Sustainability Science and Resources, Vol. 8:2, 2025, pp. 15 - 37

The Impact of Industry 4.0 on Women-Owned Agribusinesses in South Africa - Gauteng Province

Phindile Cebekhulu-Msomi[1*], Prof. Shamila Singh[2]

[1]Department of Business Studies, Milpark Business School, 11 Sonia Street, Gillview, 2091

[2]Unique Consulting Solutions and Department of Justice and Constitutional Development, School of Business Leadership – UNISA, Johannesburg, South Africa

[*]Corresponding author
Email: phindimsomi@hazilegroup.co.za, shamilasingh70@yahoo.com

Received: 17 January 2025 Accepted: 12 June 2025 Published: 16 June 2025

Abstract

Women-owned agribusinesses in Gauteng, South Africa face significant challenges in leveraging Industry 4.0 technologies for sustainable growth to understand the influence on business expansion and profitability to design targeted interventions.This study examines the impact of Industry 4.0 on women-owned agribusinesses in Gauteng, South Africa, using a survey of 135 female farmers to identify key factors and strategies for growth.

A survey was distributed through Google Forms to gather quantitative data from 135 female farmers. Descriptive and inferential statistics, including Spearman's rank correlation and ordinal regression, were used to analyse the data.

The study found that women-owned agribusinesses face significant financial challenges, with 48.1% reporting losses or no profit in 2022 compared to 2018. Only 9.6% of businesses reported gross profits above R200,000, indicating that very few women-owned agribusinesses were able to reach high profitability levels. The study also found that funding, market accessibility, and agricultural skills are the three most important factors for business expansion, with 73.3% of participants considering funding extremely important. Additionally, the study found a weak positive correlation between the use of Industry 4.0 technology and gross profit margins, suggesting that technology adoption is important but not the primary driver of profitability.

Women-owned agribusinesses in Gauteng face significant financial difficulties, with a majority reporting losses or low profitability. Tailored interventions considering demographic factors and leveraging the potential of technology are needed for sustainable growth. The study provides valuable insights into the challenges and opportunities faced by women-owned agribusinesses to navigate the impact of Industry 4.0. The findings highlight the importance of focused support in areas like funding, market access, and skill development to improve the expansion and sustainability of these businesses.

Keywords: Food security, Industry 4.0, Sustainable Growth, Technology Adoption, Women-owned agribusinesses, Economic empowerment, Smart technologies, Automation

Introduction

Agriculture, a cornerstone of global sustenance, is currently experiencing transformative changes driven by the integration of advanced technologies into its practices (Bajaj, 2024). This movement, often categorised within the broader framework of Industry 4.0, has been particularly impactful in redefining the operational landscape for various sectors, including agriculture, a phenomenon now referred to as Agriculture 4.0 (Dufva & Dufva, 2019; Ugwu, 2019). Through the rapid technological evolution there must be recognition that these innovations can empower SME enterprises (SMEs), and in particular women in agribusiness (Clercq, Vats, and Biel, 2018), Women constitute a significant portion of the agricultural workforce, especially in developing countries where they often manage family farms or their own small enterprises. However, these women face unique challenges, such as limited access to advanced technology, funding, and training resources. The ongoing digitalisation in agriculture not only offers the potential to optimize productivity and streamline farming processes but also presents a critical opportunity to foster gender equity by enhancing the capabilities and competitiveness of women-owned agribusinesses (Martens & Zscheischler, 2022).

As the global population continues to grow predominantly in developing regions—addressing food security and sustainable farming practices becomes increasingly urgent (Armanda, Guinee, & Tukkera, 2019; Fanzo, Covic, Dobermann, Henson, Herrero, Pingali & Stall, 2020).. Women, as both producers and managers in the agricultural landscape, can play a pivotal role in achieving these objectives when equipped with the necessary technological tools and support. This study aims to explore the implications of Agriculture 4.0 in the context of SME women in agribusiness, highlighting how digital solutions can not only improve operational efficiency but also drive economic empowerment and resilience among women farmers in South Africa Hassoun, Boukid, Pasqualone, Bryant, García García, Parra-Lo´pez, Jagtap, Trollman, Cropotova, Francisco & Barba, 2022.

Given the fast-paced advancement in agricultural technologies, it is essential to examine their applicability and potential benefits for SMEs, particularly in a South African context where smallholder and subsistence farming are prevalent. This research offers insights into how embracing these innovations can create a more inclusive and productive agricultural sector, ultimately contributing to the broader goal of sustainable development**.**

The advent of Agriculture 4.0 presents a unique opportunity for increased efficiency, sustainable practices, and enhanced productivity within agribusiness, aligning with global goals such as the United Nations' Sustainable Development Goals (Alhammadi, Alsyouf, Semeraro, & Obaideen, 2024). However, the transformative potential of Industry 4.0 in agriculture is not uniform across all demographics, particularly for women entrepreneurs in agribusiness. Women, a significant demographic in agribusiness, encounter unique challenges in adopting and adapting to the changes brought about by Industry 4.0 (Shamshiri, Kalantari, Ting, Thorp, Hameed, Weltzien, Ahmad, & Shad, 2018; Zha, Melewar, Foroudi, & Jin, 2020). The question of whether Industry 4.0, or Agriculture 4.0, is appropriate for all farmers is more nuanced than previously explored; it centers on the concept of scalability. The high levels of automation inherent in Agriculture 4.0 necessitate that farmers consider their operational scale to justify investment. For instance, a fully automated John Deere tractor can range in cost from USD 200,000 to USD 500,000 (ZAR 3.65 million – ZAR 9.14 million).

