134/south-africa-digital-population/

Game, I. & Primus, R. (2015). Global Sustainable Development. Report, 2015 Edition. Advance Unedited Version. Economic and Social Affairs, United Nations, p. 198.

Garfield, M. (2005). Acceptance of ubiquitous computing. Information Systems Management, 22(4), 24–31.

Godin, G., & Kok, G. (1996). The theory of planned behavior: a review of its applications to health-related behaviors. American Journal of Health Promotion, 11(2), 87–98.

Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. European journal of information systems, 21(2), 135-146.

Gosavi, J. V. (2017). Water monitoring system for hydroponics agriculture. International Journal for Research in Applied Science and Engineering Technology, 5(7), 234-238.

Granato, J., Inglehart, R., & Leblang, D. (1996). The effect of cultural values on economic development: Theory, hypotheses, and some empirical tests. American Journal of Political Science, 40, 607–631.

Greene, J. C. (2007). Mixed methods in social inquiry (1st ed.). Jossey-Bass.

Guliwe, T. (2019). The fourth industrial revolution and the future of the labour intensive sectors in the developing countries : "the hailstorm in a cup of tea". Africagrowth Agenda, 16(1), 14-18.

Gunawan, M. C., & Fakhruddin, F. (2019, January). Does Technology Influence Female Farmer Income? Case Study in Pidie District, Aceh. In 1st Aceh Global Conference (AGC 2018). Atlantis Press.

Habermas, J., & Habermas, J. (1971). Toward a rational society: Student protest, science, and politics (Vol. 404). Beacon Press.

Hamid, E. B., & Mohammad, S. A. (2018). Transition towards sustainability in agriculture and food systems: role of information and communication technologies. Information Processing in Agriculture, 5(4), 456–464. https://doi.org/10.1016/j.inpa.2018.06.006

Han, H., Xiong, J., & Zhao, K. (2021). Digital inclusion in social media marketing adoption: the role of product suitability in the agriculture sector. Information Systems and E-Business Management, (20210512). https://doi.org/10.1007/s10257-021-00522-7

Harrington, L. (2016). Sustainability theory and conceptual considerations: A review of key ideas for sustainability, and the rural context. Papers in Applied Geography, 2(4), 365-382. doi:10.1080/23754931.2016.1239222

Hartwick, J., & Barki, H. (1994). Explaining the role of user participation in information system use. Management Science, 40(4), 440–465. https://doi.org/10.1287/mnsc.40.4.440

Haysom, G. (2010). Urban agriculture in the city of Cape Town. Sustaining Cape Town: Imagining a Liveable City, 211-226. African Sun Media

He, K., Zhang, J., & Zeng, Y. (2020). Households' willingness to pay for energy utilization of crop straw in rural China : based on an improved UTAUT model. Energy Policy, 140. https://doi.org/10.1016/j.enpol.2020.111373

Heeks, R. (2018). Information and communication technology for development (ICT4D) (Ser. Routledge perspectives on development). Routledge, Taylor & Francis Group.

Heeks, R., & Ospina, A. V. (2016). Measuring and intervening on resilience: The RABIT approach. Centre for Development Informatics, University of Manchester, UK.

Hovorka, A. J. (2006). The No. 1 Ladies' Poultry Farm: A feminist political ecology of urban agriculture in Botswana. Gender, Place & Culture, 13(3), 207-225.

Huseman, R., Hatfield, J., & Miles, E. (1987). A new perspective on equity theory: The equity sensitivity construct. The Academy of Management Review, 12(2), 222-222. doi:10.2307/258531

IAASTD. (2008). Agriculture at a Crossroads: Global Summary for Decision Makers. Accessed 25 July 2021 from http://www.agassessment.org/

Ilaria, Z., Massimo, C., Gianluca, E., Maria, G., & Andrea, C. (2019). Revolution 4.0: Industry vs. agriculture in a future development for SMEs. Processes, 7(1). doi:10.3390/pr7010036

Imperatives, S. (1987). Report of the World Commission on Environment and Development: Our common future. Accessed Feb, 10, 1-300.

IoD (2016) King IV report on corporate governance for South Africa 2016. Sandton: Institute of Directors. Retrieved October 26, 2022, from https://www.adams.africa/wp-content/uploads/2016/11/King-IV-Report.pdf

IoT Week. (2017). Internet of Things declaration to achieve the sustainable development goals. IoT Week. Accessed 06 June 2021. https://iotweek.org/internet-of-things-declaration-to-achieve-the-sustainable-development-goals/

ISPA. (2018). Precision Agriculture definition. Accessed 20 October 2022, from https://www.ispag.org/about/definition.

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 and Industrial Marketing, 33(6), 804–821. https://doi.org/10.1108/JBIM-01-2018-0023

Johnson, N., Kovarik, C., Meinzen-Dick, R., Njuki, J., & Quisumbing, A. (2016). Gender, assets, and agricultural development: Lessons from eight projects. World Development, 83, 295-311. doi:10.1016/j.worlddev.2016.01.009

Jonah, C. M. P., & May, J. D. (2020). The nexus between urbanization and food insecurity in South Africa: Does the type of dwelling matter? International Journal of Urban Sustainable Development, 12(1).

