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Affordable Fourth Industrial Revolution Tools to Enhance Subsistence Farming: A Case Study of Small-Scale Farmers in KwaDlangezwa, KwaZulu-Natal, South Africa

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ABSTRACT

Subsistence farming remains critical to rural livelihoods and food security in South Africa, yet farmers face persistent challenges including climate variability, resource constraints, and limited market access. The Fourth Industrial Revolution (4IR) presents opportunities to transform subsistence agriculture through affordable technologies such as IoT sensors, mobile advisory platforms, solar-powered irrigation, and digital marketplaces. However, high costs, infrastructure deficits, and digital literacy gaps hinder adoption among resource-constrained farmers. This qualitative case study explores the current farming practices, challenges, and potential for 4IR technology adoption among subsistence farmers in KwaDlangezwa, KwaZulu-Natal. Through semi-structured interviews with ten experienced farmers and thematic analysis of their narratives, the study identifies eight key themes: traditional farming practices, economic constraints, infrastructure challenges, digital literacy barriers, perceived technology inappropriateness, marketing strategies, climate adaptation, and institutional support gaps. Findings reveal a significant reality-technology gap, where commercially-designed 4IR tools remain inaccessible for subsistence contexts. The study recommends phased implementation strategies, government subsidies, digital literacy training, infrastructure development, and context-specific technology design to facilitate inclusive 4IR adoption. These findings contribute to sustainable development goals (SDGs 1, 2, 8, and 12) and provide practical pathways for enhancing agricultural productivity while acknowledging traditional knowledge systems.

Keywords: Subsistence Farming, Small-Scale Farmers, Agricultural Technology, South Africa, Digital Agriculture

INTRODUCTION

Background and Context

The subsistence farming, is characterized by food production primarily for household consumption rather than commercial sale, over the years it has been a cornerstone of rural livelihoods in South Africa (Mnguni, Mbatha, & Mubecua, 2021). Such farming systems, usually operating on small landholdings, with substance limited mechanization and traditional methods. Yet, support millions of rural households while contributing significantly to national food security (Sithole & Olorunfemi, 2024). According to Moon, 2024; Sarkar et al.,(2023) notwithstanding their significance, subsistence farmers confront a number of obstacles, such as the effects of climate change, resource scarcity, restricted market access, and technical marginalization.

Digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), precision agriculture, and mobile platforms are starting to revolutionize agriculture globally as part of the Fourth Industrial Revolution (4IR); (Javaid et al., 2022). These innovations promise increased climate resilience, resource efficiency, and production (Bacco, 2019). International case studies from India, Kenya, and Brazil demonstrate that, when properly planned and used, inexpensive 4IR tools can greatly help smallholder farmers (Sharma & Singh, 2021; Schwab & Davis, 2018). Smallholder agricultural systems' resilience and efficiency can be significantly increased by the 4IR. Research from sub-Saharan Africa suggests that small digital interventions can increase the use of better farming techniques (Gliessman, 2014). A reasonably priced adapted 4IR technologies for resource-constrained farmers can enhance the agricultural output and efficiency (Javaid et al. 2022). Internet of Things, sensors for weather and soil management, mobile-based farm advising platforms, inexpensive drones for crop monitoring, and precision irrigation systems are just a few examples of affordable agricultural tools (Munyua et al., 2021). According to Joy et al. (2022), the following technologies are part of the Fourth Industrial Revolution (4IR), internet of things (IoT) sensors, remote sensing, financial technology, solar power on demand, and platforms for common automation. Small-scale farmers can benefit greatly from these low-cost, high-impact solutions, which can increase their productivity, efficiency in resource usage, resilience, and access to markets.

Nonetheless, there is still little 4IR technology uptake among subsistence farmers in South Africa. Significant obstacles are created by exorbitant prices, poor digital infrastructure, little technology literacy, and the incompatibility of commercially manufactured products with subsistence farming environments (Makgala et al., 2022; Dlamini, Chizema, & Van Greunen, 2023). The study aims to, examine current subsistence farming practices and traditional knowledge systems in KwaDlangezwa. Identify affordable 4IR tools suitable for resource-constrained farming contexts. Analyze multidimensional barriers to 4IR technology adoption among subsistence farmers. Develop practical, context-specific recommendations for inclusive technology implementation and contribute evidence-based insights to support policy development and sustainable agricultural transformation in SA.