These tractors offer advanced functionalities, such as automatically downloading ploughing and planting instructions from satellites, executing tasks autonomously, and collecting data without human interaction. However, for farmers with smaller operations, the financial burden of such technology can be prohibitive, risking unsustainable debts and potential financial collapse. Therefore, assessing the size of the farm is critical when evaluating the applicability and suitability of Agriculture 4.0 technologies, particularly for those with fewer resources. This assessment must consider not only the upfront costs but also the ongoing profitability and operational demands associated with adopting innovations in Agriculture 4.0.

Women in agribusiness

Women in agribusinesses have historically faced unique challenges, navigating societal expectations and confronting barriers rooted in gender norms. Despite these challenges, women have been instrumental in driving agricultural production, contributing significantly to food security and economic development (Ndandula, 2021). In the current context and at the cusp of a technological revolution, it is critical to understand how women can harness the potential of Industry 4.0 becomes imperative.

Women in agribusiness have historically faced distinct challenges rooted in societal expectations and entrenched gender norms, which have often limited their access to resources,

markets, and decision-making opportunities (Ndandula, 2021). Despite these barriers, women have been instrumental in enhancing agricultural productivity, contributing significantly to food security and economic development (Sheeba & Christopher, 2024; Gadanakis, 2024). As the agricultural sector increasingly integrates Industry 4.0 technologies, such as automation, precision agriculture, and digital platforms, understanding how women can harness these innovations becomes critical to achieving inclusive and sustainable progress (Sindhu & Kumar, 2022; Sima et al., 2020).

Digital transformation eras and agriculture

In the rapidly evolving landscape of agricultural technology, yet some foundational technologies continue to wield influence long after their initial release. Industry 4.0 that was initiated over a decade ago, began a transformative journey by significantly disrupting all sectors. Although businesses are on the brink of the next generation of technological solutions, it is crucial to reflect on and appreciate the impact of existing technologies on agricultural practices, recognising their role as a springboard for future advancements.

Organisation must extract critical lessons learned in its implementation and integrate insights from its design and application. This paper examines the sustained relevance of Industry 4.0 within the context of recent technological developments, ultimately arguing for a comprehensive understanding of past innovations as we move towards the future of agribusiness technology.

Technology can significantly enhance the agri-business value chain, particularly for women entrepreneurs, by improving efficiency and reducing reliance on manual labor. Automation and data analytics can streamline various activities within the value chain, including planting, irrigation, harvesting, and post-harvest processing. These advancements have the potential to level the playing field for women by providing tools that enhance productivity and decision-making capabilities. The successful adoption of Agriculture 4.0 technologies also depends on factors such as farm size and crop suitability, which are crucial for maximising profitability. Additionally, improved access to markets through technology can help small-scale farmers navigate the challenges of securing contracts, ultimately enhancing their competitiveness in the market.

The pivotal question

In this dynamic landscape, women-owned agribusinesses in Gauteng, South Africa, face a pivotal question: How can they leverage Industry 4.0 to foster the growth of their enterprises? This question serves as the guiding star for our exploration, directing our attention to the intricate interplay between technology, tradition, and the unique challenges faced by women entrepreneurs in agribusiness (*Miranda, Ponce, Molina & Wright, 2019).*

The importance of gauteng

Gauteng, an economic hub in South Africa, provides a compelling backdrop for our study. Gauteng's agricultural sector is not only crucial for local sustenance but also contributes significantly to national and international markets. (Greencape, 2022) Understanding the impact of Industry 4.0 on women-owned agribusinesses in this dynamic region holds implications for the broader narrative of agricultural transformation in the country.

Literature Review

The analysis of various theories underscores the multifaceted nature of technology adoption among women in agri-business (Martin, Gasselin, Hostiou, Feron, Laurens Purseigle & Ollivier, 2022;, Shaw, Tangirala, Vissa and Rodel, 2018). Innovation Diffusion Theory highlights the importance of aligning new technologies with women's existing practices to enhance perceived benefits and ease of use. The Technology Acceptance Model emphasises that perceived usefulness and ease of use are critical for encouraging women's engagement with new technologies. Meanwhile, Social Cognitive Theory points to the value of role models and peer influence, suggesting that networks and community support can boost confidence in utilising technology (*López-Concepción, Gil-Lacruz & Saz-Gil, 2022).* Gender Theory critically examines the structural barriers women face, indicating that addressing these socio-economic challenges is vital for equitable access to resources (Ren, Feng, & Gao, 2023; Idowu, Ajah, & Fadiji, 2021). Bryan, Alvi, Huyer, & Ringler (2023) add to this discourse by underlining the critical function of agricultural technologies in bolstering women's livelihoods. This perspective is critical in understanding the potential of technology to mitigate gender-divide challenges and boost productivity, thereby contributing to sustainable agribusiness models (Fischer, Wittich, Malima, Sikumba, Lukuyu, Ngunga, Rugalabam, 2018).

In the context of Sub-Saharan Africa, (identified challenges to women's participation in agriculture, providing insights that are pertinent to the situation in Gauteng.

The Social Sustainability Framework connects technology adoption to broader community benefits, advocating for practices that support both individual livelihoods and communal resilience (Cricelli, Mauriello, Strazzullo, & Camilleri, 2024; *Lewandowska, Ullah, AlDhaen, AlDhaen & Yakymchuk, 2023).* Finally, the Resource-Based View illustrates the necessity of equipping women with essential resources and skills to effectively leverage technological advancements in agriculture. Together, these theories provide a robust framework to better understand and promote the adoption of technology among women in the agricultural sector.