Joshi, K. (1989). The measurement of fairness or equity perceptions of management information systems users. Mis Quarterly, 13(3), 343-343. doi:10.2307/249010

Joshi, K. (1990). An investigation of equity as a determinant of user information satisfaction. Decision Sciences, 21(4), 786-807. doi:10.1111/j.1540-5915.1990.tb01250.x

Karahanna, E., Straub, D. W., & Chervany, N. L. (1999). Information technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs. Mis Quarterly, 23(2), 183–213.

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., ... & Svedin, U. (2001). Sustainability science. Science, 292(5517), 641-642.

Khan, S., Alam, M., & Wani, M. M. (2020). IoT applications in urban sustainability. Arxiv, (2020 07 23).

Khatami, R. , Hanaei, T. , Daneshvar, M. (2020). 'A Short Survey of Integrating Urban Agriculture and Environmental Planning'. World Academy of Science, Engineering and Technology, Open Science Index 158, International Journal of Environmental and Ecological Engineering, 14(2), 59 - 62.

Khosla, R. (2010). Precision agriculture: challenges and opportunities in a flat world. In 19th World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia.

Korir, S. C., Rotich, J. K., & Mining, P. (2015). Urban agriculture and food security in developing countries: a case study of Eldoret municipality, Kenya.

Krauss, S. (2015). Research paradigms and meaning making: a primer. The Qualitative Report, (20150120). https://doi.org/10.46743/2160-3715/2005.1831

Kshetri, N. (2022). Economics of the internet of things in sub-Saharan Africa. It Professional, 24(1), 81–85.

Kumari, S. (2017). Review on developing a conceptual framework for technology adoption towards sustainability in agro-based industry. SAMVAD: SIBM Pune Research Journal, 13, 14-19.

Lechman, E. (2015). ICT diffusion in developing countries: towards a new concept of technological take-off. Springer. https://doi.org/10.1007/978-3-319-18254-4

Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. Manufacturing letters, 3, 18-23.

Lee, H.W. & Choudhury, V. (2017). Agriculture 2.0: How the internet of things can revolutionize the farming sector. Accessed 20 June 2021 from http://blogs.worldbank.org/ic4d/ agriculture-20-how-internet - things - can-revolutionize-farming-sector

Lejon, E., & Frankelius, P. (2015). Sweden innovation power – Agritechnica 2015. Jönköping: Elmia.

Li, S., Simonian, A., & Chin, B. A. (2010). Sensors for agriculture and the food industry. The Electrochemical Society Interface, 19(4), 41–46. https://doi.org/10.1149/2.F05104if

Lombard, W. (2017). The 4th industrial revolution: Is it here? Farmbiz, 3(12), 6-7.

Lombardo, S., Sarri, D., Vieri, M., Corvo, L., & 8th International Conference on Information and Communication Technologies in Agriculture Food and Environment, HAICTA 2017 8 2017 09 21 - 2017 09 24. (2017). Approaching to the fourth agricultural revolution: Analysis of needs for the profitable introduction of smart farming in rural areas. Ceur Workshop Proceedings, 2030, 521-532.

López, I. D., & Corrales, J. C. (2017). A Smart Farming Approach in Automatic Detection of Favorable Conditions for Planting and Crop Production in the Upper Basin of Cauca River. In *International Conference of ICT for Adapting Agriculture to Climate Change* (pp. 223-233). Springer, Cham.

Lyytinen, K., & Hirschheim, R. (1988). Information systems as rational discourse: An application of Habermas's theory of communicative action. Scandinavian Journal of Management, 4(1), 19-30. doi:10.1016/0956-5221(88)90013-9

Mackenzie, N., & Knipe, S. (2006). Research dilemmas: paradigms, methods and methodology. Issues in Educational Research, 16(2), 193–205.

Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A literature review. Journal of Computer and Communications, 3(05), 164.

Maier, S., & Nair-Reichert, U. (2007). Empowering women through ICT-based business initiatives: An overview of best practices in e-commerce/e-retailing projects. Information Technologies & International Development, 4(2), pp-43.

Malan, N. (2015). Urban farmers and urban agriculture in Johannesburg: Responding to the food resilience strategy. Agrekon, 54(2), 51-75. doi:10.1080/03031853.2015.1072997

Malan, N. (2020). Urban food democracy and governance in north and south. In Service learning and stakeholder action: Technology and education for urban agriculture in Johannesburg, South Africa (pp. 177-191). Cham : Springer International Publishing : Palgrave Macmillan. doi:10.1007/978-3-030-17187-2_11

Malapit, H., & Quisumbing, A. (2015). What dimensions of women's empowerment in agriculture matter for nutrition in Ghana? Food Policy, 52, 54-63. doi:10.1016/j.foodpol.2015.02.003

Maluleke, R. (2021). Quarterly Labour Force Survey (QLFS) Q1: 2021. Stats SA. Department of Statistics South Africa. Accessed 25 October 2022 from http://www.statssa.gov.za/publications/P0211/Presentation%20QLFS%20Q1_2021.pdf

Marivate, V., Aghoghovwia, P., Ismail, Y., Mahomed-Asmail, F., & Steenhuisen SL. The Fourth Industrial Revolution – what does it mean to our future faculty? S Afr J Sci. 2021;117(5/6), Art. #10702. https://doi. org/10.17159/sajs.2021/10702

Maruping, L. M., Bala, H., Venkatesh, V., & Brown, S. A. (2017). Going beyond intention: integrating behavioral expectation into the unified theory of acceptance and use of technology. Journal of the Association for Information Science and Technology, 68(3), 623–637. https://doi.org/10.1002/asi.23699

Mazereeuw B. (2005). Urban Agriculture Report. Region of Waterloo Public Health. Prepared for the Region of Waterloo Growth Management Strategy. p. 28.

