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The Influence of Human Resource Competence on the Implementation of Smart Farming in Horticultural Agriculture (Social and Economic Studies)

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ABSTRACT

This study aims to analyze the influence of human resource competencies on the implementation of smart farming and its impact on social and economic aspects of horticultural agriculture. The study used a quantitative approach with a survey method of 100 horticultural farmers in North Sulawesi. The analysis technique used is multiple regression. The results of the study show that human resource competence has a positive and significant effect on the implementation of smart farming. In addition, the competence of human resources and smart farming simultaneously affects the improvement of farmers' economic and social aspects. The implementation of smart farming has the most dominant influence on increasing income and efficiency of farming, as well as encouraging social change such as increasing technological literacy and collaboration between farmers. The findings also show that smart farming plays a mediating variable between human resource competence and farmer welfare. This research provides an implication that improving human resource competencies and technology support are key in encouraging the transformation of horticultural agriculture towards a more modern, efficient, and sustainable system

INTRODUCTION

The agricultural sector plays a strategic role in supporting food security, improving farmer welfare, and national economic development. In Indonesia, particularly in the horticulture subsector, its contribution to farmer incomes and the provision of nutritious food continues to increase. However, various challenges remain, including limited land, climate change, price fluctuations, and low production efficiency, which impact economic and social aspects. (Neglo et al., 2021) (Habib- your (Rahman et al., 2022)

To address these challenges, a transformation towards modern agriculture through the implementation of smart farming is necessary. Smart farming utilizes digital technologies such as the Internet of Things (IoT), sensors, geographic information systems, and automation to improve input efficiency, productivity, and environmental sustainability. The application of this technology not only increases production yields but also contributes to reducing the excessive use of fertilizers and pesticides, thus supporting sustainable agriculture. (Arvanitis & Symeonaki, 2020) (Dhanaraju et al., 2022) (Khan et al., 2021)

However, the success of smart farming implementation is not solely determined by the availability of technology but also depends heavily on the quality of farmers' human resource competencies. Human resource competencies encompass knowledge, skills, attitudes, and the ability to adapt to technological innovation. In the context of horticultural farming, farmers with high levels of competence tend to be more receptive to and adopt new technologies than those with limited knowledge and skills. (Version, 2025) (Masiko et al., 2022)

Field research shows that most horticultural farmers, particularly in developing regions, still face limitations in mastering digital technology and modern farm management. This results in low adoption rates of smart farming, thus under-utilizing the potential for increased productivity and efficiency. Furthermore, social factors such as education level, access to information, and institutional support also influence farmers' ability to implement technology-based agricultural innovations. (R. Singh et al., 2022) (Han et al., 2022)

From an economic perspective, the implementation of smart farming has the potential to increase farmers' incomes through cost-effective production and improved yield quality. From a social perspective, this technology can enhance farmers' capacity and independence. Meanwhile, from an environmental perspective, smart farming contributes to reducing land degradation and pollution caused by the uncontrolled use of chemical inputs. Therefore, a comprehensive study of the relationship between human resource competence and the successful implementation of smart farming in horticultural farming is crucial.

LITERATURE REVIEW

1. The Concept of Human Resources (HR) Competency

Human resource competence is a combination of knowledge, skills, and attitudes that individuals have in carrying out their duties effectively. Competency is the main factor that determines the success of individual

performance compared to just the level of formal education. (Midhat Ali et al., 2021) (São Paulo et al., 2024)

Furthermore, Spencer & Spencer posits that competence consists of five main characteristics, namely motives, traits, self-concept, knowledge, and skills. In the context of modern agriculture, the competence of farmers includes not only the technical capabilities of cultivation, but also the ability to operate digital technologies, analyze data, and make information-based decisions. (Mr. Salman et al., 2020) (Calvignac et al., 2025)

In this study, HR competencies are focused on three main dimensions:

- Knowledge of modern agricultural technology
- Skills in the use of smart farming technology
- Attitudes towards innovation and technological change