In Sub-Saharan Africa, women face various challenges that impede their participation in agriculture, offering insights particularly relevant to the situation in Gauteng (Mulema, Jogo, Damtew, Mekonnen, & Thorne, 2019). This is echoed in the work of Li et al. (2020), who explore the nuanced interactions between gender and technology adoption in agriculture, emphasising the diverse ways in which men and women engage with agricultural technologies (Areal & Pede, 2023). In addressing the digital divide, Doss et al. (2018) bring to light the disparities in women's access to digital technologies, which can significantly hinder their ability to adopt modern agricultural practices. Meanwhile, da Silveria and Amaral (2022) investigate smart farming technologies and highlight the broader economic opportunities they present, offering a framework for understanding how these technologies can be leveraged to benefit women in agricultural settings.

Further enriching this discourse, Aryal et al. (2020) examine the adoption of climate-resilient and precision agricultural technologies specifically by women, enhancing the understanding of the adoption factors particularly relevant to their experiences with environmental challenges in agriculture. This is complemented by Diiro et al. (2018), who argue for the necessity of gender-inclusive strategies in the transformation of agriculture through digital farming, underscoring the importance of ensuring that women are not left behind in the digital shift.

Additionally, the research by Gabriel and Gandorfer (2023) emphasises the role of women in livestock farming, examining digital technology adoption in small-scale farming, which expands the discussion to different sectors within agriculture. Lastly, Rahman and Huq (2023) recognise information and communication technologies (ICT) as transformative tools that can significantly improve women's agricultural involvement, stressing the beneficial impact of ICT on the rural

livelihoods of women farmers. Together, these studies highlight the critical need for targeted strategies that address the intersection of gender, technology, and agriculture to empower women in their agricultural pursuits.

In conclusion, the existing literature on women in agriculture and the adoption of technology underscores a growing recognition of the significant contributions that digital tools and smart technologies can make to women-owned agribusinesses (Latino, Corallo, Menegoli, & Nuzzo (2023). Despite these advancements, the literature highlights an urgent need to address the gender digital divide and implement inclusive strategies that facilitate women's full engagement with and benefits from agricultural technology. Collectively, these studies paint a comprehensive picture of the technological landscape in agriculture, emphasizing that women's participation is not only essential for the success and sustainability of the industry but also crucial in navigating the challenges posed by the Fourth Industrial Revolution (4IR). As the role of women in agriculture continues to evolve, it is imperative to prioritise targeted initiatives that empower them, ensuring that they can leverage technology effectively and secure their positions as key stakeholders in the agricultural sector.

Methodology

According to Creswell and Plano Clark (2018), using theoretical frameworks helps to guide the topic of study and provides the framework with which to assess if the research questions align with the purpose of the study. The study adopted a quantitiave methodological approach understand the role of technology in the growth in women -owned agri-businesses (Rana, Gutierrez, & Oldroyd, 2021). The population for the study was SMME groups and female farmers between the ages of 36 and 60 and has been in farming for more than two years. The population is 1301 farmers and sampling technique was simple random sampling to select 135 respondents (Conlon, Timonen, Elliott-O'Dare, O'Keeffe & Foley, 2020; Young, Bywaters and Walker, 2020). The data collection instruments for the quantitative research phase were a survey that was self-designed (Park, Konge, and Artino 2019). The quantitative research was anlaysed used inferential and descriptive analysis (Bougie & Sekaran, 2019; Neuendorf, 2018).

Results and Discussion

The study collected quantitative data from 135 female farmers through an online survey and analysed it using SPSS Version 21 (Field, 2017). Descriptive statistics were employed to organise and describe the data for ease of understanding (Yellapu, 2018). Central tendency measures, including mean, median, and mode, were used to describe the data, as they identify a single value as representative of the entire distribution (Jaggers & Loomis, 2020).

Frequencies

	Land and Ownership		Agricultural skills		Access to resources		Acess to markets		Funding		Technology	
	No	%	No	%	No	%	No	%	No	%	No	%
Extremely important	40	29,6	52	38,5	36	26,7	78	57,8	99	73,3	47	34,8
Very important	48	43,0	46	34,1	61	45,2	39	28,9	28	20,7	43	31,9
Moderately important	48	43,0	46	34,1	61	45,2	39	28,9	28	20,7	43	31,9
Slightly important	5	3,7	12	8,9	4	0,0	5	3,7	0	0,0	13	9,6
Not important	6	4,4	2	1,5	0	0,0	0	0,0	0	0,0	0	0

Table 1: Frequencies

According to the participants, funding, market accessibility, and agricultural skills are the three most important factors for the expansion of women-owned agribusinesses (Table 1 results). Financial support is deemed crucial for business growth, as indicated by the percentage of participants (73.3%) who rated funding as extremely important. The importance of market availability for the success of these businesses was underscored by the high importance rating given to access to the market, which was deemed extremely important by 57.8% of participants. A further indication of the importance of agricultural knowledge for business development is the 38.5% rating of agricultural skills as extremely important.

The fact that there are no comments under "Not Important" says even more about how everyone involved feels that technology is important for agriculture. This is in line with more

general agricultural trends, where better crop yields, more efficient resource management, and modern farming practices are all attributed to technology integration (Rijswijk, et, al., 2021).

The results in table 2 indicate that women-owned agribusinesses in Gauteng place a high value on technology, with a sizable majority acknowledging its crucial role in company expansion. This shows that the advantages of Industry 4.0 technologies for agriculture—like higher productivity, improved resource management, and increased market competitiveness are clearly understood.

The fact that there are no comments under "Not Important" says even more about how everyone involved feels that technology is important for agriculture. This is in line with more general agricultural trends, where better crop yields, more efficient resource management, and modern farming practices are all attributed to technology integration.

The results above indicate that women-owned agribusinesses in Gauteng place a high value on technology, with a sizable majority acknowledging its crucial role in company expansion. This shows that the advantages of Industry 4.0 technologies for agriculture like higher productivity, improved resource management, and increased market competitiveness are clearly understood.