Problem Statement

Subsistence farmers in South Africa face a conundrum: although there are cutting-edge agricultural technology that could significantly increase their resilience and output, they are still mainly out of reach and unsuitable for their environments. This problem is best shown by the farmers of KwaDlangezwa in KwaZulu-Natal, who have a wealth of traditional farming knowledge and consistently provide local markets, but they also face challenges from climate uncertainty, a lack of finance, poor infrastructure, and a lack of access to technical advancements. This lack of access to technology reduces agricultural output, erodes food security in rural areas, and prolongs cycles of poverty. Subsistence farmers will continue to lag behind in the agricultural revolution if deliberate efforts are not made to create and deploy accessible, context-appropriate 4IR instruments together with the required support networks. This will exacerbate the gap between rural and urban areas and jeopardize sustainable development objectives.

Significance of the Study

This study adds to a number of important fields. First, it contributes to the limited literature on the adoption of 4IR in subsistence farming by offering concrete data from a particular South African environment. Secondly, it prioritizes farmer perspectives and experiences, guaranteeing that suggestions are grounded on actual experiences rather than theoretical presumptions. Thirdly, it promotes the attainment of the Sustainable Development Goals, including SDGs 12 (Responsible Consumption and Production), 8 (Decent Work and Economic Growth), 2 (Zero Hunger), and 1 (No Poverty). Fourth, it provides useful advice for development organizations, agricultural extension agencies, technology developers, and legislators who are trying to improve smallholder agriculture. Lastly, it illustrates the importance of community-engaged scholarship by functioning as applied research with immediate implementation possibilities in KwaDlangezwa.

LITERATURE REVIEW

Theoretical Framework

The Diffusion of Innovation Theory (Rogers, 2003) is used in this study to examine how 4IR technology is being adopted by subsistence farmers. Five adopter categories innovators, early adopters, early majority, late majority, and laggards as well as five crucial characteristics relative advantage, compatibility, complexity, trialability, and observability that affect adoption choices are outlined in Rogers' paradigm. Adoption by subsistence farmers depends on the perceived benefits outweighing the costs, compatibility with traditional methods and values, ease of use, chances for experimentation, and peer success. This theory explains why, despite their technological sophistication, commercially created 4IR technologies have not spread widely enough among resource-constrained farmers; they perform poorly in the compatibility, complexity, and trialability dimensions. The theory assists us in examining the barriers to adoption of new technology and provides suggestions for accelerating its adoption through improved design, demonstration initiatives, and peer-to-peer learning networks.

Subsistence Farming in South Africa

As for Mnguni et al., (2021) small land plots often less than 5 hectares, relaying on physical effort(outdated tools), traditional crop varieties, and mixed farming methods that incorporate crops and livestock are characteristics of subsistence farming in South Africa. Small-scale farmers are generating income and ensuring the family has enough food. They have used these approaches preserving agricultural biodiversity and traditional knowledge while assisting rural residents in earning a living. However, there are structural issues, such as difficulty obtaining loans and inputs, insufficient extension services, vulnerability to climate shocks, and inability to secure land tenure (Sithole & Olorunfemi, 2024). Despite these issues, Moon (2024) argues that subsistence farming is crucial for ensuring food security in both urban and rural areas, creating jobs, preserving cultural traditions, and serving as a social safety net during difficult economic times.

Challenges Facing Subsistence Farmers

According to Sithole & Olorunfemi, (2024) contemporary subsistence farmers are confronted by multifaceted challenges. An erratic rainfall, increased temperatures, droughts, and floods, directly threatening crop yields and livestock productivity are manifests through climate change. Resource constraints include limited land, water scarcity, restricted access to quality seeds and fertilizers, and insufficient capital for investments (FAO, 2020). Wale & Mkuna, (2023) adds on that the market access remains problematic due to poor infrastructure, middleman exploitation and price volatility. As for Moon (2024) emphases on the lack knowledge gaps persist despite farmers' traditional expertise, particularly regarding climate-smart practices, pest management, and technological innovations. Gender dynamics further complicate these challenges, as women farmers often face discrimination in land ownership, credit access, and extension services despite their crucial agricultural roles (Moon, 2024). Policy implementation remains weak, with government support programs suffering from corruption, inadequate funding, poor coordination, and urban bias (Sithole & Olorunfemi, 2024).