2. Smart Farming Concept

The technologies used include the Internet of Things (IoT), soil sensors, drones, automated irrigation systems, and artificial intelligence-based data analysis. Digitalization of agriculture through smart farming can increase the efficiency of resource use, reduce production risks, and strengthen food security. This concept is also in line with precision agriculture, which allows for more accurate and data-driven land management. However, the successful implementation of smart farming is highly dependent on the readiness of human resources, technological infrastructure, and institutional support. Without adequate competence, the available technology cannot be utilized optimally. (Balasundram et al., 2023) (Giua et al., 2022) (Olofsson et al., 2020)

3. Implementation of Smart Farming in Horticultural Agriculture

Horticultural agriculture has different characteristics compared to food crops, such as a level of sensitivity to the environment, faster production cycles, and more intensive management needs. Therefore, the application of smart farming in horticulture is very relevant to improve the efficiency and quality of production results. (Bakshi et al., 2022) (Said Mohamed et al., 2021)

Technologies such as soil moisture sensors, automated irrigation systems, and application-based monitoring are very helpful for farmers in managing horticultural crops more precisely. This implementation not only has an impact on increased productivity, but also on the reduction of production costs and the risk of crop failure. (Seyar & Ahamed, 2024)

However, some studies show that the rate of technology adoption in the horticulture sector is still relatively low, especially in smallholder farmers, due to limited knowledge, skills, and access to technology. (Valdes et al., 2023)

4. The Relationship between Human Resource Competency and Smart Farming Implementation

The successful adoption of innovation is influenced by individual characteristics, including knowledge and skill levels. In the context of agriculture, farmers with higher competencies tend to adopt new technologies more quickly, are better able to operate technological devices, are more adaptive

to change. On the contrary, the low competence of human resources is one of the main obstacles in the implementation of smart farming. Therefore, increasing the capacity of farmers through training and mentoring is an important strategy in encouraging technology adoption. (Yoon et al., 2020) (Alabdali et al., 2023)

5. The Impact of Smart Farming on Economic and Social Aspects

The implementation of smart farming has a significant impact on the economic aspects of farmers. The use of modern technology such as the Internet of Things (IoT), agricultural sensors, drones, automated irrigation systems, and digital applications is able to increase the productivity of farming businesses through more efficient and targeted land management. This technology helps farmers in determining planting, fertilizing, watering, and pest control time more accurately based on field data. This condition causes agricultural production to increase, while the use of inputs such as fertilizers, pesticides, water, and labor can be suppressed so that production costs are lower. In addition, smart farming also helps farmers obtain market information quickly and expand marketing access through digital platforms, so that the selling price of products becomes more competitive and farmers' income increases. With the increase in efficiency and quality of production products, the competitiveness of agricultural products is also getting stronger both in the local and national markets. (Chen, 2025) (Size - Rubio & Rovira -Más, 2020) (Stuart O'Neill & Gunathilake, 2022) (Balyan et al., 2024)

On the social side, the implementation of smart farming has brought a big change in the mindset and behavior of farmers in running a farming business. Farmers who previously relied on traditional methods began to transform towards modern agriculture based on technology and data. The use of digital technology encourages the improvement of literacy and competence of farmers' human resources, especially in the operation of digital tools, the use of agricultural applications, and information-based decision-making. Smart farming also increases the interest of the younger generation to get involved in the agricultural sector because agriculture is seen as more modern, innovative, and has promising prospects. In addition, digital technology strengthens social networks between farmers through online communities, social media, and digital farming platforms that facilitate the exchange of information, experiences, and innovations. However, the implementation of smart farming can also create a social gap between farmers who have access to technology and farmers who are still limited in terms of capital, education, and infrastructure. Therefore, government support, counseling, and continuous training are needed so that the implementation of smart farming can run evenly and provide benefits to all farmers. (McCaig et al., 2023) (Misra & Ghosh, 2024) (Wang et al., 2025) (Arvanitis & Symeonaki, 2020) (Omulo & Kumeh, 2020) (Shrub, n.d.)

6. Research Framework of Thought

Based on the theoretical study above, it can be concluded that human resource competence has an important role in determining the success of smart farming implementation, which further has an impact on improving social and economic aspects in horticultural agriculture.

The relationship between variables in this study can be explained as follows:

- Human Resources Competencies → Smart Farming Implementation
- Implementation of Smart Farming → Social and Economic Impact
- Human Resource Competencies → Social and Economic Impact (direct or indirect)

Thus, this study develops a model that places human resource competence as the main variable in encouraging technology-based agricultural transformation.