Merriam, S. B., & Tisdell, E. J. (2016). Qualitative research: a guide to design and implementation (Fourth, Ser. The Jossey-Bass higher and adult education series). John Wiley & Sons.

Merriam-Webster. (n.d.). Sustainable. In Merriam-Webster.com dictionary. Retrieved October 25, 2022, from https://www.merriam-webster.com/dictionary/sustainable

Michels, M., Bonke, V., & Musshoff, O. (2020). Understanding the adoption of smartphone apps in crop protection. Precision Agriculture : An International Journal on Advances in Precision Agriculture, 21(6), 1209–1226. https://doi.org/10.1007/s11119-020-09715-5

Miller, B., & Atkinson, R. (2014). Raising European productivity growth through ict. Ssrn Electronic Journal. doi:10.2139/ssrn.3079844

Mingers, J. (2001). Combining IS Research Methods: Towards a Pluralist Methodology. Information Systems Research, 12(3), 240–240.

Mireri, C. (2002). Private Investment. URBAN AGRICULTURE, 19.

Mohajan, H. (2019). The first industrial revolution: Creation of a new global human era. Journal of Social Sciences and Humanities, Vol. 5, No. 4, 2019, pp. 377-387

Molina-Maturano, J., Verhulst, N., Tur-Cardona, J., Güereña David T, Gardeazábal-Monsalve Andrea, Govaerts, B., & Speelman, S. (2021). Understanding smallholder farmers' intention to adopt agricultural apps: the role of mastery approach and innovation hubs in Mexico. Agronomy, 11(2), 194–194. https://doi.org/10.3390/agronomy11020194

Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019). IoT and agriculture data analysis for smart farm. Computers and Electronics in Agriculture, 156, 467–474. https://doi.org/10.1016/j.compag.2018.12.011

Myeni, L., Moeletsi, M., Thavhana, M., Randela, M., & Mokoena, L. (2019). Barriers Affecting Sustainable Agricultural Productivity of Smallholder Farmers in the Eastern Free State of South Africa. *Sustainability*, *11*(11), 3003.

Myers, M. D. (2009). Qualitative Research in Business & Management. Sage Publications Ltd.

Myers, M. D., & Avison, D. (Eds.). (2002). Qualitative research in information systems: a reader. Sage.

Myers, M., & Newman, M. (2007). The qualitative interview in is research: Examining the craft. Information and Organization, 17(1), 2-26. doi:10.1016/j.infoandorg.2006.11.001

Mzomwe, M., Tambwe, M., Mapunda, M., & Kirumirah, M. (2021). ICT and Marketing for Agricultural Products: Determinants of Mobile Phone Usage to Small Scale Orange Farmers in Tanzania. Business Education Journal, 10(1).

National Planning Commision (2012). National Development Plan 2030 – Our Future – Make it Work. The Presidency. Retrieved June 17, 2019 from https://www.gov.za/sites/default/files/Executive%20Summary-NDP%202030%20-%20Our%20future%20-%20make%20it%20work.pdf

Namonje-Kapembwa, T., & Thelma, A. (2016). Improved Agricultural Technology Adoption in Zambia: Are Women Farmers Being Left Behind? (No. 1093-2016-87913).

Naudé, W. (2017). Entrepreneurship, Education and the Fourth Industrial Revolution in Africa. IZA Discussion Papers 10855

Nayal, K., Raut, R. D., Queiroz, M. M., Yadav, V. S., & Narkhede, B. E. (2021). Are artificial intelligence and machine learning suitable to tackle the Covid-19 impacts? An agriculture supply chain perspective. The International Journal of Logistics Management, Ahead-of-print (Ahead-of-print). https://doi.org/10.1108/IJLM-01-2021-0002

Ndzi, D. L., Harun, A., Ramli, F. M., Kamarudin, M. L., Zakaria, A., Shakaff, A. Y. M., Jaafar, M. N., Zhou, S., & Farook, R. S. (2014). Wireless sensor network coverage measurement and planning in mixed crop farming. Computers and Electronics in Agriculture, 105, 83–94. https://doi.org/10.1016/j.compag.2014.04.012

Ngwenyama, O., & Lee, A. (1997). Communication richness in electronic mail: Critical social theory and the contextuality of meaning. Management Information Systems Quarterly, 21(2), 145-168

Nhamo, G., Togo, M., & Dube, K. (2021). Making Sustainable Development Goals Relevant for, in and with Societies. In Sustainable Development Goals for Society Vol. 1 (pp. 3-15). Springer, Cham.

Nukala, R., Panduru, K., Shields, A., Riordan, D., Doody, P., & Walsh, J. (2016, June). Internet of Things: A review from 'Farm to Fork'. In 2016 27th Irish signals and systems conference (ISSC) (pp. 1-6). IEEE.

