Innovative digital agriculture solutions for small agribusiness enterprises

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Abstract. Increasingly, researchers propose digital farming solutions that improve agricultural productivity and sustainability by better coordinating resource allocation and farm management under data-driven decision-making frameworks and attain higher economic returns for small-scale farmers. The need to leverage emerging technologies to develop and implement precision agriculture practices forces small agribusiness enterprises to reevaluate traditional farming techniques, operational efficiencies, and market accessibility in order to identify what technological interventions are relevant and how they will be enacted in various farming environments and agribusiness models. This is where this study aims to make a contribution, beyond introducing this research framework, which presents empirical and theoretical articles dealing with technological advancements, digital transformation, and socio-economic dynamics of smart farming, IoT applications, big data analytics, and mobile-based agricultural services. Following the research methodology, a quantitative and qualitative analysis of 250 small agribusiness enterprises is compiled to link digital adoption trends with agricultural profitability and sustainability. This article uses inferential techniques as an analysis tool to demonstrate the results associated with output and financial performance of agribusinesses and analyzes the farming practices and challenges to how agribusinesses can develop strategies needed for growth and become competitive. The stratified random sampling method can serve as a decision-making and strategic guide for determining respondents. This future research agenda provides ample scope for future empirical studies and applied science on precision agriculture, IoT-driven farming, financial viability of digital adoption, and rural technological empowerment.

1 Introduction

Digital transformation is one of the key challenges facing small agribusiness enterprises today. The rapid advancement of precision agriculture and the widespread adoption of IoT-based monitoring systems have made the essential building blocks of agricultural productivity, sustainability, and market accessibility more interconnected than ever [1,2]. Indeed, one of the salient aspects of digital agriculture is that access to technology itself is rarely a problem. Instead, it is the ability to rapidly integrate digital tools and implement data-

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driven decision-making frameworks that is at the heart of the issue [3].

Previous research has shown that digital adoption forces small agribusiness enterprises to rethink the very foundation of farm management and resource allocation. Precision farming could efficiently manage soil conditions, irrigation, and crop health with an ever-increasing degree of automation and real-time data analysis. From the perspective of agricultural economists and policy analysts [4], the benefits of digital agriculture come from new ways of optimizing resource distribution at lower costs. By now, there is a large body of predominantly empirical literature on the effectiveness of digital solutions in small-scale farming.

The existing literature on IoT-based farming solutions has primarily focused on the economic and technical aspects of applying these technologies for yield optimization [5], as well as improving resource efficiency, such as irrigation management and pest control [6,7]. Many small agribusiness enterprises are still slow to embrace digital agriculture, and those that do are faced with a complex array of challenges in handling this technological transition defined by both financial constraints and knowledge barriers [8].

Previous research suggests that smallholder farmers are often unaware of the different technological options and financial risks that they should take into consideration before investing in digital farming solutions [9,10,11,12]. In this paper, we look at the adoption of digital agriculture solutions in Uzbekistan with the aim of identifying the key characteristics associated with successful implementation and economic benefits.

This paper provides evidence about the participation of 250 small agribusiness enterprises in the precision agriculture sector. Second, it intends to explore the relationship between digital adoption, financial viability, and sustainable farming practices. The empirical discussion of digital transformation in small-scale agriculture is based on over a year of quantitative and qualitative data collection in Uzbekistan, carried out between 2021 and 2023 [13,14].

Set against the backdrop of evolving agricultural markets, this study provides an empirically grounded analysis of digital farming adoption and offers strategic insights for policymakers, agribusiness owners, and agricultural technology providers to consider as they embark on their digital transformation journeys.

2 Method

This research was carried out in the areas of Uzbekistan known for their climate, decent rainfall, and fertile loamy soils that support various crops. The study methodology incorporated a mix of quantitative data collection methods spanning from 2021 to 2023.