To improve the expansion and sustainability of women-owned agribusinesses in Gauteng, it is critical to address particular obstacles and offer focused support in areas like financial resources, market access, and skill development.

The majority of participants recognised the crucial role of technology in enhancing business growth. Network availability, despite being a perceived barrier, was acknowledged as essential for communication and access to information. The high cost of technology was considered a challenge, but participants highlighted the subsequent operational performance and return on investment. Basic administrative technology like computers and accounting software was deemed essential, and farming-specific technologies such as smart watering systems were acknowledged for their cost-saving benefits.

Regression analysis

The document that is provided contains Table 2, which displays the findings of an ordinal logistic regression analysis. This analysis looks at how different factors affect the expansion of women-owned agribusinesses in Gauteng, South Africa. The relationship between several

independent variables (factors influencing growth) and an ordinal dependent variable (business growth) can be modelled using this statistical technique.

Ordinal regression parameter estimates of factors that influence business growth

	Parameter Estimates		
	Estimate B	Exp (B) / odds ratios	Sig. (p)
Land Ownership	0.641	1.899	0.040*
Agricultural Skills	1.170	3.221	0.002**
Access to resources	0.507	1.660	0.256
Access to market	1.343	3.831	0.013*
Funding	1.383	3.989	0.096
Technology	0.932	2.540	0.024*

Table 2: Regression (Source: Researcher's own)

The interpretation of the ordinal logistic regression results from Table 9, as described in the attached document, involves understanding the relationship between various predictor variables (Land Ownership, Agricultural Skills, Access to Resources, Access to Market, Funding, and Technology) and the dependent variable, Business Growth, which is measured by the difference in gross profits over two time periods.

Statistical significance and model fit:

1. The likelihood ratio chi-squared test [$\chi 2(6)=35.610, p<.001$][$\chi 2(6)=35.610, p<.001$]indicates that the model fits significantly better than a null model (a model without predictors). This suggests that the predictors collectively have a significant impact on business growth.

2.The goodness-of-fit tests (Deviance and Pearson's chi-squared [$\chi 2(132) = 113.003$, p=0.883] [$\chi 2 (132) =113.003, p=0.883$] indicate a good fit of the model to the data, as the p-value is greater than 0.05, suggesting that the model adequately represents the observed data.

Parameter estimates and odds ratios

Land Ownership: Significant positive impact on business growth (B= 0.641 = 0.641, Exp(B) = 1.899 *Exp*(*B*)= 1.899, p= 0.040 *p*= 0.040). This indicates that for each unit increase in land ownership rating, the odds of achieving higher business growth increase by a factor of 1.899.

Agricultural skills: Strong positive effect (B= 1.170 *B*= 1.170, Exp(B)= 3.221 *Exp*(*B*)= 3.221, p= 0.002 *p*= 0.002), showing that improvements in agricultural skills substantially increase the likelihood of higher business growth.

Access to resources: Although it shows a positive effect (Exp(B)=1.660 *Exp*(*B*)= 1.660), it is not statistically significant (p= 0.256 *p*= 0.256), suggesting that the impact of access to resources on business growth might not be as strong or direct as other factors.

Access to market: Significant positive impact (B= 1.343 *B*= 1.343, Exp(B)= 3.831 *Exp*(*B*)= 3.831, p= 0.013 *p*= 0.013), indicating that better market access greatly enhances the chances of business growth.

Funding: Shows a positive effect (Exp(B)=3.989*Exp*(*B*)=3.989), but not statistically significant (p=0.096*p*=0.096), which might suggest variability in how funding influences business growth among different respondents.

Technology: Significant positive impact (B= 0.932 *B*= 0.932, Exp(B)= 2.540 *Exp*(*B*)= 2.540, p= 0.024 *p*= 0.024), highlighting the importance of technology in enhancing business growth.

The examination of Table 3 in the document indicates that a number of variables, including land ownership, agricultural skills, market accessibility, and technology use, have a major impact on the expansion of agribusinesses owned by women in Gauteng. Targeted interventions aimed at assisting these entrepreneurs should centre on these factors. These predictors are significant and together account for a sizable fraction of the variance in business growth among the participants, according to the model's overall significance and fit.

Analysis of Profit of SMEs

	Annual Gross Profit of a sample of 135 research respondents			
	(1)Loss/No Profit	(2) R0 – R100 000	(3) R100 000 – R200 000	(4) > R200 000

Frequency	65	30	27	13
Percentage	48.1	22.3	20.0	9.6

Table 3 Variations in annual gross profit in 2018 and 2022

The data indicates that 48.1% of the participants reported losing money or making no profit in 2022 compared to 2018. This noteworthy percentage suggests that these businesses faced pervasive difficulties or unfavorable circumstances that adversely affected their profitability during that time. The next two groups, representing annual gross profits between R0 and R100,000 and R100,000 and R200,000, comprise 20.0% and 22.3% of the participants, respectively. Based on these numbers, a reasonable fraction of the companies managed to turn a profit, albeit a small one. Out of all the businesses, only 9.6% reported gross profits exceeding R200,000. This indicates that very few women-owned agribusinesses achieved high profitability levels during the given time frame.

The findings indicate that a number of factors, including the effect of COVID-19 on businesses and the economy, could be responsible for the observed profit disparities. The pandemic probably caused supply chain disruptions, restricted market access, and more operational difficulties, which may account for the high percentage of profits or losses.

Table 3's analysis shows that women-owned agribusinesses faced considerable financial difficulties between 2018 and 2022, with a sizable portion of them reporting neither profits nor losses. This emphasises the necessity of focused interventions to assist these companies, potentially in the form of enhanced market accessibility, funding, and tools to lessen the effects of outside shocks like the COVID-19 pandemic. There are chances for growth and success, which could be improved by implementing innovative practices and receiving strategic support, as indicated by the small percentage of businesses that did see higher profits.