Fourth Industrial Revolution Technologies in Agriculture

Joy et al., (2022) states that the 4IR encompasses several technology categories relevant to agriculture. IoT sensors monitor soil moisture, temperature, humidity, and crop health in real-time, enabling precision resource management. Mobile platforms deliver weather forecasts, agronomic advice, pest alerts, and market information directly to farmers' phones (Sharma & Singh, 2021). According to Schwab & Davis, (2018) drones provide, pest surveillance, aerial crop monitoring and targeted interventions at lower costs than traditional methods . Javaid et al., (2022) observes that solar-powered irrigation systems offer climate-resilient water management through pay-as-you-go financing models. Mwaura et al., (2021) proclaim that digital marketplaces connect farmers directly to buyers, reducing middleman exploitation and improving price realization. Javaid et al., (2022) found that equipment-sharing platforms enable access to mechanization without individual ownership through collaborative models. These technologies, when appropriately scaled and priced, can enhance productivity, reduce post-harvest losses, improve climate resilience, and strengthen market linkages.

International Case Studies of Affordable 4IR Adoption

Successful examples from other developing countries demonstrate the potential of context-appropriate 4IR tools.

INDIA- The solar-powered irrigation systems combined with mobile advisory applications have improved yields while reducing labor dependency among smallholders (Sharma & Singh, 2021).

KENYA'S- The community-based drone programs allow shared access to crop monitoring technology, distributing costs across multiple farmers (Schwab & Davis, 2018).

BRAZIL- Has implemented precision irrigation technologies and low-cost soil sensors that significantly enhance water efficiency in smallholder farms (Costa et al., 2020).

SOUTH AFRICA'S -Khula-style digital marketplaces enable bulk selling, reduce transaction costs, and improve farmer-buyer connections (Wainaina et al., 2022). These cases share common success factors: affordability through subsidies or shared ownership, strong training and support systems, locally-adapted designs, and enabling policy environments. Mtshali (2024) aptly observed that small-scale farmers at KwaDlangezwa afford tools that are not technologically advanced and less likely depending on electricity; they hire tractors and pay employees for labour. The findings of the study continued assert that, small-scale farmers they failing to purchase advanced /technological agricultural tools. However, they have been relying mostly on outdated equipment for years, because of financial crises . Moreover, the findings also revealed this predicament also challenges the department of agriculture, as they distribute outdated agricultural tools to assist small-scale farmers.

Barriers to 4IR Adoption in Subsistence Contexts

Campuzano et al., (2023) found that literature identifies several adoption barriers for small-scale farmers to fully participating to the 4IR tools. Economic constraints include high upfront costs, limited access to credit, inability to absorb failure risks, and competing household priorities .Infrastructure deficits encompass unreliable electricity, poor internet connectivity, inadequate rural roads, and limited service networks (Dlamini et al., 2023). Digital literacy gaps reflect low formal education levels, unfamiliarity with digital devices, language barriers in software interfaces, and absence of technical support (Hassoun et al., 2023). Cultural and social factors include risk aversion, preference for proven methods, age-related technology resistance, and gender-based exclusion (Moon, 2024). Institutional weaknesses manifest through fragmented extension services, weak farmer organizations, policy-implementation gaps, and inadequate public-private partnerships (Sithole & Olorunfemi, 2024). Design inappropriateness arises when technologies assume commercial farming contexts, require conditions unavailable to subsistence farmers, or ignore local knowledge and practices (Almadani & Mostafa, 2021).

METHODOLOGY

Research Design and Approach

This study employed a qualitative exploratory case study design to investigate 4IR adoption potential among subsistence farmers in KwaDlangezwa, KwaZulu-Natal. The qualitative approach was selected for its capacity to capture rich, contextualized data about farmer experiences, perceptions, and practices that quantitative methods might overlook (Clarke & Braun, 2017). The case study method enabled intensive examination of the specific geographic and social context, facilitating deep understanding of local farming systems and technology adoption barriers.

Study Area

KwaDlangezwa is a rural community in the uThungulu District of KwaZulu-Natal, South Africa. The area is characterized by traditional subsistence farming practices, with households cultivating small plots for food security and supplementary income. The community faces typical rural challenges including limited infrastructure, restricted market access, and climate vulnerability. KwaDlangezwa was selected purposively due to its representative subsistence farming practices, accessibility for research, and the author's established community relationships facilitating trust and sincere participation.