Hypothesis Development

1. The Influence of Human Resource Competence on the Implementation of Smart Farming

Human resource competence is the main factor in determining the success of technology adoption. In the context of modern agriculture, such competencies include technological knowledge, operational skills, and attitudes towards innovation.

In addition, the theory of innovation diffusion put forward by Everett Rogers explains that the level of technology adoption is greatly influenced by individual characteristics, specifically the level of knowledge and readiness to accept change. Farmers with good competence tend to be quicker to understand the benefits of smart farming technology and be able to implement it effectively.

Thus, high human resource competence will encourage an increase in the implementation of smart farming in horticultural agriculture.

Hypothesis:

H1: Human resource competence has a positive and significant effect on the implementation of smart farming.

2. The Influence of Human Resource Competence on Economic Aspects

Human resource competencies not only affect technology adoption, but also have a direct impact on the economic performance of farming businesses. Farmers who have good knowledge and skills tend to be able to manage resources efficiently, reduce production costs, and increase productivity and income. Individual competencies contribute directly to performance, which in the context of agriculture can be measured through increased production output and economic gains. With adequate competence, farmers can make more informed decisions in the use of production inputs and marketing strategies.

Hypothesis:

H2: Human resource competence has a positive and significant effect on improving the economic aspects of horticultural farmers.

3. The Influence of Human Resource Competence on Social Aspects

In addition to the economic aspect, human resource competence also affects social change in the agricultural community. Farmers who have high competence tend to be more open to innovation, have good communication skills, and are able to collaborate in farmer groups. Competencies also contribute to changes in mindset, collaboration skills, and technological literacy. This is in

line with the concept of social development which emphasizes the importance of increasing individual capacity in dealing with change.

Hypothesis:

H3: Human resource competence has a positive and significant effect on improving the social aspects of horticultural farmers.

4. The Effect of Smart Farming Implementation on Economic Aspects

The implementation of smart farming has a direct impact on increasing the efficiency and productivity of farming businesses. Technologies such as sensors, automatic irrigation, and monitoring systems allow for more precise use of inputs, thereby reducing costs and increasing production yields. Agricultural digitalization is able to increase the efficiency of resource use and increase farmers' income through optimizing production and market access.

Hypothesis:

H4: The implementation of smart farming has a positive and significant effect on improving the economic aspects of horticultural farmers.

5. The Influence of Smart Farming Implementation on Social Aspects

In addition to the economic impact, the implementation of smart farming also brings social changes in agricultural communities. The use of digital technology encourages increased technology literacy, expands communication networks, and increases collaboration between farmers and institutions.

However, this process also requires social adaptation that is not simple, so the success of implementation is greatly influenced by the readiness of the community to accept change.

Hypothesis:

H5: The implementation of smart farming has a positive and significant effect on improving the social aspects of horticultural farmers.

Hypothesis Summary

Code Hypothesis

- H1 Human Resources Competence → Smart Farming
- H2 Human Resource Competencies → Economic Aspects
- H3 Human Resource Competencies → Social Aspects
- H4 Smart Farming → Economic Aspects
- H5 Smart Farming → Social Aspects