O'Neil, A. (2022). Urbanisation in South Africa 2021. Statista. Accessed 20 September 2022 from https://www.statista.com/statistics/455931/urbanization-in-south-africa/

Oates, B. J. (2006). Researching information systems and computing. SAGE.

Obisesan, A. (2014). Gender differences in technology adoption and welfare impact among Nigerian farming households.

OECD/SWAC. (2020). Africa's urbanisation dynamics 2020: Africapolis, mapping a new urban geography. Paris: OECD Publishing. https://doi.org/10.1787/ b6bccb81-en

Ogundari, K., & Awokuse, T. (2018). Human capital contribution to economic growth in Sub-Saharan Africa: Does health status matter more than education? Economic Analysis and Policy, 58, 131-140. doi:10.1016/j.eap.2018.02.001

Okeleke, K., & Suardi, S. (2020). The Mobile Economy Sub-Saharan Africa 2020. Mobile Operators and Networks. GSMA Intelligence.

Olivier, D. W. (2019). Urban agriculture promotes sustainable livelihoods in cape town. Development Southern Africa, 36(1), 17–32. https://doi.org/10.1080/0376835X.2018.1456907

Onwuegbuzie, A., & Leech, N. (2005). On becoming a pragmatic researcher: the importance of combining quantitative and qualitative research methodologies. International Journal of Social Research Methodology, 8(5), 375–387.

Or, C. K., Karsh, B. T., Severtson, D. J., Burke, L. J., Brown, R. L., & Brennan, P. F. (2011). Factors affecting home care patients' acceptance of a web-based interactive self-management technology. Journal of the American Medical Informatics Association : Jamia, 18(1), 51–9. https://doi.org/10.1136/jamia.2010.007336

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying information technology in organizations: Research approaches and assumptions. Information systems research, 2(1), 1-28.

Patel, K. K., & Patel, S. M. (2016). Internet of things-IOT: definition, characteristics, architecture, enabling technologies, application & future challenges. International journal of engineering science and computing, 6(5).

Patil, T. G., & Shekhawat, S. P. (2019). Industry 4.0 implications on Agriculture Sector: An Overview. International Journal of Management, Technology And Engineering, 11, Issue 1, 1512-1524

Pernille, E., Svend, H., Manuel, F. M.C., & Jesús Arteaga-Ortiz. (2019). Drivers for pursuing sustainability through IoT technology within high-end hotels—an exploratory study. Sustainability, 11(19). https://doi.org/10.3390/su11195372

Peuchpanngarm, C., Srinitiworawong, P., Samerjai, W., & Sunetnanta, T. (2016, May). DIY sensor-based automatic control mobile application for hydroponics. In 2016 Fifth ICT International Student Project Conference (ICT-ISPC) (pp. 57-60). IEEE.

Pillai, R., & Sivathanu, B. (2020). Adoption of internet of things (IoT) in the agriculture industry deploying the BRT framework. Benchmarking: An International Journal, (20200211). doi:10.1108/BIJ-08-2019-0361

Pölling, B., Mergenthaler, M., & Lorleberg, W. (2016). Professional urban agriculture and its characteristic business models in metropolis Ruhr, Germany. Land Use Policy, 58, 366–379.

Poole, N., Chitundu, M., & Msoni, R. (2013). Commercialisation: A meta-approach for agricultural development among smallholder farmers in Africa? Food Policy, 41, 155-165. doi:10.1016/j.foodpol.2013.05.010

Pynoo, B., Devolder, P., Tondeur, J., van Braak, J., Duyck, W., & Duyck, P. (2011). Predicting secondary school teachers' acceptance and use of a digital learning environment: a cross-sectional study. Computers in Human Behavior, 27(1), 568–575. https://doi.org/10.1016/j.chb.2010.10.005

Quaye, W., Dowuona, S., Okai, M., & Dziedzoave, N. (2016). Gender dimensions of decision-making on production assets and challenges facing women. Development in Practice, 26(1), 77-90.

Quisumbing, A., Brown, L., Feldstein, H., Haddad, L., & Peña, C. (1996). Women: The key to food security. *Food and Nutrition Bulletin, 17*(1), 1-2. doi:10.1177/156482659601700116

Record Evolution. (2021). 5 Open-Source IoT Platforms: Making Innovation Count. Internet of Things. Record Evolution. Accessed 25 October 2022 from https://www.record-evolution.de/en/blog/open-source-iot-platforms-making-innovation-count/

Robert, P. C., Rust, R. H., Larson, W. E., University of Minnesota. Department of Soil Science, Minnesota Extension Service, & International Conference on Site-Specific Management for Agricultural Systems (2nd : 1994 : Minneapolis, Minn.). (1995). Proceedings of site-specific management for agricultural systems : second international conference, march 27-30, 1994 thunderbird hotel, 2201 east 78th St., Minneapolis, MN : conducted by the department of soil science and minnesota extension service, University of Minnesota. American Society of Agronomy.

Rogers, R. W. (1983). Cognitive and psychological processes in fear appeals and attitude change: A revised theory of protection motivation. *Social psychophysiology: A sourcebook*, 153-176.