Data Collection

The research employed both secondary and primary data sources. The secondary data was from peer-reviewed journals, government reports, policy papers, and international case studies that we found in the Google Scholar, Scopus, and Taylor & Francis databases. Some of the search terms were "subsistence farming," "Fourth Industrial Revolution," "adoption of agricultural technology," "smallholder farmers South Africa," and other similar words. To make sure the works were up-to-date, the focus was on works published between 2018 and 2024, but earlier works that were important were also included.

The primary data collection consisted of semi-structured interviews with ten subsistence farmers in KwaDlangezwa. The participants were chosen using purposive sampling based on the following criteria: at least ten years of farming experience in KwaDlangezwa, active involvement in subsistence farming as their main source of income, a willingness to participate voluntarily, and availability during the research period.

The sample size of ten was established based on the principle of information richness rather than statistical representation, suitable for qualitative exploratory research where depth is prioritized over breadth. The interviews were conducted in isiZulu, the participants' preferred language, with the researcher acting as the interviewer because they were fluent in the language and familiar with the culture. Each interview lasted about 45 to 60 minutes and looked at things like current farming practices, problems that farmers face, their knowledge of agricultural technologies, their opinions on 4IR tools, their resource constraints, and their support needs. We recorded the interviews with the participants' permission and then wrote them down word for word. To keep their identities secret, participants were given codes (P1-P10).

Data Analysis

Data analysis followed Braun and Clarke's (2006) six-phase thematic analysis framework: (1) familiarization through repeated reading of transcripts; (2) systematic coding of meaningful data segments; (3) collating codes into potential themes; (4) reviewing and refining themes for internal coherence and external distinctiveness; (5) defining and naming final themes; and (6) producing the analytical narrative with illustrative quotations. Analysis was conducted manually without software, allowing intimate engagement with data. The researcher maintained reflexive awareness of positionality as both academic researcher and community member, recognizing how this dual role influenced data interpretation while leveraging it for cultural insight.

Adoption of the Fourth Industrial Revolution by Small-Scale Rural Farmers

Staneva and Elliot (2023) agrees that historically, technological advancements have initiated significant industrial revolutions, facilitating mass production, promoting economic growth, and transitioning employment from agriculture to manufacturing and subsequently to services. The integration of fourth industrial revolution technologies by small-scale rural farmers can significantly transform agriculture, optimize resource management, improve livelihoods, and bolster global food security (Campuzano et al. 2023). However, this necessitates addressing challenges associated with access to innovation, affordability, capacity building, and the customization of solutions. This means government departments along with state-owned entities, and the private sector needs to work on resolves these issues to support small-scale farmers in effectively adopting the Fourth Industrial Revolution in rural areas (Schirpke et al. 2019)

Hassoun et al. (2023) state that the literature suggests that small-scale rural farmers should consider several factors for successful adoption of the Fourth Industrial Revolution, including digital infrastructure, connectivity, data analytics, mobile applications, budget, capacity, training, and policies. (Campuzano et al. 2023) stipulates that various scholars propose that access to digital infrastructure, particularly reliable internet connectivity, should be considered a prerequisite for the adoption and affordability of the Fourth Industrial Revolution in small-scale rural farming contexts.

Other scholars have indicated that mobile devices play a significant role in the adoption of the Fourth Industrial Revolution (4IR) by small-scale farmers for resource management and monitoring. Conversely, research indicates that restricted access to digital infrastructure and internet connectivity can impede the effective adoption of the Fourth Industrial Revolution by small-scale farmers (Dlamini, Chizema and Van Greunen 2023). Data analytics can help small-scale farms by providing additional insights into market trends, crop management, pest control, transportation logistics, etc. (Elijah et al. 2021; Debauche et al. 2022).

Almadani and Mostafa (2021) state that the, small-scale farmers may be able to obtain useful information on weather forecasts, market prices, and agronomic guidance by using mobile applications. Additionally, farmers will be able to manage their farming operations from any location thanks to mobile applications (Liu et al. 2021; Choi and Shin 2023). Furthermore, farmers can utilize mobile applications to direct digital devices to carry out their tasks, such as crop watering enabled by the Internet of Things (Sharma et al. 2022). Small-scale farmers must be trained to use 4IR technologies, though; as it is essential that they comprehend how to use them efficiently and effectively (Spanaki et al. 2022).