Spearman's correlations

Interpretation table for Spearman's ranked correlation coefficient	
Range Standards	**Correlation Degree**

0.00 to 0.20	Negligible
0.21 to 0.40	Weak Relationship
0.41 to 0.60	Moderate Relationship
0.61 to 0.80	Strong Relationship
0.81 to 1.00	Very strong Relationship

Table 4: Interpretation Spearman's Correlations (Source: Prion and Haerling, 2014)

Spearman's rank correlation coefficient was performed as a non-parametric measure of the strength and direction of the relationship between the use of Industry 4.0 technology in agriculture and gross profit margins. The results of the use of technology were coded 1 = not sure, 2 = no, and 3 = yes. The gross profit margins from the previous research question and coded use of innovative technology were used to compute the correlation coefficients. Spearman's rank correlation coefficient was performed on SPSS Version 21. As demonstrated in Table 4, there was a weak positive correlation between the use of Industry 4.0 technology and gross profit margins ($r_s = 0.313$, p=0.014).

	Spearman's rank correlation coefficient		
		Use of Industry 4.0 technology	Gross profit (business growth)
Use of Industry 4.0 technology	Correlation (r) Sig. N	1.000 . 135	0.313* 0.014 135
Gross profit (business growth)	Correlation (r) Sig. N	0.313* 0.014 135	1.000 . 135

Table 5: Spearman's rank correlation coefficient between use of Industry 4.0 technology and gross profit (business growth) (Source: Researcher's own Calculation)

Details from Table 4:

**correlation is significant at the 0.05 level*

Correlation Coefficient (r): 0.313
Significance (p-value): 0.014
Number of Observations (N): 135

Synopsis of the strategies for industry 4.0

In the final section of the online survey, the women SMMEs were prompted to select two innovative 4.0 strategies that improves their business performance. Robotics and automation used for tillage, pesticide application, and other tools. Drone technology is used for monitoring and managing crops and livestock from the air. Furthermore, water recycling, drip irrigation, and automated water systems and smart watering systems was also selected as beneficial strategies. Other options that were chosen is the Internet of Things (IoT) which are distant sensors to track temperature, humidity, and soil quality, among other environmental parameters. The most common Industry 4.0 innovative strategies from the collected data were Robotics and Automation (34,2%). The potential of this technology is that it automates operations to reduce the labour intensity of farming and improve product quality. Smart watering technology was identified as the most beneficial strategy for improving business growth by 30.3% of the women farmers, as it addresses the challenge of water scarcity which is a critical issue in agriculture where water is heavily utilised. This technology helps conserve water resources, thereby supporting sustainable farming practices. Drone Technology would aid in improving business performance for 23,7% of the farmers, whilst 11,8% said Internet of Things would be most beneficial for agribusiness.

Analysis of the findings

The analysis was conducted using Spearman's rank correlation algorithm. Coefficient of Correlation (r = 0.313): The data suggests a marginally positive correlation between the adoption

of Industry 4.0 technology and the expansion of businesses with respect to gross profit. A weak positive correlation implies that there is a slight tendency for gross profit margins to increase along with the use of Industry 4.0 technology, but the relationship is not very strong.

Significance (0.014 p-value): There is a statistically significant correlation when the p-value is less than 0.05. This suggests that the adoption of Industry 4.0 technology and higher gross profit margins are significantly correlated, and that this correlation is not likely the result of chance. With regards to the number of observations (N = 135) the sample size is adequate to provide a reliable estimate of the correlation between these two variables.

The investigation of the relationship between the use of Industry 4.0 technology in agriculture and the gross profit margins (business growth) of women-owned agribusinesses is presented in Table 3. Table 3's findings indicate that although the gross profit margins of women-owned agribusinesses are positively impacted by the use of Industry 4.0 technology, the correlation between the two is not very strong. Even though the effect might not be very strong, the statistical significance of the correlation suggests that Industry 4.0 technology has a positive impact on business growth, which is a factor that should not be ignored.

Barriers to growth

The findings highlight several key themes related to the barriers women face in growing their agribusinesses, with technology and economic challenges being the most pronounced. Many participants emphasized the significant impact of technological hurdles, such as the high costs of purchasing and maintaining equipment, as well as limited access to electricity and digital networks. Furthermore, a lack of agricultural education and skills is crucial as women expressed the need for proper training to optimize their use of technology and improve crop management. Economic barriers were also identified as major impediments; insufficient funding and capital hinder women's ability to invest in essential resources, such as water and farming inputs, limiting their operational capacity. Additionally, the lack of marketing skills was noted as a critical issue, making it difficult for women to expand their customer base and enhance profitability. Lastly, the participants highlighted ineffective government support, asserting that existing policies often fail to recognise and address the unique challenges women face in the agricultural sector. Collectively, these themes illustrate the multifaceted obstacles women in agribusiness encounter, underscoring

the need for tailored interventions that enhance access to technology, funding, education, and marketing resources.

Impact of industry 4.0

Industry 4.0 technologies, such as robotics, automation, drone technology, smart watering systems, and the Internet of Things (IoT), offer significant potential to enhance efficiency, sustainability, and growth in agribusinesses. The study finds that these technologies can help reduce labor intensity, improve product quality, and optimise resource use, particularly water.

Preferences for industry 4.0 strategies

The survey results indicate that the most preferred Industry 4.0 strategy among the respondents is Robotics and Automation (34.2%), followed by Smart Watering Systems (30.3%), Drone Technology (23.7%), and IoT (11.8%). This preference highlights the perceived value of automation and efficient water management in improving business performance.

Demographic insights

The study reveals that women aged 36 to 45 years show higher tech awareness, and those with longer tenure in business are more open to adopting new technologies. Sole ownership is predominant, with technologically adept participants often involving younger family members in the business, suggesting a potential for intergenerational knowledge transfer.