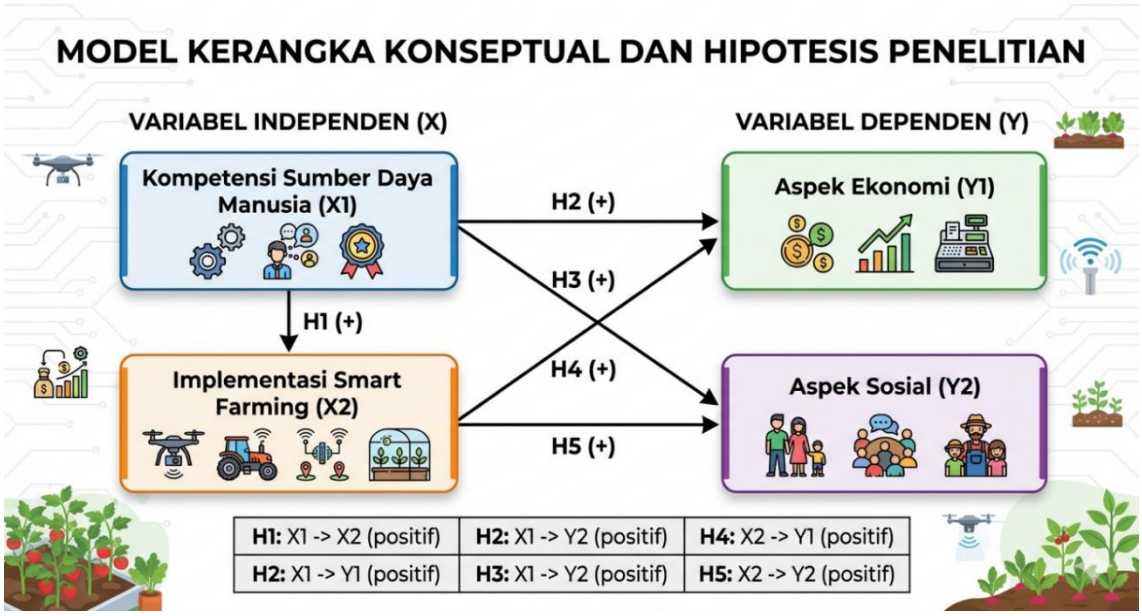

Figure 1. Conceptual framework model and research hypotheses

METHODOLOGY

Types and Approaches to Research

This study uses a quantitative approach with a survey method. The quantitative approach was chosen because the study aims to examine the causal relationship between the competency variables of human resources (HR), the implementation of smart farming, and its impact on social and economic aspects. This type of research is explanatory research, which is research that explains the relationship between variables through testing hypotheses that have been formulated.

Research Location and Time

The research was carried out on horticultural agriculture centers in Tomohon City, which have the potential and have begun to adopt smart farming technology. The research time is planned for ± 6 months,

Population and Sample

Population

The population in this study is all horticultural farmers who have used or are using, or who have access to smart farming technology in Tomohon City.

Sample

The sampling technique uses purposive sampling, with the following criteria:

Active horticultural farmer, have at least 2 years of farming experience, have used or know smart farming technology, Number of samples used 100 respondents.

Data Types and Sources

Primary Data

Primary data is obtained through:

- Questionnaire (Likert scale 1–5)
- Limited interviews (for in-depth interviews)

Secondary Data

Secondary data is obtained from:

- Agriculture Office
- Central Statistics Agency (BPS)
- Scientific literature and related journals

Research Variables and Operational Definitions

1. Independent Variable (X): HR Competence

Indicator:

- Agricultural technology knowledge
- Technology use skills
- Attitude towards innovation

2. Intervening Variable (Y1): Smart Farming Implementation

Indicator:

- Use of digital technologies (sensors, apps, etc.)
- Intensity of technology use
- Technology operability

3. Dependent Variables (Y2 & Y3):

a. Economic Aspects (Y2)

- Increased production
- Cost efficiency
- Farmers' income

b. Social Aspect (Y3)

- Mindset change
- Collaboration capabilities
- Technology literacy

Data Collection Techniques

The data collection methods in this study include:

- Questionnaire: Main instruments with Likert scale
- Observation: Observing smart farming practices
- Documentation: Supporting data from relevant agencies

Data Analysis Techniques

1. Descriptive Analysis

It is used to describe the characteristics of respondents and the distribution of answers.

2. Classic Assumption Test

Includes:

- Normality test
- Multicollinearity test

- Heteroscedasticity test

3. Multiple Regression Analysis

This study uses three regression models:

Model 1

The effect of HR competence on smart farming:

- $Y1 = \alpha + \beta1\ X1 + \beta2\ X2 + \beta3\ X3 + e$
- Y1: Smart Farming Implementation
- α = Constant
- X1: Knowledge
- X2: Attitude
- X3: Skills
- β = regression coefficient
- e = error term

Model 2

The influence of human resource competence and smart farming on economic aspects:

- $Y2 = \alpha + \beta1\ X(SDM) + \beta2\ Y1 + e$
- Y2: Economic Aspects (Revenue, cost efficiency, productivity)
- X(HR): HR Competency (Can be a total score from model 1)
- Y1: Smart Farming Implementation (Variables from model 1)

Model 3

- $Y3 = \alpha + \beta1\ X(SDM) + \beta2\ Y1 + e$
- Y3: Social Aspects (Mindset change, Collaboration skills, Technology literacy),
- X (HR): HR Competencies
- Y1: Smart Farming Implementation

RESEARCH RESULTS

1. Respondent Description

This study involved 100 respondents of horticultural farmers in Tomohon City.