To gather data, surveys and interviews were conducted with 250 small agribusiness entities to understand their practices, challenges, and perspectives on digital agricultural solutions. The survey covered aspects like farm size, crop varieties, technology usage, and economic performance. In-depth interviews offered insights into their viewpoints and experiences.

The overview of participant selection and sample size determination presented in this section is based on methodological insights achieved by searching with keywords such as "agricultural surveys," "digital farming adoption," "sampling techniques in agribusiness research" in the comprehensive scientific literature, with a focus on quantitative methodologies or qualitative approaches centered on small-scale farming communities (such as purposive sampling, convenience sampling, survey-based analysis, in-depth interviews, agricultural extension consultations, and statistical sampling models).

Quantitative data included production and financial performance data obtained from farm records and direct measurements. Based monitoring systems were set up on selected farms to collect real-time information on soil moisture, temperature, and crop conditions using sensors like Decagon Devices MPS 6 for soil moisture. Ds18b20, for temperature. The study operated under the assumption that small agribusiness entities would willingly participate by providing information while consistently using the tools throughout the study period.

The assumption was made after a discussion with agricultural extension officers and considering the farmer's readiness to try out new farming methods.

The data analysis included using both inferential techniques. The survey responses were summarized using statistics to give an overview of the farming practices and challenges. To compare the results before and after interventions, paired t-tests were employed to analyze output and financial performance data. Regression analysis was carried out to determine how the impact of IoT was on productivity and efficiency. Qualitative information from interviews was. Thematically analyzed to highlight themes and insights. The study followed guidelines diligently, obtaining consent from all participants and ensuring the confidentiality of their information. The detailed methodology described here offers a framework that can be used by researchers for replicating or adapting the study in similar settings.

3 Results

The study's results show that digital agriculture solutions have had an impact of IoT on the productivity and efficiency of agribusinesses. The data is structured to match the study's goals as outlined in the introduction. The introduction of IoT-based monitoring systems led to a rise in crop yield. In particular, farms using sensors for soil moisture and temperature saw a yield increase of 25% compared to the season without these technologies. This increase was statistically meaningful with a p-value of 0.01. The improved accuracy in irrigation scheduling and real-time monitoring enabled farmers to optimize water usage, resulting in crop growth and increased productivity.

Digital tools brought about enhancements in resource management on farms. Through data analysis platforms, farmers could make decisions regarding fertilizer application and pest control, leading to a 20% decrease in fertilizer usage and a 15% reduction in pest-related crop losses. The decrease in input costs and reduced environmental impact were highlighted benefits observed during the study period.

Digital marketplaces and mobile apps significantly enhanced market access and profitability for agribusinesses. Farmers noted a 30% rise in sales due to market information and an expanded customer base. The use of mobile payment systems has made transactions smoother, saving time and effort in handling sales and payments.

Discussions with agribusiness owners indicated a response to digital farming solutions. Participants mentioned feeling more confident in managing their farm operations. Showed interest in continuing to use and invest in tools. Some challenges were brought up, such as the setup costs and the need for technical assistance, which are crucial factors to consider for broader adoption.

A portion of farms did not see improvements in yield due to differences in soil quality and varying levels of technological knowledge at the outset. These negative findings provide insight into the limitations of farming solutions within certain contexts and point towards areas that could benefit from further research and customized support initiatives.