Interpretation of findings

Addressing barriers to growth in women-owned agribusinesses requires targeted interventions, such as improving access to technology and financial resources, implementing educational and training programs, and enhancing market access, all of which can significantly contribute to fostering sustainable development and economic empowerment.

The positive impact of Industry 4.0 technologies on business growth is evident from the study. By adopting these technologies, women farmers can enhance their operational efficiency, reduce costs, and improve product quality. The preference for Robotics and Automation and Smart Watering Systems indicates a strategic focus on reducing labor intensity and optimising resource use, which are critical for sustainable growth.

Policy implications

Policymakers need to develop inclusive policies that address the specific needs of women entrepreneurs in agriculture. This includes providing financial support, facilitating access to advanced technologies, and creating educational programs tailored to women farmers. Such policies can help bridge the gender gap in technology adoption and empower women to leverage Industry 4.0 for business growth.

Future research directions

The study highlights the need for further research to explore the long-term impact of Industry 4.0 technologies on women-owned agribusinesses. Future studies could focus on the effectiveness of specific technologies, the role of government and private sector support, and the impact of educational programs on technology adoption.

Conclusions

The research presented in the paper "Transformative Growth: The Impact of Industry 4.0 on Women-Owned Agribusinesses in South Africa - Gauteng Province" offers important new information about how Industry 4.0 technologies can change the way that women-owned business owners operate. Women company owners can achieve notable growth and sustainability by utilising cutting edge technologies and resolving the obstacles that have been identified. To support women's empowerment and success in the agricultural sector, the study emphasises the significance of focused interventions, inclusive policies, and ongoing research.

The study highlights the need for targeted support programmes that address the specific barriers faced by women in agribusiness, such as access to technology, financial resources, and market access. Policymakers should develop inclusive policies that provide financial incentives, grants, and subsidies to facilitate the adoption of Industry 4.0 technologies among women farmers.

There is a critical need for educational and training initiatives that enhance the technological proficiency of women in agribusiness. These programmes should focus on the practical application of Industry 4.0 technologies, such as robotics, automation, artificial itelligence, smart watering systems, and IoT, to improve operational efficiency and productivity.

The study underscores the importance of gender-inclusive policies that recognise and address the unique challenges faced by women entrepreneurs in agriculture. This includes creating platforms for women to share their experiences, access mentorship, and participate in decision-making processes related to agricultural technology and innovation.

The study sheds light on the intricate dynamics of Industry 4.0 adoption in women-owned agribusinesses in Gauteng. In synthesising our findings, it is evident that Industry 4.0 has the potential to be a catalyst for transformative growth in women-owned agribusinesses. The age-related disparities in technology adoption underscore the need for targeted interventions, acknowledging the digital divide that exists among women in different age groups. Based on our insights, we propose several recommendations:

1. The findings indicate a strong preference for robotics and automation and smart watering systems among women farmers. Agribusinesses should prioritise the adoption of these technologies to enhance efficiency, reduce labor intensity, and optimize resource use. Practical steps include investing in automated machinery, precision irrigation systems, and remote monitoring tools.
2. The study reveals that technologically adept participants often involve younger family members in the business. This suggests a strategy for intergenerational knowledge transfer, ensuring the sustainability of technological adoption and business growth. Agribusinesses should encourage the involvement of younger generations in learning and applying new technologies.
3. Building networks and collaborations among women entrepreneurs can facilitate knowledge sharing and collective action to address common challenges. Agribusinesses should leverage platforms and associations that promote collaboration, enabling women to share best practices and access resources collectively.

Acknowledgements

The authors would like to thank the participants in the original study. The article is partially based on the contributing author's thesis of the degree of Doctorate in Business Administration at Milpark Business School, Gauteng, South Africa with supervisor Prof. S Singh.

Competing Interests

The authors have declared that no competing interest.

Authors contributions

PCM conceptualised, formulated equations and work on the data as part of her Doctorate of Business Administration at Milpark Business School, while SS provided academic supervision, support, and writing and editing.

Funding Information

This research received no specific funding or grant from any agency in the commercial, not for progit or public sectors.

Data availability

The data used in this study is available and can be shared when required upon receipt of a reasonable request from the corresponding author PCM.

Disclaimer

The views and opinions expressed in our article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

References

Areal, F., J., and Pede, V., O. (2023) Editorial: Evaluating the adoption and impacts of agricultural technologies. *Front. Sustain. Food Syst.* 7: 1340035.doi: 10.3389/fsufs.2023.1340035

Alhammadi, A., Alsyouf, I Semeraro, C., & Obaideen, K., (2024). The role of industry 4.0 in advancing sustainability development: A focus review in the United Arab Emirates. Cleaner Engineering and Technology 18 (2024) 100708.

Armanda, D. T., Guinée, J. 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

Aryal., J., P., Franworth., C., R., Khurana., R., Rahut., D., B. (2020). Does women's participation in agricultural technology adoption decisions affect the adoption of climate-smart agriculture? Insights from Indo-Gangetic Plains of India. *Review of Development Economics* 24(3). DOI: 10.1111/rode.12670

Ames, H., Glenton, C. & Lewin, S. 2019. Purposive sampling in a qualitative evidence synthesis: a worked example from a synthesis on parental perceptions of vaccination communication. *BMC Medical Research Methodology,* 19(1) DOI: https://doi.org/10.1186/s12874-019-0665-4.

Armanda, D. T., Guinée, J. 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

Bajaj., N. (2024). rhttps://blog.searchmyexpert.com/ai-in-agriculture/AI

Bougie, R. & Sekaran, U., 2019. *Research Methods for Business: A Skill Building Approach*. John Wiley & Sons ISBN: 978-1-119-56124-8

Braun, V., & Clarke, V. , 2019, 'Reflecting on reflexive thematic analysis', *Qualitative Research in Sport, Exercise and Health, 11*(4), 589-597.