Spanaki et al. 2022; Hassoun et al. (2023) suggest that the department of agriculture should building capacity sufficient of funds to send farmers for training and workshops on the 4IR tools. Schirpke et al. (2019) adds on that small-scale farmers should be informed with digital infrastructure, connectivity, data analytics, mobile applications, budget, capacity, training, and policies. Javaid, Javaid, Haleem, Singh, & Suman, (2022) further point that digital infrastructure, such as dependable internet and participation in workshops, is also recommended by various academics and scholars. Such findings and recommendations should be successfully implemented. A sufficient budget could assist farmers in removing obstacles that could prevent 4IR for smart agriculture from being successfully adopted and implemented (Campuzano et al. 2023).

Table 1: Advantage of using fourth industrial revolution by small-scale farmers in rural areas

4IR TOOLS	ADVANTAGE	BENEFIT
1.Weather-advisory apps	Will improve better timing and input efficiency	The soil sensors and weather-advisory apps are useful to help farmers plant, fertilize, and water crops precisely, lowering waste and yield losses and improving compliance, which raises yields and lowers input costs.
2.Equipment-sharing platforms	Is good at reducing labour and timely operations	These platforms are for sharing equipment, such as Hello Tractor, allow for speedy tasks and save time, which lowers yield losses, especially for small plots. Clear pricing and digital onboarding are preferred by farmers.
3.Solar-powered	Will benefit the farmers by Increasing resilience to climate variability	While advisory systems offer seasonal forecasts, solar-powered irrigation systems guard against drought and irregular rainfall. With financing options, PAYG models assist those with low incomes in using irrigation.
4. Market platforms	This will improve market access and price realization	The smallholders can access working capital and market intelligence through digital marketplaces such as Khula, which also expedite payments, streamline transactions, cut down on middlemen, and improve transparency.
5.Reasonable storage	This will reduce post-harvest loss and improved nutrition	The basic grains and perishable foods are kept fresh by inexpensive storage devices like PICS bags and evaporative coolers, which lowers food loss and increases family food and income.

Source: *Javaid, Haleem, Singh, & Suman, (2022)*

The above table elucidate essentiality of using 4IR affordable tools to enhance and sustain agricultural output for small-scale and emerging farmers particularly the ones that are rural based. Through these partnerships, farmers can receive training on how to effectively utilize new technologies, access affordable digital tools, and navigate from other existing challenges. By leveraging the expertise and resources of multiple stakeholders, the agricultural sector can harness the power of 4IR to improve productivity, increase resilience to climate change, and ultimately boost income for small-scale farmers. KwaDlangezwa small-scale farmers can benefit from the above technological alternatives by implementing advance agricultural information. As for emerging and small-scale farmers they are still behind with technology, but from the above suggested information few could be utilised as innovation technological tools.

Table 2: Solutions from Other Countries

Several countries have successfully integrated affordable 4IR tools in small-scale agriculture:

COUNTRIES	SOLUTION	REFERENCES
1.India	The solar-powered irrigation systems and mobile advisory apps have improved yield and decreased reliance on labour.	Sharma & Singh, 2021
2.Kenya	The smallholders can share access through community-based drone programs, which lowers individual expenses.	Schwab, &Davis, (2018).
3.Brazil	The water efficiency in smallholder farms is increased by precision irrigation technologies and inexpensive soil sensors.	Costa et al., 2020
4.South African	***Khula-style digital marketplaces and Digital platforms allow smallholders to sell in bulk, lower transaction costs, and connect farmers to markets.***	Mwaura et al., 2021; & Wainaina et al., 2022

Source: *Sharma & Singh, 2021; Schwab, &Davis, 2018; Costa et al., 2020& Mwaura et al., 2021; & Wainaina et al., 2022*

The above table, gave examples on the available and affordable tools to enhance small-scale farmers agricultural output. The suggested small tools and techniques are more fitting to the KwaDlangezwa short and long term resolutions. It may take years to accomplish it, but farmers could adapt over time.

The Figures Below Are Were Taken by The Researcher from Kwadlangezwa

Figure 1: *The above pictures shows sweet potato and cabbage*

Figure 2: *White and red sweet potato and onion*

Figure 3: *Orange tree before harvest and a table set for selling the harvest of sweet potato, avocado, mango and oranges*

FINDINGS

Participant Profile

The ten individuals (P1–P10) were skilled subsistence farmers with ten to more than forty years of farming experience. Six female farmers and four male farmers, ages 45 to 72, were included in the sample. The participants' educational backgrounds ranged from high school (seven) to no formal schooling (three). Four individuals engaged in vegetable production, two engaged in chicken farming, and four engaged in mixed crop-livestock systems. Every member grew food mostly for their own consumption, with extra money coming from sales.