- Respondent Characteristics
- Dominant age: 30–50 years (60%)
- Education: High School (45%), Bachelor (25%)
- Length of farming: >5 years (70%)
- Land area: 0.5–1 ha (50%)

This shows that the respondents have sufficient experience in farming, but the level of education still varies.

2. Test Research Instruments

1. Validity Test

The test results showed that all items had a value of r calculated > r of the table (0.196), so that all indicators were declared valid.

2. Reliability Test

Cronbach Alpha Values:

- HR competence = 0.89
- Smart Farming = 0.87
- Economic Aspect = 0.85
- Social Aspect = 0.86

All variables have a α > value of 0.70, so they are declared reliable.

3. Classical Assumption Test

- Normality: Normalized distributed data (Sig. > 0.05)
- Multicollinearity: VIF < 10 (no multicollinearity occurs)
- Heteroscedasticity: No symptoms of heteroscedasticity found

Thus, the regression model meets classical assumptions.

3. Multiple Regression Analysis Results

The results of multiple regression analysis in model 1: The Influence of Human Resources Competence on Smart Farming, can be seen in Table 1.

Table 1: The Influence of Human Resources Competence on Smart Farming

Variable	Coefficients	t count	Sig
HR Competencies (X)	0,65	8,45	0,000

$R^2 = 0.58$

Interpretation:

Human resource competence has a positive and significant effect on the implementation of smart farming. This means that the higher the competence of farmers, the higher the level of technology adoption.

The results of multiple regression analysis in model 2: the impact of human resource and smart farming competence on economic aspects can be seen in Table 2.

Table 2. The Influence of Human Resources and Samrt Farming Competencies on Economic Aspects

Variable	Coefficients	t count	Sig
HR Competencies (X)	0,30	3,20	0,002
Smart Farming (Y1)	0,50	5,60	0,000

$R^2 = 0.67$

Interpretation:

Human resource competence has a positive effect on economic aspects smart farming has a stronger influence on improving farmers' economies.

The results of multiple regression analysis in model 3: The Influence of Human Resources and Smart Farming Competencies on Social Aspects can be seen in Table 3.

Table 3. The influence of human resource competence and smart faringes on social aspects

Variable	Coefficients	t count	Sig
HR Competencies (X)	0,25	2,85	0,005
Smart Farming (Y1)	0,55	6,10	0,000

$R^2 = 0.69$

Interpretation:
Smart farming has a significant social impact.
HR competence also has an effect, but it is smaller than the influence of technology

Key Research Findings

Some of the key findings in this study are:

- Human resource competence is the main key factor in encouraging the adoption of smart farming.
- Smart farming has the greatest influence on improving economic and social aspects.
- There are indications that smart farming plays a mediating variable between human resource competence and farmers' welfare.
- Farmers with higher technological skills show better productivity and income.
- From the social side, technology improves: Digital literacy, Collaboration between farmers, Modern mindset

DISCUSSION

The Influence of Human Resource Competence on the Implementation of Smart Farming

The results of the study show that human resource competence has a positive and significant effect on the implementation of smart farming. This indicates that farmers' abilities in terms of knowledge, skills, and attitudes towards technology are the main factors in determining the level of adoption of modern agricultural technology. These results are supported by the opinion stating that the relationship between psychological factors and the adoption of Smart Agriculture technological innovations in the context of small-scale agricultural economics (Chuang et al., 2020)

Individual competencies have a positive impact on organizational performance. In this context, performance is defined as the ability of farmers to implement technology effectively. In addition, the theory of innovation diffusion also asserts that individual characteristics, in particular the level of knowledge and readiness to accept change, greatly influence the adoption of innovation. (Mohammad Salman et al., 2020) (Alhammadi et al., 2023)

Empirically, these results show that farmers who have a good understanding of technology, as well as skills in its use, are better able to integrate smart farming into their farming practices. This strengthens the argument that increasing the capacity of human resources through training and mentoring is a key strategy in the transformation of technology-based agriculture. (Six et al., 2025)

The Influence of Human Resources Competence on Economic Aspects

The results of the study show that human resource competence has a positive and significant effect on the economic aspects of horticultural farmers. This means that the higher the competence of farmers, the greater the opportunity to increase productivity and income.