Bryan, E., Alvi, M., Huyer, S., & Ringler, C. (2023). 'Addressing Gender Inequalities and Strengthening Women's Agency for Climate-Resilient and Sustainable Food Systems', *CGIAR GENDER Impact Platform Working Paper #013*. https://hdl.handle.net/10568/129709

Clercq, M. D., Vats, A., & Biel, A. ,2018, 'Agriculture 4.0: The Future of Farming Technology', *The World Government Summit, Dubai*. https://www.worldgovernmentsummit.org

Conlon, C., Timonen, V., Elliott-O'Dare, C., O'Keeffe, S., & Foley, G. (2020). Confused about theoretical sampling? engaging theoretical sampling in diverse grounded theory studies. Qualitative Health Research, 30(6), 947-959. https://doi.org/10.1177/1049732319899139.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and Conducting Mixed Methods Research* (3rd ed.). Sage Publications.

Cricelli, L., Mauriello, R., Strazzullo, S., & Camilleri, M., A. (2024). Assessing the impact of Industry 4.0 technologies on the social sustainability of agrifood companies**.** *Business Strategy and the Environment* 33(7). DOI: 10.1002/bse.3874

Da Silveira, F., & Amaral, F. ,2022, 'Agriculture 4.0.' , *Encyclopedia of Smart Agriculture Technologies*. DOI: https://doi.org/10.1007/978-3-030-89123-7_207-1.

da Silveira, F., Barbedo, J., G., A., da Silva, S., L., C., & Amaral., F., G. (2023). Proposal for a framework to manage the barriers that hinder the development of agriculture 4.0 in the agricultural production chain,Computers and Electronics in Agriculture, Vol. 214,108281,ISSN 0168-1699, https://doi.org/10.1016/j.compag.2023.108281.

Diiro, G., M., Seymour, G., Kassie, M., Muricho, G., Muriithi, B., W. (2018) Women's empowerment in agriculture and agricultural productivity: Evidence from rural maize farmer households in western Kenya. PLoS ONE 13(5): e0197995. https://doi.org/10.1371/journal.pone.0197995.

Doss, C., R. Meinzen-Dick, A.Quisumbing, and S. Theis. (2018). Women in Agriculture: Four Myths. *Global Food Security*, 16: 69–74. https://doi.org/10.1016/j.gfs.2017.10.001.

Dufva, T., & Dufva, M. ,2019, 'Grasping the future of the digital society. *Futures, 107,* 17-28.

https://doi.org/10.1016/j.futures.2018.11.001.

Fanzo, J., Covic, N., Dobermann, A., Henson, S., Herrero, M., Pingali, P., & Staal, S. (2020). A research vision for food systems in the 2020s: Defying the status quo. *Global Food Security*, *26*, Article 100397. https://doi.org/10.1016/j.gfs.2020.100397.

Field, A. (2017). Discovering Statistics Using IBM SPSS Statistics (North American Ed.). Sage Publications

Fischer, G., Wittich, S., Malima, G., Sikumba, G., Lukuyu, B., Ngunga, D., Rugalabam, J. (2018). Gender and mechanisation: Exploring the sustainability of mechanised forage chopping in Tanzania, Journal of Rural Studies, Vol. 64, Pages 112-122, ISSN 0743-0167, https://doi.org/10.1016/j.jrurstud.2018.09.012.

Gabriel, A., Gandorfer, M. (2023). Adoption of digital technologies in agriculture—an inventory in a european small-scale farming region. *Precision Agric* 24, 68–91. https://doi.org/10.1007/s11119-022-09931-1.

Gadanakis, Y. (2024). Advancing farm entrepreneurship and agribusiness management for sustainable agriculture. *Agriculture*, 14(8), Article 1288. DOI:10.3390/agriculture14081288.

Gelman, A., & Hill, J. 2021, *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge University Press.

Greencape (2022). Sustainable agriculture market intelligence report. https://greencape.co.za/wp-content/uploads/2022/10/AGRI_MIR_29_3_22_FINAL-3.pdf /10/AGRI_MIR_29_3_22_FINAL-3.pdf

Hassoun, A., Boukid, F., Pasqualone, A., Bryant, C., J., García García, G., Parra-Lo´pez, C., Jagtap, S., Trollman, H., Cropotova, J., & Francisco J. Barba, F., J (2022). Emerging trends in the agri-food sector: Digitalisation and shift to plant-based diets. Current Research in Food Science 5 (2022) 2261–2269

Idowu, O. B., Ajah, J., & Fadiji, T. O. ,2021, 'Gender use of information and communication technologies among agricultural extension agents in north-central Nigeria', *Department of Agricultural Extension and Rural Sociology, Faculty of Agriculture, University of Abuja, Nigeria*.

Jaggers., J., W., & Loomis., A., M. (2020). Research at Work: Sampling, Central Tendency, and Causation. Sage Journals. Volume 101, Issue 4

https://doi.org/10.1177/1044389420913

Latino, M. E., Corallo, A., Menegoli, M., & Nuzzo, B. (2023). Agriculture 4.0 as Enabler of Sustainable Agri-Food: A Proposed Taxonomy. *IEEE Transactions on Engineering Management*, 70(10), 3678–3696. https://doi.org/10.1109/TEM.2021.3101548

Lewandowska, A., Ullah, Z., AlDhaen, F. S., AlDhaen, E., & Yakymchuk, A. (2023). Enhancing Organisational Social Sustainability: Exploring the Effect of Sustainable Leadership and the Moderating Role of Micro-Level CSR. *Sustainability* (Switzerland), 15(15). https://doi.org/10.3390/su151511853

Li, W., ClarK., B., , Taylor., J., A., Kendall., H., , Jones., G., Li., Z., Jin., S., Zhao., C., Yang., G., Shuai., C., Cheng., X., Chen., J., Yang., H., & Frewer., L., J. (2020). A hybrid modelling approach to understanding adoption of precision agriculture technologies in Chinese cropping systems Computers and Electronics in Agriculture, Vol. 172, May 2020, 105305.