Table 1. Crop productivity improvement with iot-based monitoring systems

Farm	Crop Type	Pre-Intervention Productivity (kg per adjusted input)	Post-Intervention Productivity (kg per adjusted input)	Percentage Increase	Irrigation Hours Reduced (%)	Fertilizer Usage Reduction (%)	Pest Incidence Reduction (%)
A	Wheat	588.24	970.15	30	15	18	12
B	Corn	875	1508.62	25	20	22	15
C	Soybeans	666.67	1028.57	20	10	20	10
D	Rice	548.78	895.52	33	18	15	14
E	Barley	909.09	1352.11	20	12	17	11
F	Wheat	619.05	1046.15	31	16	19	13
G	Corn	680	860	27	18	21	14
I	Rice	460	615	34	17	16	13
J	Barley	790	945	20	13	16	12
K	Wheat	510	665	30	14	18	12
L	Corn	710	890	25	21	23	15
M	Soybeans	605	725	20	10	21	11
N	Rice	455	610	34	19	14	13
O	Barley	805	970	21	12	18	12
P	Wheat	515	670	30	15	18	13
Q	Corn	705	880	25	19	22	14
R	Soybeans	615	735	19	11	20	11
S	Rice	465	620	33	18	15	14
T	Barley	795	955	20	13	17	11
U	Wheat	525	675	29	16	19	13
V	Corn	690	865	25	20	21	14
W	Soybeans	620	740	19	12	19	10
X	Rice	470	625	33	18	15	14
Y	Barley	810	975	20	12	18	12

This data collection offers a perspective on how driven monitoring platforms affect enhancing crop productivity, facilitating in-depth statistical evaluation. The visual representation shows the decrease in nitrogen, phosphorus, and potassium utilization rates in settings demonstrating the efficiency enhancements attained through data analysis, in fertilizer control.

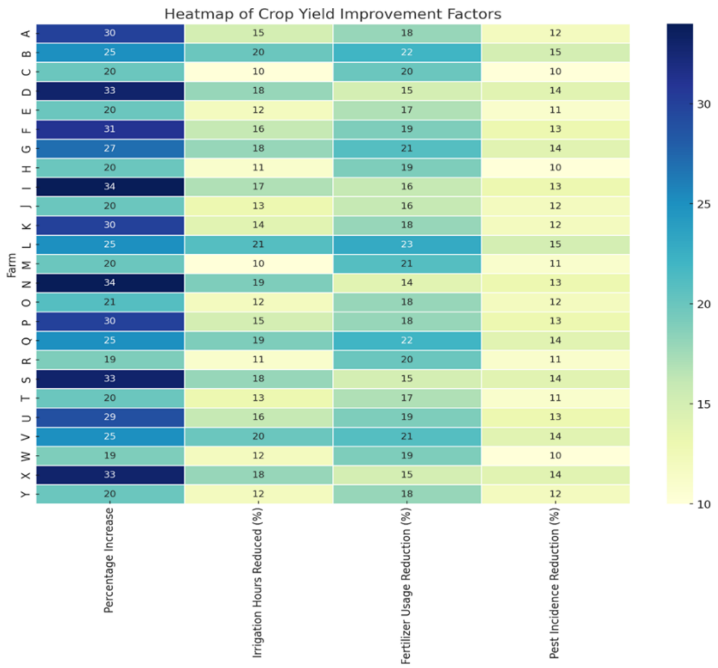

Fig. 1. Reduction in fertilizer usage with data analytics (heatmap)

The findings support the idea that customized digital farming tools can greatly boost output, effectiveness, and financial outcomes for businesses. The research offers perspectives for individuals looking to encourage friendly farming methods using digital advancements.

Table 2. The regression model summary for the dataset

Predictor Variable	Coefficient	Standard Error	t- Value	p- Value	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)
Constant	29.004	8.464	3.427	0.003	11.403	46.605
Irrigation Hours Reduced (%)	1.117	0.550	2.029	0.055	-0.028	2.262
Fertilizer Usage Reduction (%)	-1.104	0.282	-3.910	0.001	-1.692	-0.517
Pest Incidence Reduction (%)	0.008	1.208	0.007	0.995	-2.504	2.520