These findings support the view that competence has a direct relationship with individual performance. In the context of agriculture, this performance is reflected in the efficiency of input use, increased production yield, and the ability to manage farming optimally. (Ahmad & Dar, 2020)

However, the influence of human resource competence on the economic aspect in this study is smaller than the influence of smart farming. This shows that human resource competence alone is not enough to significantly improve the welfare of farmers without being supported by the application of technology. In other words, competence plays a role as a foundation, while technology is the main tool in creating economic value.

The Influence of Human Resource Competence on Social Aspects

Human resource competence has also been proven to have a positive effect on social aspects. Farmers who have high competence tend to be more open to change, have better communication skills, and are able to adapt to technological developments.

These results show that improving competencies not only has an impact on technical and economic aspects, but also on social transformation in agricultural communities. Competent farmers are more active in sharing information, working together in farmer groups, and improving technological literacy. (Yuan et al., 2025)

However, the influence of human resource competence on social aspects is also relatively smaller than the influence of smart farming. This indicates that social change is driven more by direct interaction with technology and digital systems than by individual abilities alone.

The Effect of Smart Farming Implementation on Economic Aspects

The results of the study show that the implementation of smart farming has the strongest influence on the economic aspect. This reflects that the use of

digital technology is able to increase production efficiency, reduce costs, and increase farmers' yields and incomes.

These findings are in line with the view that agricultural digitalization is able to improve resource use efficiency and strengthen food security. Technologies such as sensors, automated irrigation, and data-driven applications allow farmers to make more informed and faster decisions. (Balasundram et al., 2023) (Aarif K. O. et al., 2025)

In the context of this study, farmers who adopt smart farming show a significant increase in productivity, as well as being able to optimize the use of inputs such as water, fertilizer, and labor. This has a direct impact on increasing farm profits.

The Effect of Smart Farming Implementation on Social Aspects

The implementation of smart farming has also been proven to have a significant positive impact on social aspects. Technology not only functions as a means of production, but also as a medium of social transformation in agricultural society.

The use of digital technology encourages increasing technological literacy, expanding access to information, and improving communication and collaboration between farmers. Farmers are becoming more connected to the market, extension workers, and fellow farmers through digital platforms. (Arangurí et al., 2025)

In addition, smart farming also encourages a change in farmers' mindset from traditional to modern. Farmers have become more adaptive to innovation, more open to change, and more confident in managing farming.

The Role of Smart Farming Mediation

Based on the results of the study, smart farming has an important role as a mediating variable between human resource competencies and economic and social aspects. Human resource competence does not directly have a maximum impact on the welfare of farmers, but through the implementation of technology.

This shows that:

- Human resource competencies → improve technology adoption capabilities
- Smart farming → be the main mechanism for improving welfare

Thus, the relationship between the variables can be described as follows:

- Human resource competence increases farmers' readiness
- Smart farming translates this readiness into real results
- These findings reinforce the importance of an integrative approach between human resource development and technology provision in the development of the agricultural sector.

Theoretical and Practical Implications

1. Theoretical Implications

This research enriched the literature with:

- Integrating competency theory and innovation adoption in the context of agriculture
- Demonstrate the role of technology mediation in the relationship between human resources and well-being
- Providing a new empirical model for the horticulture sector

2. Practical Implications

The results of the study provide recommendations:

- The need for training and capacity building of farmers
- Strengthening technology-based counseling programs
- Government support in the provision of smart farming infrastructure
- Collaboration between farmers, government and the private sector

CONCLUSION AND RECOMMENDATION

Conclusion

Based on the results of the analysis and discussion of the influence of human resource competence on the implementation of smart farming in horticultural agriculture, several conclusions can be drawn as follows:

- Human resource competence has a positive and significant effect on the implementation of smart farming. This shows that farmers' knowledge, skills, and attitudes are the main factors in determining the success of the adoption of modern agricultural technology.
- Human resource competence has a positive effect on the economic aspect of horticultural farmers.
- Farmers with better competence tend to be able to increase productivity, farming efficiency, and income. However, this influence is not as great as the influence of technology.
- Human resource competence has a positive effect on social aspects.
- Competencies encourage increased technological literacy, openness to innovation, and the ability to collaborate in farmer groups.
- The implementation of smart farming has the strongest effect on improving economic aspects.
- Technology has been proven to be able to increase production efficiency, reduce costs, and increase farmers' yields and income.
- The implementation of smart farming also has a significant effect on social aspects.
- The use of technology encourages changes in mindsets, increases access to information, and strengthens farmers' social networks.