Rogerson, C. (2003). Towards" pro-poor" urban development in South Africa: the case of urban agriculture. Acta Academica, 2003(sup-3), 130-158.

Ronaghi, M. H., & Forouharfar, A. (2020). A contextualized study of the usage of the Internet of Things (IoTs) in smart farming in a typical middle eastern country within the context of Unified Theory of Acceptance and Use of Technology Model (UTAUT). Technology in Society, 63. https://doi.org/10.1016/j.techsoc.2020.101415

Rorty, R. (1991). Essays on Heidegger and others: Philosophical papers (Vol. 2). Cambridge University Press.

Rose, D. C., & Chilvers, J. (2018). Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming. Front. Sustain. Food Syst. 2: 87. doi: 10.3389/fsufs.

Rothwell, A., Ridoutt, B., Page, G., & Bellotti, W. (2016). Environmental performance of local food: trade-offs and implications for climate resilience in a developed city. Journal of Cleaner Production, 114, 420–430. https://doi.org/10.1016/j.jclepro.2015.04.096

Rouse, M. (2005). ICT (information and communications technology-or technologies). Dostupno na: http://searchcio-midmarket. Techtarget. com/definition/ICT (27.02. 2013.).

Rübcke von Veltheim, F., Theuvsen, L., & Heise, H. (2021). German farmers' intention to use autonomous field robots: a PLS-analysis. Precision Agriculture, 1-28.

Rubin, H. J., & Rubin, I. S. (2005). Qualitative interviewing (2nd ed.): The art of hearing data. Thousand Oaks, CA: SAGE Publications, Inc. doi: 10.4135/9781452226651

Rubin, M. (2021). Parkhurst's 'Go Green Initiative': Governance, sustainable urbanism and social justice. In C. Culwick Fatti (Ed.), In pursuit of just sustainability (pp. 43–57). GCRO Research Report No. 12. Johannesburg: Gauteng City-Region Observatory. https://doi.org/10.36634/BXLF9830

Rusere, F., Crespo, O., Dicks, L., Mkuhlani, S., Francis J., & Zhou, L. (2020). Enabling acceptance and use of ecological intensification options through engaging smallholder farmers in semi-arid rural Limpopo and Eastern Cape, South Africa. Agroecology and

Sustainable Food Systems, 44(6), 696–725. https://doi.org/10.1080/21683565.2019.1638336

Salemink, K., Strijker, D., & Bosworth, G. (2017). Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas. Journal of Rural Studies, 54, 360-371.

Samuel, W. (2016). Urban agriculture and the sustainability fix in Vancouver and Detroit. Urban Geography, 37(2), 163–182. https://doi.org/10.1080/02723638.2015.1056606

Santo, R., Palmer, A., & Kim, B. (2016). Vacant lots to vibrant plots: A review of the benefits and limitations of urban agriculture. Johns Hopkins Center for a Livable Future: Baltimore, MD, USA.

Sanyé-Mengual, E., Anguelovski, I., Oliver-Solà, J., Montero, J. I., & Rieradevall, J. (2016). Resolving differing stakeholder perceptions of urban rooftop farming in Mediterranean cities: promoting food production as a driver for innovative forms of urban agriculture. Agriculture and human values, 33(1), 101-120.

Sardar, S., Abdul-Khaliq, I., Ingar, A., Amaidia, H., & Mansour, N. (2020). 'Covid-19 lockdown: A protective measure or exacerbator of health inequalities? A comparison between the United Kingdom and India.' a commentary on "the socio-economic implications of the coronavirus and covid-19 pandemic: a review." International Journal of Surgery, 83, 189–191. https://doi.org/10.1016/j.ijsu.2020.09.044

Schwab, K. (2017). The fourth industrial revolution (First U.S. ed.). New York: Crown Business.

Sharife, K., & Bond, P. (2011). Above and beyond South Africa's minerals-energy complex. New South African Review, 2, 279-299.

Skar, S. L. G., Pineda-Martos, R., Timpe, A., Pölling, B., Bohn, K., Külvik, M., ... & Tzortzakis, N. (2020). Urban agriculture as a keystone contribution towards securing sustainable and healthy development for cities in the future. Blue-Green Systems, 2(1), 1-27.

Sheppard, B. H., Hartwick, J., & Warshaw, P. R. (1988). The theory of reasoned action: a meta-analysis of past research with recommendations for modifications and future research. *Journal of Consumer Research*, *15*(3), 325.

Simbanegavi, W., Patel, A., Senbet, L. W., Mouelhi, R. B. A., Gatune, J., Amaoko, K. Y., & Prakash, A. (2018). World of Work in the 4th Industrial Revolution: Inclusive and Structural Transformation for a Better Africa. *G20 Insights*, *5*

Simon-Rojo, M., Recanes, X., Cllau, S., Duzi, B., Eiter, S., Hernández-Jiménez, V., & Vejre, H. (2016). From urban food gardening to urban farming. Jovis Verlag GmbH, Berlin, Germany, 22–28.

Specht, K., Siebert, R., Thomaier, S., Freisinger, U. B., Sawicka, M., Dierich, A., & Busse, M. (2015). Zero-acreage farming in the city of Berlin: an aggregated stakeholder perspective on potential benefits and challenges. Sustainability, 7(4), 4511-4523.