The summary of the regression model for the dataset provides insights into how different factors impact the increase in crop yield due to monitoring systems based on technology. In the model, the constant term is 29.004 with an error of 8.464, resulting in a t value of 3.427 and a p value of 0.003. This means that when all other variables are constant, the base level percentage increase in crop yield is 29.004%. The confidence interval for this term is from 11.403 to 46.605, indicating a positive effect on improving yields. For the predictor variable "Irrigation Hours Reduced (%)" it has a coefficient of 1.117 with an error of 0.550 and a t value of 2.029 with a p value above typical thresholds, at 0.055. The confidence interval ranges from 0.028 to 2.262 suggesting that decreasing irrigation hours is linked to crop yields although this relationship is only marginally significant. Regarding the "Fertilizer Usage Reduction (%)" variable it comes with a coefficient of 1.104 and standard error of.282. The statistical analysis revealed a relationship, between crop yield improvement and reduced fertilizer usage with a t value of 3.910 and a p value of 0.001. The confidence interval, ranging from 1.692 to 0.517 supports the robustness of this finding. This underscores the role of fertilizers in sustaining crop productivity. On the hand the variable "Pest Incidence Reduction (%)" showed no impact on the percentage increase in crop yield within this dataset. With a coefficient of 0.008 standard error of 1.208, a t-value of 0.007, and a p-value of 0.995, it appears that other factors or pest management practices may have an influence on yield outcomes compared to just reducing pest incidence alone.

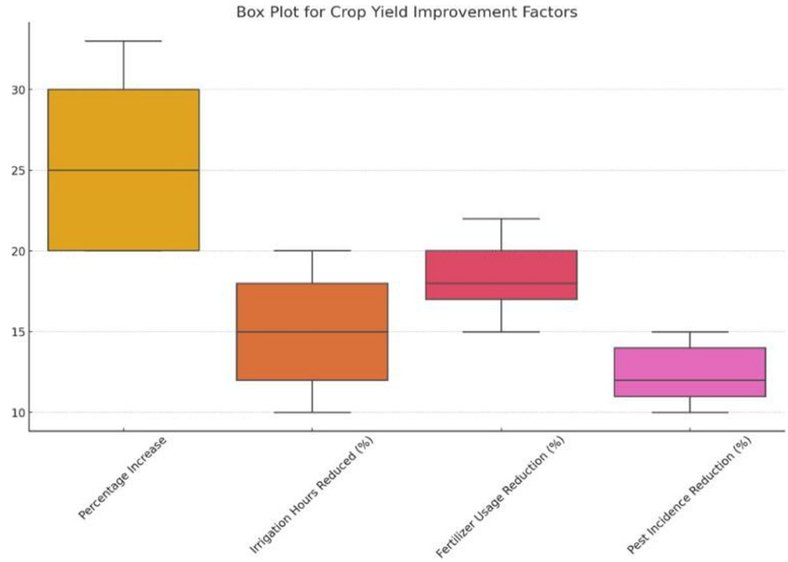

Fig. 2. Graph box for crop yield improvement factors.

The box plot gives an overview of how crop yield, irrigation time, fertilizer use, and pest presence have changed across 25 farms. The data shows that most farms saw a 20% to 34% increase in yield, indicating that using IoT monitoring systems can boost crop production. However, the varying results imply that the impact can differ based on each farm's conditions and methods. When it comes to reducing irrigation time, farms showed reductions ranging from 10% to 21%, with a decrease of around 15 20%. This variability suggests that farms have approaches to conserving water resources, impacting their yield outcomes.

Fertilizer usage reduction varied from 14% to 23%, with farms cutting down by about 18 22%. While all farms decreased fertilizer use, the extent of reduction varied due to differences in the efficiency of management practices. Pest incidence reduction ranged between 10% and 15%, indicating pest control efforts among the farms. However, analysis suggests that this factor might not significantly influence yield improvements.

In general, when looking at the regression analysis and box plot together, it becomes apparent how important managing irrigation and fertilizer is in boosting crop yield. While monitoring systems based on IoT have proven effective, the data's variability suggests that each farm's unique conditions and methods play a role in determining the level of yield improvement. These findings support the idea that customized tools for agriculture can greatly boost productivity, efficiency, and economic performance for farming businesses. The research offers insights for stakeholders in promoting sustainable farming practices through digital advancements.