Theme 1: Traditional Farming Practices and Indigenous Knowledge

Participants demonstrated deep traditional agricultural knowledge acquired through intergenerational transmission and experiential learning. P7 explained: "*My parents worked for commercial farmers from the time I was a young child, so I didn't need schooling to learn how to farm. I am thankful for the experience they gave me. I do manage my own farm and feed my family."* This knowledge encompassed seasonal patterns, crop selection, soil management, and weather prediction based on environmental indicators. P6 stated: *"I am still relying on word of mouth, and television/radio for weather forecasting. I am old and know all the seasons by heart and when to plant also harvest."*

Traditional methods emphasized manual labor, community cooperation, and resource recycling. Farmers saved seeds, practiced crop rotation through indigenous understanding, and utilized organic fertilization methods. This traditional knowledge represents valuable capital that technology adoption strategies must respect and build upon rather than displace.

Theme 2: Economic and Resource Constraints

Financial limitations emerged as the most prominent barrier to agricultural advancement, including 4IR adoption. P9 articulated this challenge comprehensively: *"The majority of 4IR tools, such as drones, AI-driven systems, automated machinery, and precision agriculture sensors, are simply too costly. They demand a significant initial outlay of funds, which we small-scale farmers just lack. Additionally, we have limited access to credit, and neither the public nor private sectors are doing much to help us afford these technologies."*

Basic infrastructure needs competed with technology investment. P5 described: *"Animals wander around because they are not supervised, I have a big field and failing to fence my planted areas. This proves that, it would be difficult to purchase 4IR tools, while struggling with simple things."* The economic reality for these farmers prioritizes immediate survival needs—food security, basic equipment, essential inputs—over longer-term technological investments, regardless of their potential benefits.

P4 noted: "*There may be a chance to use the 4IR tools for increased agricultural output and better profit if we can get government funding."* This highlights farmers' recognition of technology potential coupled with realistic assessment of financial impossibility without external support.

Theme 3: Infrastructure and Connectivity Deficits

Physical and digital infrastructure limitations fundamentally constrained 4IR adoption potential. P10 explained: *"Even in 2025, our region continues to face issues with unstable electricity and inadequate internet access. Furthermore, many of us lack the digital skills necessary to operate these new tools. It is nearly impossible for small-scale farmers like us to use the technologies efficiently, even when they are available, without the right infrastructure, technical assistance, or training."*

Unreliable electricity supply prevented the use of electrically-dependent technologies. Poor internet connectivity limited access to mobile applications, digital marketplaces, and online advisory services that could function on existing smartphones. Poor roads hindered market access and equipment delivery. Absence of nearby technical support services meant that equipment breakdowns could result in extended downtime. These infrastructure deficits create an enabling environment problem—even if farmers could afford technologies, the physical conditions for their effective operation do not exist.

Theme 4: Educational and Digital Literacy Barriers

Limited formal education and digital literacy compounded adoption challenges. P1 stated simply: *"I never received an opportunity to attend school; if you talk about the 4IR and other technological tools, they are complex for an old man like me."* This complexity perception reflects not merely technological sophistication but a fundamental mismatch between tool design assumptions and farmer capabilities.

P3 acknowledged: *"We grew up surviving like this, it will be hard for us to adjust into technology unless we receive assistance from government training."* This statement reveals both the recognition of personal limitations and the identification of training as a necessary precondition for adoption. The digital literacy gap extends beyond operating devices to understanding data interpretation, troubleshooting problems, and integrating technology outputs into decision-making processes.

Theme 5: Perceived Technology Inappropriateness

Farmers perceived 4IR tools as designed for commercial rather than subsistence contexts, creating a fundamental mismatch. P8 articulated: *"Smart farming technologies look like they were made for commercials not for small-scale and emerging farmers. Simply because they have money to purchase the most expensive tools and maintain them. Whereas, for small-scale farmers the aim is to make sure that households have food instead of businesses."*

This perception reflects reality—many agricultural technologies assume scale, capital availability, technical support access, and commercial objectives that subsistence farmers lack. The statement also reveals different farming philosophies: commercial farmers prioritize profit maximization while subsistence farmers prioritize food security and risk minimization. Technologies designed without understanding these fundamental differences will fail to gain acceptance regardless of their technical capabilities.