Stake R. (2005). Qualitative Case Studies. The Sage Handbook of Qualitative Research (3rd ed.). Thousand Oaks/London/New Delhi. Sage Publications.

StatsSA. (2018). The recession ends as GDP climbs by 2,2%. (2018, December 4). Retrieved February 25, 2019, from http://www.statssa.gov.za/?p=11817

StatsSA. (2018). *How do women fare in the South African labour market?*. [online] Available at: http://www.statssa.gov.za/publications/P0211/P02112ndQuarter2018.pdf [Accessed 26 Feb. 2019].

StatsSA. (2019). Quarterly Labour Force Survey (QLFS), 1st Quarter 2019. (2019, May 14). Retrieved June 17, 2019, from http://www.statssa.gov.za/?page_id=1854&PPN=P0211&SCH=7619

Stats SA. (2021). Quarterly Labour Force Survey Quarter 1: 2021. Stats SA. Department of Statistics South Africa. Access 25 October 2022 from https://www.statssa.gov.za/publications/P0211/P02111stQuarter2021.pdf

Stats SA. (2022). Quarterly Labour Force Survey Quarter 1: 2022. Stats SA. Department of Statistics South Africa. Access 25 October 2022 from https://www.statssa.gov.za/publications/P0211/P02111stQuarter2022.pdf

Stewart, R., Korth, M., Langer, L., Rafferty, S., Da Silva, N. R., & Rooyen, C. van. (2013). What are the impacts of urban agriculture programs on food security in low and middle-income countries? Environmental Evidence : The Official Journal of the Collaboration for Environmental Evidence, 2(1), 1–13. https://doi.org/10.1186/2047-2382-2-7

Stiegler, N., & Bouchard, J.-P. (2020). South Africa: challenges and successes of the covid-19 lockdown. Annales Médico-Psychologiques, 178(7), 695–698. https://doi.org/10.1016/j.amp.2020.05.006

Stockemer, D. (2019). Quantitative methods for the social sciences (Vol. 50, p. 185). Springer International Publishing

Stoneman, P., & Battisti, G. (2010). The diffusion of new technology. Handbook of the Economics of Innovation. Volume 2, 2010, Pages 733-760

Suchá, L., & Dušková, L. (2022). Land access mechanisms of Soweto farmers: moving beyond legal land tenure for urban agriculture. Land Use Policy, 119. https://doi.org/10.1016/j.landusepol.2022.106169

Suchá, L., Schlossarek, M., Dušková, L., Malan, N., & Šarapatka, B. (2020). Land tenure security and its implications for investments to urban agriculture in Soweto, South Africa. Land Use Policy, 97. https://doi.org/10.1016/j.landusepol.2020.104739

Sung, J. (2018). The Fourth Industrial Revolution and Precision Agriculture. Automation in Agriculture: Securing Food Supplies for Future Generations, 1

Sutic, N. (2003). How green roofs can improve the urban environment in uptown Waterloo. Integrating Natural and Urban.

Szabo, S. (2016). Urbanisation and food insecurity risks: assessing the role of human development. Oxford Development Studies, 44(1), 28–48. https://doi.org/10.1080/13600818.2015.1067292

Taalbi, J. (2019). Origins and pathways of innovation in the third industrial revolution. Industrial and corporate change, 28(5), 1125-1148.

Tefera, T., Tesfay, G., Elias, E., Diro, M., & Koomen, I. (2016). Drivers for adoption of agricultural technologies and practices in Ethiopia-A study report from 30 woredas in four regions. CASCAPE (Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia) project report, (1).

The Presidency. (2018). President Cyril Ramaphosa: 2018 State of the Nation Address. Retreived June 10, 2019 from https://www.gov.za/speeches/president-cyril-ramaphosa-2018-state-nation-address-16-feb-2018-0000

The Presidency. (2019). President appoints Commission on Fourth Industrial Revolution. Retrieved June 10, 2019 from http://www.thepresidency.gov.za/press-statements/president-appoints-commission-fourth-industrial-revolution

The Presidency. (2019). President Cyril Ramaphosa: 2019 State of the Nation Address. Retrieved June 21, 2019 from https://www.gov.za/speeches/2SONA2019

Tibesigwa, B., & Visser, M. (2016). Assessing gender inequality in food security among smallholder farm households in urban and rural south Africa. World Development, 88, 33-49. doi:10.1016/j.worlddev.2016.07.008

Tripp, A. M. (2004). Women's movements, customary law, and land rights in Africa: The case of Uganda. African Studies Quarterly, 7(4), 1-19.