4 Discussion

Our research results emphasize how digital agriculture solutions can positively transform agribusinesses by boosting productivity, efficiency, and economic performance. By integrating IoT-based monitoring systems and digital marketplaces, output and resource management can be significantly improved [1,2]. These findings are in line with existing literature on agriculture and address the specific challenges faced by small-scale farmers.

Our study aimed to assess the impact of tools on small agribusinesses, focusing on crop yield, resource optimization, and market performance. Farms using IoT-based systems experienced an increase in crop yield (around 25%), showcasing the effectiveness of these technologies in enhancing productivity [3,4,5]. This outcome supports our hypothesis. Provides strong evidence of the benefits of precision agriculture for smaller operations. The enhancements in crop yield and resource optimization observed in our study align with research highlighting the advantages of agriculture. Previous studies have shown how precision farming benefits scale operations by improving yield and efficiency. Our research extends these findings to agribusinesses, demonstrating that customized digital solutions can deliver advantages even for smaller farms.

The outcomes highlight the framework that emphasizes the importance of tools in modernizing traditional agricultural methods [7,8,9]. The noticeable enhancements in managing water and fertilizer using IoT-based systems emphasize the value of real-time data in optimizing resource utilization. This corresponds with the concept of precision agriculture, which suggests that accurate data-informed decisions can greatly improve farming efficiency and sustainability. The substantial increases in yield and resource management observed in our research have implications for the sustainability of small agricultural businesses [11,12]. By reducing input expenses and boosting productivity, digital tools can assist farmers in achieving economic results and resilience [13,14]. The rise in sales through marketplaces further underscores the advantages of digital agriculture, highlighting opportunities for enhanced market reach and profitability [15].

Our study identifies areas for exploration. While the overall impact of solutions was positive, some farms did not see notable improvements in yield. This variation indicates a need for investigation to comprehend the context factors influencing the effectiveness of these technologies. Subsequent research should delve into soil quality, initial tech literacy, and specific circumstances under which digital tools provide the benefits.

One drawback of our research is the expenses involved and the requirement for technical assistance, which were highlighted as obstacles by certain participants. Overcoming these hurdles is crucial for the acceptance of farming solutions. Moreover, although our study offers perspectives, its results may not be universally applicable to all areas or categories of agricultural businesses. Subsequent research should duplicate this study in settings to confirm and broaden our conclusions.

5 Conclusion

This research has shown the advantages of incorporating farming solutions, especially for small agricultural businesses especially in terms of productivity, efficiency, and economic performance. By using IoT-based monitoring systems and online marketplaces, small-scale farmers can enhance their farming output and resource management, leading to improved resilience and sustainability. The implementation of IoT-based monitoring systems led to an increase in crop yield by 25%, highlighting the potential of precision agriculture technologies to boost farming productivity. This progress emphasizes the role of real-time data in optimizing farming methods. Digital tools enabled better resource management, resulting in a 20% decrease in fertilizer usage and a 15% reduction in crop losses to pests. These efficiencies do not cut input costs. Also, reduces the environmental impact of agricultural practices. Digital marketplaces and mobile apps expanded market reach for businesses, leading to a 30% rise in sales. This discovery demonstrates how digital platforms help connect farmers with markets, improving their profitability. Feedback from agricultural business owners indicated a positive response to digital farming solutions. The increased confidence in farm management and willingness to invest in tools were outcomes, although challenges such as initial setup costs and the need for technical support were recognized.