P8 continued: *"As small-scale farmers we believe in hard labour and creating job opportunities for our communities."* This reveals another dimension: technologies that displace labour may be viewed negatively in contexts where employment generation is valued, contrasting with commercial contexts where labour reduction increases profitability.

Theme 6: Market Access and Business Models

Despite challenges, farmers demonstrated entrepreneurial capabilities and established market relationships. P2 explained: *"I have to hire a car to sell my product by the side road and make money. I started this business 10 years ago, because of consistency my family gets food to eat after we have sold few avocados."* This reveals adaptive marketing strategies working within resource constraints.

P3 described: *"As you can see, I am selling small portions because after harvest the output should be divided for business and household. We grew up surviving like this... I am used to selling under the tree and there is money since people pass by my house on daily basis. There are customers who place orders before harvest, I am blessed!"* This illustrates established customer relationships, predictable demand, and dual-purpose production systems that technologies must accommodate rather than disrupt.

These existing marketing systems, while informal, function effectively for farmers' current scales and objectives. Digital marketplace platforms could enhance these systems by expanding customer reach, improving price transparency, and facilitating bulk sales, but must build upon rather than replace existing relationships.

Theme 7: Climate Adaptation Strategies

Farmers employed traditional climate adaptation strategies including seasonal knowledge, water harvesting, and crop diversification. P6 stated: *"I am still relying on word of mouth, and television/radio for weather forecasting. I am old and know all the seasons by heart and when to plant also harvest. Advancement would be greater but financially we are limited as small-scale farmers."*

P7 noted: *"Even though sometimes we suffer from drought but we collect water from rivers and dams to nourish our plants."* These strategies demonstrate resilience and resourcefulness but remain vulnerable to increasingly unpredictable climate patterns. This is where affordable 4IR tools could provide significant value—mobile weather advisories, soil moisture sensors, and solar irrigation could enhance existing adaptation strategies without requiring complete practice transformation.

Theme 8: Institutional Support Gaps

Farmers identified insufficient government and institutional support as a critical constraint. P4 observed: *"Since I began my poultry business long time ago and am appreciative of my devoted customers (community members), government and* *stakeholder support is insufficient."* This reflects a broader pattern of rural neglect where agricultural extension services remain under-resourced and poorly coordinated.

P3 suggested: *"Unless we receive assistance from government training."* This identifies capacity building as a key support need. The institutional gap encompasses not only financial subsidies but also training programs, demonstration projects, technical support services, and coordinated implementation.

RECOMMENDATIONS ON THE USE OF 4IR TOOLS

Suggestion	Benefit	Prospect for KwaDlangezwa
• Promote Climate-Smart Agriculture • Leverage Digital Technologies • Smartphone and SMS • Portable Soil Test Kits and Community Soil Moisture Probes • Community SolarPumps and Modular Drip Irrigation Kits • Digital Marketplaces for Aggregated Adopting • Risk management	• To increase resilience to climate change, promote the use of sustainable farming techniques like crop rotation • These diagnostic tools support Sustainable Development Goals, reduce environmental degradation, and improve water-use efficiency and crop fertilizer • SMS-based platforms are low-cost and adaptable, enabling farmers in remote areas to receive timely information, addressing knowledge. • Give smallholder farmers access to markets/agricultural information via mobile platforms. • Solar-powered water pumps and modular drip irrigation kits offer a sustainable and affordable solution for small-scale farmers in sub-Saharan Africa. • technology in agriculture requires reliable market access, and digital marketplaces like South Africa's Khula app help by connecting farmers directly to buyers, reducing reliance on middlemen, and enabling aggregated sales. By bringing farmers and buyers together online • Weather forecasting apps and early pest detection methods reduce crop losses due to disease and climate variability IoT devices. •	• This will be beneficial to KwaDlangezwa Farmers (small-scale and emerging) • Farmers at KwaDlangezwa distribute food to the community as customers • Most of the farmers have cell phones and are able to receive information on agricultural activities. • The University of Zululand could work with farmers on teaching farmers as community engagement free programme. • Boreholes are expensive this, could work for farmers and sustain their fields. • As for farmers at KwaDlangezwa they will benefit from reaching out on other customers besides the once on their area. • Farmers will have access to informative data and use it when needed at lower cost

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