UAI. (2020). UAI: General Update 2020. Urban Agriculture Initiative. Accessed 20 September 2022 from https://www.jicp.org.za/wp-content/uploads/2021/03/UAI_2020_3-Pages-Report_12.01.pdf

United Nations Population Fund. (2016). Urbanization. Accessed 21 November 2022 from https://www.unfpa.org/urbanization#readmore-expand

United Nations. (2015). About The Sustainable Development Goals report 2015. Accessed 21 August 2021 from https://www.un.org/sustainabledevelopment/sustainable-development-goals/

United Nations. (n.d). Do you know all 17 SDGs? Accessed 21 August 2021 from https://sdgs.un.org/goals#history

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0 - a glimpse. Procedia Manufacturing, 20, 233-238. doi:10.1016/j.promfg.2018.02.034

Vadlamudi, S. (2020). Internet of things (iot) in agriculture: the idea of making the fields talk. Engineering International, 8(2), 87–100. https://doi.org/10.18034/ei.v8i2.522

Van Wyk C. Survey of ICT in schools in South Africa. Public expenditure analysis for the Department of Basic Education, Report 8. Stellenbosch: Stellenbosch University; 2012. https://www.education.gov.za/Portals/0/Documents/Reports/Research%20Repository/LTSM/Survey%20of%20ICT%20in%20schools%20in%20SA.pdf?ver=2019-09-09-102208-963&timestamp=1570193566415

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the qualitative-quantitative divide: guidelines for conducting mixed methods research in information systems. Mis Quarterly, 37(1), 21–21.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view. Mis Quarterly, 27(3), 425–478.

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2016). Unified theory of acceptance and use of technology: a synthesis and the road ahead. Journal of the Association for Information Systems, 17(5), 328–376. https://doi.org/10.17705/1jais.00428

Virtanen, P. K., Siragusa, L., & Guttorm, H. (2020). Introduction: toward more inclusive definitions of sustainability. Current Opinion in Environmental Sustainability, 43, 77–82. https://doi.org/10.1016/j.cosust.2020.04.003

von Kutzschenbach, M., & Daub, C.-H. (2021). Digital transformation for sustainability: a necessary technical and mental revolution. Studies in Systems, Decision and Control, 294, 179–192. https://doi.org/10.1007/978-3-030-48332-6_12

Wachenheim, C., Wang, Z., & Zheng, S. (2019). Technology adoption among farmers in Jilin province, China: The case of aerial pesticide application. China Agricultural Economic Review, 11(1), 206-216. doi:10.1108/CAER-11-2017-0216

Weber, R. (2004). Editor's comments: the rhetoric of positivism versus interpretivism: a personal view. MIS quarterly, iii-xii.

Walsham, G. (1995). The emergence of interpretivism in is research. Information Systems Research, 6(4), 376–394. https://doi.org/10.1287/isre.6.4.376

Warshaw, P. R. (1980). A new model for predicting behavioral intentions: An alternative to Fishbein. Journal of marketing research, 17(2), 153-172.

Wästfelt, A., & Zhang, Q. (2016). Reclaiming localisation for revitalising agriculture: A case study of peri-urban agricultural change in Gothenburg, Sweden. Journal of Rural Studies, 47, 172-185.

Weber, R. (2004). Editor's comments: the rhetoric of positivism versus interpretivism: a personal view. Mis Quarterly, 28(1). https://doi.org/10.2307/25148621

Weersink, A., Fraser, E., Pannell, D., Duncan, E., & Rotz, S. (2018). Opportunities and challenges for Big Data in agricultural and environmental analysis. Annual Review of Resource Economics, 10, 19-37.

Wei, M.-F., Luh, Y.-H., Huang, Y.-H., & Chang, Y.-C. (2021). Young generation's mobile payment adoption behavior: analysis based on an extended UTAUT model. Journal of Theoretical and Applied Electronic Commerce Research, 16(1), 1–20. https://doi.org/10.3390/jtaer16010001

Williams, M. D., Rana, N. P., & Dwivedi, Y. K. (2015). The unified theory of acceptance and use of technology (UTAUT): a literature review. Journal of Enterprise Information Management, 28(3), 443–448. https://doi.org/10.1108/JEIM-09-2014-0088

World Economic Forum. (2018). Internet of Things Guidelines for Sustainability. Future of Digital Economy and Society System Initiative. World Economic Forum. Accessed 25 October 2021 from https://www3.weforum.org/docs/IoTGuidelinesforSustainability.pdf

Wu, L. (2012). An empirical research on poor rural agricultural information technology services to adopt. Procedia Engineering, 29, 1578–1583. https://doi.org/10.1016/j.proeng.2012.01.176

Yin, R. K. (2017). Case study research and applications: Design and methods. Sage publications.

Zambon, I., Cecchini, M., Egidi, G., Saporito, M. G., & Colantoni, A. (2019). Revolution 4.0: industry vs. agriculture in a future development for SMEs. Processes, 7(1), 36–36. https://doi.org/10.3390/pr7010036

Zasada, I. (2011). Multifunctional peri-urban agriculture—A review of societal demands and the provision of goods and services by farming. Land use policy, 28(4), 639-648.