Recommendations

Based on the results of the research, some suggestions that can be given are as follows:

1. Practical Advice

a. For the Government

- Improving agricultural technology-based training and extension programs

- Provide smart farming infrastructure (internet access, technological tools, and applications)
- Providing subsidies or technological assistance to farmers

b. For Farmers

- Improve competence through training and self-learning
- More open to innovation and the use of technology
- Active in farmer groups to share knowledge and experiences

c. For Institutions/Private

- Developing user-friendly agricultural technology
- Providing assistance in technology implementation
- Encouraging the digitalization of horticultural product marketing

2. Academic Advice

Further research is recommended for:

Using more complex methods such as SEM-PLS or structural models

Add other variables such as:

- Access technology
- Institutional support
- Environmental factors
- Expanding research locations to make results more generalizable
- Using a mixed methods approach to get a more in-depth analysis

REFERENCES

Aarif K. O., M., Alam, A., & Hotak, Y. (2025). Smart Sensor Technologies Shaping the Future of Precision Agriculture: Recent Advances and Future Outlooks. Journal of Sensors, 2025(1), 2460098. https://doi.org/https://doi.org/10.1155/js/2460098

Ahmad, S. F., & Dar, A. H. (2020). Precision Farming for Resource Use Efficiency (S. Kumar, R. S. Meena, & M. K. Jhariya, Eds.; pp. 109–135). Springer Singapore. https://doi.org/10.1007/978-981-15-6953-1_4

Alabdali, S. A., Pileggi, S. F., & Cetindamar, D. (2023). Influential Factors, Enablers, and Barriers to Adopting Smart Technology in Rural Regions: A Literature Review. In Sustainability (Vol. 15, Number 10, p. 7908). https://doi.org/10.3390/su15107908

Alhammadi, K., Marashdeh, H., & Hussain, M. (2023). Assessing the effect of innovation diffusion and technology readiness theories on attitude, behavioral intention and implementation of smart learning. Cross Cultural & Strategic Management, 30(4), 657–675. https://doi.org/10.1108/CCSM-12-2022-0213

Anim, P. A., Mahmoud, M. A., & Odoom, R. (2025). Technology meets agriculture: will green knowledge management and green intellectual capital be the game changer for sustainable farming among rural women. International Journal of Productivity and Performance Management, 74(10), 3551–3576. https://doi.org/10.1108/IJPPM-01-2025-0038

Arangurí, M., Mera, H., Noblecilla, W., & Lucini, C. (2025). Digital Literacy and Technology Adoption in Agriculture: A Systematic Review of Factors and Strategies. In AgriEngineering (Vol. 7, Number 9, p. 296). https://doi.org/10.3390/agriengineering7090296

Arvanitis, K. G., & Symeonaki, E. G. (2020). Agriculture 4.0: The Role of Innovative Smart Technologies Towards Sustainable Farm Management. The Open Agriculture Journal, 14(1), 130–135. https://doi.org/10.2174/1874331502014010130

Bakshi, P., Singh, M., Kour, K., Iqbal, M., Kumar, R., & Sarita. (2022). Horticulture: A Key for Sustainable Development BT - Innovative Approaches for Sustainable Development: Theories and Practices in Agriculture (S. S. Mahdi & R. Singh, Eds.; pp. 169–190). Springer International Publishing. https://doi.org/10.1007/978-3-030-90549-1_11

Balasundram, S. K., Shamshiri, R. R., Sridhara, S., & Rizan, N. (2023). The Role of Digital Agriculture in Mitigating Climate Change and Ensuring Food

Security: An Overview. In Sustainability (Vol. 15, Number 6, p. 5325). https://doi.org/10.3390/su15065325