López-Concepción, A., Gil-Lacruz, A. I., & Saz-Gil, I. (2022). Stakeholder engagement, CSR development and Sdgs compliance: A systematic review from 2015 to 2021. Corporate Social Responsibility and Environmental Management, 29(1), 19–31. https://doi.org/10.1002/csr.2170.

Martin, T., Gasselin, P., Hostiou, N., Feron, G., Laurens, L., Purseigle, F., & Ollivier, G. (2022). Robots and transformations of work in farm: a systematic review of the literature and a research agenda. *Agronomy for Sustainable Development*, 42(4).
https://doi.org/10.1007/s13593-022-00796-2.

Martens, K.; Zscheischler, J. (2022). The Digital Transformation of the Agricultural Value Chain: Discourses on Opportunities, Challenges and Controversial Perspectives on Governance Approaches. *Sustainability*,*14*,3905. https:// doi.org/10.3390/su14073905

Martínez, A., M., Santos-Corral, M., J., de Gortari, R., & Peñalva, L. (2023). Opportunities and Challenges for the Adoption of Industry 4.0 in Mexico. UNAM / Plaza Y Valdes. ISBN: 978-607-30-7670-8.

Miranda, J., Ponce, P., Molina, A., & Wright, P. (2019). Sensing, smart and sustainable technologies for Agri-Food 4.0. *Computers in Industry*, 108, 21–36.
https://doi.org/10.1016/j.compind.2019.02.002.

Neuendorf, K., A., (2018). *Content analysis and thematic analysis.* In book: Advanced Research Methods for Applied Psychology. DOI: 10.4324/9781315517971-21

Mulema, A.A., Jogo, W., Damtew., E., Mekonnen, K., & Thorne, P., 2019, 'Women farmers' participation in the agricultural research process: implications for agricultural sustainability in Ethiopia', *International Journal of Agricultural Sustainability, 17*, 1-19. https://doi.org/10.1080/14735903.2019.1569578

Ndandula, S., (2021). Women in Agriculture: The Unexplored Challenge. https://www.institute.leadersofafrica.org/analysis/confronting-barriers-to-gender-equity-in-africa-challenges-facing-women-in-the-agricultural-space/

Prion., S., R., & Haerling., K., A. (2020). Making Sense of Methods and Measurements: Simple Linear Regression. Clinical Simulation in Nursing, Vol. 48, Pages 94-95, ISSN 1876-1399, https://doi.org/10.1016/j.ecns.2020.07.004.

Rahman, M.M.; Huq, H. (2023). Implications of ICT for the Livelihoods of Women Farmers: A Study in the Teesta River Basin, Bangladesh. *Sustainability*,*15*, 14432. https://doi.org/10.3390/su151914432.

Rana., J., Gutierrez., P., L., L., & Oldroyd., J. (2021). Quantitative Methods. In book: Global Encyclopedia of Public Administration, Public Policy, and Governance Edition: Springer

Reference Living Edition, Chapter: Section: Methodology. Publisher: Springer, Cham. DOI: 10.1007/978-3-319-31816-5_460-1

Ren, Y., Feng, H., & Gao, T. , 2023, 'The Effect of Empowerment on the Adoption of Soil and Water Conservation Technology in the Loess Plateau of China', *Land, 12(8), 1502;* https://doi.org/10.3390/land12081502.

Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I., & Brunori, G. (2021). Digital transformation of agriculture and rural areas: A socio-cyber physical system framework to support responsibilisation. *Journal of Rural Studies,* 85, 79–90. https://doi.org/10.1016/j.jrurstud.2021.05.003

Shaw, J., D., Tangirala., S., Vissa, B., & Rodell., J. (2018). New Ways of Seeing: Theory Integration across Disciplines. Academy of Management Journal 61(1): 1-4.

Sheeba, D., & Christopher, B. P. (2024). A five-decade journey of women dynamics in global agriculture. International Research Journal of Multidisciplinary Scope (IRJMS), 2024; 5(3): 51-69. DOI: 10.47857/irjms.2024.v05i03.01059.

Sima, V., Gheorghe, I. G., Subić, J., & Nancu, D. (2020). Influences of the Industry 4.0 revolution on human capital development and consumer behavior: A systematic review. *Sustainability,* 12(10), Article 4035. DOI:10.3390/su12104035.

Sindhu, S., & Kumar, R. (2022). Modeling the challenges for agri-food supply chain 4.0: TISM approach. Agri-Food 4.0, Vol, 27.

Ugwu, P., C., (2019). Women in agriculture: challenges facing women in African farming. https://www.researchgate.net/profile/Paula-Ugwu/publication/332053861/

Yellapu, V. (2018). Descriptive Statistics. International Journal of Academic Medicine 4(1):60. DOI: 10.4103/IJAM.IJAM_7_18

Young, J.C., Rose, D.C., Mumby, H.S., Benitez-Capistros, F., Derrick, C.J., Finch, T., Garcia, C., Home, C., Marwaha, E. Morgans, C., Parkinson, S., Shah, J., Wilson, K.A. & Mukherjee, N. 2018. A methodological guide to using and reporting on interviews in conservation science research. *Qualitative Methods for Eliciting Judgements for Decision Making,* January 2018 DOI: https://doi.org/10.1111/2041-210X.12828