Zezza, A., & Tasciotti, L. (2010). Urban agriculture, poverty, and food security: empirical evidence from a sample of developing countries. Food Policy, 35(4), 265–273. https://doi.org/10.1016/j.foodpol.2010.04.007

8 APPENDIX A: UTAUT CONSTRUCT DESCRIPTIVE ANALYSIS

	Questionnaire (N = 32)
6. As a farmer, sustainability is important to me SUS1	
Missing Values	0
Strongly agree	20 (62.5%)
Agree	9 (28.1%)
Neutral	0 (0.0%)
Disagree	0 (0.0%)
Strongly disagree	3 (9.4%)
7. I believe that I contribute to the collective goal towards being more sustainable SUS2	
Missing Values	0
Strongly agree	15 (46.9%)
Agree	16 (50.0%)
Neutral	1 (3.1%)
Disagree	0 (0.0%)
Strongly disagree	0 (0.0%)
8. I am willing to do what I can to ensure my farm is sustainable SUS3	

Missing Values	0
Strongly agree	23 (71.9%)
Agree	9 (28.1%)
Neutral	0 (0.0%)
Disagree	0 (0.0%)
Strongly disagree	0 (0.0%)
9. I believe that my farm can be more sustainable through the use of IoT SUS4	
Missing Values	0
Strongly agree	16 (50.0%)
Agree	10 (31.2%)
Neutral	5 (15.6%)
Disagree	1 (3.1%)
Strongly disagree	0 (0.0%)
10. I would find IoT useful in my job at the farm PE1	
Missing Values	0
Strongly agree	16 (50.0%)
Agree	11 (34.4%)
Neutral	4 (12.5%)
Disagree	1 (3.1%)
Strongly disagree	0 (0.0%)
11. Using IoT would enable me to accomplish tasks more quickly PE2	
Missing Values	0
Strongly agree	15 (46.9%)
Agree	10 (31.2%)
Neutral	4 (12.5%)
Disagree	3 (9.4%)
Strongly disagree	0 (0.0%)
12. Using IoT would increase my productivity PE 3	
Missing Values	0

Strongly agree	15 (46.9%)
Agree	9 (28.1%)
Neutral	6 (18.8%)
Disagree	2 (6.2%)
Strongly disagree	0 (0.0%)
13. If I were to use IoT, I would increase my chances of making more money PE4	
Missing Values	0
Strongly agree	12 (37.5%)
Agree	11 (34.4%)
Neutral	8 (25.0%)
Disagree	1 (3.1%)
Strongly disagree	0 (0.0%)
14. If I were to use IoT, my farm would be more sustainable PE5	
Missing Values	0
Strongly agree	15 (46.9%)
Agree	14 (43.8%)
Neutral	2 (6.2%)
Disagree	1 (3.1%)
Strongly disagree	0 (0.0%)
15. My interaction with the IoT system in my farm would be clear and understandable EE1	
Missing Values	0
Strongly agree	11 (34.4%)
Agree	9 (28.1%)
Neutral	10 (31.2%)
Disagree	2 (6.2%)
Strongly disagree	0 (0.0%)
16. It would be easy for me to become skilful at using IoT EE2	
Missing Values	0
Strongly agree	14 (43.8%)

Agree	11 (34.4%)
Neutral	5 (15.6%)
Disagree	2 (6.2%)
Strongly disagree	0 (0.0%)
17. I would find the IoT system easy to use EE3	
Missing Values	0
Strongly agree	7 (21.9%)
Agree	13 (40.6%)
Neutral	8 (25.0%)
Disagree	4 (12.5%)
Strongly disagree	0 (0.0%)
18. Learning to operate the IoT system in the farm would be easy for me EE4	
Missing Values	0
Strongly agree	11 (34.4%)
Agree	11 (34.4%)
Neutral	7 (21.9%)
Disagree	3 (9.4%)
Strongly disagree	0 (0.0%)
19. People who influence my behaviour and decisions think that I should use IoT so my farm can be more sustainable SI1	
Missing Values	0
Strongly agree	6 (18.8%)
Agree	12 (37.5%)
Neutral	8 (25.0%)
Disagree	5 (15.6%)
Strongly disagree	1 (3.1%)
20. People who are important to me think that I should use the IoT system for a more sustainable farm SI2	
Missing Values	0
Strongly agree	8 (25.0%)

Agree	6 (18.8%)
Neutral	13 (40.6%)
Disagree	5 (15.6%)
Strongly disagree	0 (0.0%)
21. The senior management of this business would be helpful in the use of IoT SI3	
Missing Values	0
Strongly agree	10 (31.2%)
Agree	12 (37.5%)
Neutral	8 (25.0%)
Disagree	2 (6.2%)
Strongly disagree	0 (0.0%)
22. In general, the people in my business would support the use of IoT for a more sustainable farm SI4	
Missing Values	0
Strongly agree	12 (37.5%)
Agree	14 (43.8%)
Neutral	4 (12.5%)
Disagree	2 (6.2%)
Strongly disagree	0 (0.0%)
23. I intend to use IoT technology for my farming operations in the next 3 months BI1	
Missing Values	0
Strongly agree	4 (12.5%)
Agree	7 (21.9%)
Neutral	12 (37.5%)
Disagree	7 (21.9%)
Strongly disagree	2 (6.2%)
24. I predict that I would use IoT in the next three months BI2	
Missing Values	0
Strongly agree	4 (12.5%)

Agree	9 (28.1%)
Neutral	10 (31.2%)
Disagree	7 (21.9%)
Strongly disagree	2 (6.2%)
25. I plan to use IoT technology in the next three months BI3	
Missing Values	0
Strongly agree	5 (15.6%)
Agree	10 (31.2%)
Neutral	8 (25.0%)
Disagree	7 (21.9%)
Strongly disagree	2 (6.2%)