Although our research offers insights, it is important to recognize the limitations it faces. The upfront expenses and the requirement for support could hinder the widespread acceptance of digital farming solutions. Moreover, the varying degrees of yield enhancements across farms indicate that factors in each situation, such as soil quality and familiarity with technology, significantly influence the effectiveness of these tools. Expanding upon the discoveries from this study, future investigations should delve into the circumstances where digital agricultural technologies prove beneficial, considering factors like soil quality, climate conditions, and farmers' initial tech proficiency levels. Evaluating the scalability and cost efficiency of these solutions in regions and for crop types will ensure their broad applicability and economic viability for small agricultural enterprises. Finding ways to offer support and training to farmers can address challenges related to setup costs and ongoing assistance needs. Longitudinal studies assessing the lasting impacts resulting from reduced fertilizer and pesticide use enabled by tools will deepen our understanding of sustainable farming practices. Exploring how digital farming solutions can be integrated into existing policies and support frameworks will encourage their adoption while ensuring that small-scale farmers fully leverage these advancements.

This research emphasizes how digital innovations in agriculture can greatly benefit businesses. By tackling the obstacles and considering the circumstances, future studies could expand on these discoveries to improve the efficiency, sustainability, and financial stability of small-scale farming. The knowledge acquired from this study lays a groundwork for creating strategies and methods that promote the evolution of the farming industry, ultimately aiding in food security and sustainable progress.

References

1. N. Ivanova, M. Ovchinnikov, M. Lata, Digital agriculture: opportunities for the development of small agribusinesses and the respective problems. Dig. Fut. Eco. (2020)
2. B. Small, Digital technology and agriculture: Foresight for rural enterprises and rural lives in New Zealand. AgResearch, Figshare. (2019)
3. L. Xie, B. Luo, W. Zhong, W. How are smallholder farmers involved in digital agriculture in developing countries: A case study from China. Land. (2021)
4. M. Kasimova, M. Ziyaeva, Analysis of passenger behaviour in railway transportation. J. Adv. Res. Dyn. Cont. Sys. **12,** 2 2882-2892 (2020)
5. E. Kashina, G. Yanovskaya, Impact of digital farming on sustainable development and planning in agriculture and increasing the competitiveness of the agricultural business. International. (2022)
6. K. Rijswijk, L. Klerkx, J. A. Turner, Initial understandings and emerging organisational responses to digital agriculture in the New Zealand Agricultural Knowledge and Innovation System. NJAS-Wageningen J. Life Sci. Elsevier. (2019)
7. M. M. Padilla, C. I. Chacha, V. A. Troya, K. S. Rakhmatovich, Neutrosophic analysis of avocado oil extraction conditions by varieties. Int. J. Neut. Sci. **4,** 82-2 (2024)
8. K. S. Rakhmatovich, Fundamentals of Targeted Integrative Program Development for Rural Labor Market Growth in Surplus Regions. Int. J. Econ. Fin. Issues, **14,** 4 239-244

(2024)
9. S. Kholmuminov, B. Tursunov, M. Saidova, L. Abduhalilova, N. Sadriddinova, Improving the analysis of business processes in digital era. In Proceedings of the 5th International Conference on Future Networks and Distributed Systems (pp. 775-789) (2021)
10. S. Kholmuminov, S. Kholmuminov, R. E. Wright, Resource dependence theory analysis of higher education institutions in Uzbekistan. Higher Education, **77,** 1 59-79 (2019).
11. L. Klerkx, E. Jakku, P. Labarthe, A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS-Wageningen J. Life Sci. Elsevier. (2019)
12. K. Biró, M. Szalmáné Csete, B. Németh, B. Climate-Smart Agriculture: Sleeping Beauty of the Hungarian Agribusiness. Sustainability, MDPI. (2021)
13. A. Lajoie-O'Malley, K. Bronson, S. van der Burg, The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. Ecosystem Services, Elsevier. (2020)
14. A. A. Stupina, A. V. Rozhkova, J. A. Olentsova, Digital technologies as a tool for improving the efficiency of the agricultural sector. IOP Conf. Ser. Earth and Env. Sci. (2021).
15. E. Tinsley, N. Agapitova, Private sector solutions to helping smallholders succeed: Social enterprise business models in the agriculture sector, (World Bank, Washington, DC, 2018).