Balyan, S., Jangir, H., Tripathi, S. N., Tripathi, A., Jhang, T., & Pandey, P. (2024). Seeding a Sustainable Future: Navigating the Digital Horizon of Smart Agriculture. In Sustainability (Vol. 16, Number 2, p. 475). https://doi.org/10.3390/su16020475

Calvignac, C., Potier, V., & Labarthe, P. (2025). Growing on digital soil: French farmers' everyday acquisition of new skills online. Agriculture and Human Values, 42(3), 2111–2127. https://doi.org/10.1007/s10460-025-10758-5

Chen, X. (2025). The role of modern agricultural technologies in improving agricultural productivity and land use efficiency. Frontiers in Plant Science, Volume 16. https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2025.1675657

Chuang, J.-H., Wang, J.-H., & Liou, Y.-C. (2020). Farmers' Knowledge, Attitude, and Adoption of Smart Agriculture Technology in Taiwan. In International Journal of Environmental Research and Public Health (Vol. 17, Number 19, p. 7236). https://doi.org/10.3390/ijerph17197236

Dhanaraju, M., Chenniappan, P., Ramalingam, K., Pazhanivelan, S., & Kaliaperumal, R. (2022). Lee, C. H., & Kim, J. S., 2020, Smart farming and IoT-based solutions for sustainable agriculture, Journal of Agricultural Informatics, 11(1), 23-34. Agriculture (Switzerland), 12(10), 1–26.

Giua, C., Materia, V. C., & Camanzi, L. (2022). Smart farming technologies adoption: Which factors play a role in the digital transition? Technology in Society, 68, 101869. https://doi.org/https://doi.org/10.1016/j.techsoc.2022.101869

Habib-your-Rahman, M., Ahmad, A., Raza, A., Hasnain, M. U., Alharby, H. F., Alzahrani, Y. M., Bamagoos, A. A., Hakeem, K. R., Ahmad, S., Nasim, W., Ali, S., Mansour, F., & E. L. Sabagh, A. (2022). Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. Frontiers in Plant Science, 13. https://doi.org/10.3389/fpls.2022.925548

Han, M., Liu, R., Ma, H., Zhong, K., Wang, J., & Xu, Y. (2022). The Impact of Social Capital on Farmers' Willingness to Adopt New Agricultural Technologies: Empirical Evidence from China. In Agriculture (Vol. 12, Number 9, p. 1368). https://doi.org/10.3390/agriculture12091368

Hemathilake, D. M. K. S., & Gunathilake, D. M. C. C. (2022). Chapter 31 - Agricultural productivity and food supply to meet increased demands (R.

B. T.-F. F. Bhat, Ed.; pp. 539–553). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-323-91001-9.00016-5

Khan, N., Ray, R. L., Sargani, G. R., Ihtisham, M., Khayyam, M., & Ismail, S. (2021). Current progress and future prospects of agriculture technology: Gateway to sustainable agriculture. Sustainability (Switzerland), 13(9), 1–31. https://doi.org/10.3390/su13094883

Lalaeng, C., Subongkod, M., & Sinlapasawet, W. (2024). INDIVIDUAL COMPETENCY CAUSAL FACTORS AFFECTING PERFORMANCE OF ACADEMIC PERSONNEL IN HIGHER EDUCATION INSTITUTION. Proceedings of Computer Science, 237, 502–509. https://doi.org/https://doi.org/10.1016/j.procs.2024.05.133

Masiko, P. B., Oluka, P. N., Kajjumba, G. W., Mugurusi, G., & Nyesiga, S. D. (2022). Technology, human resource competencies and productivity in nascent petroleum industries: an empirical study. Technological Sustainability, 1(2), 132–144. https://doi.org/10.1108/TECHS-10-2021-0018

McCaig, M., Dara, R., & Rezania, D. (2023). Farmer-centric design thinking principles for smart farming technologies. Internet of Things, 23, 100898. https://doi.org/https://doi.org/10.1016/j.iot.2023.100898

Midhat Ali, Muhammad, Qureshi, Sheheryar Mohsin, Memon, Muhammad Saad, Mari, Sonia Irshad, & Ramzan, Muhammad Babar. (2021). Competency Framework Development for Effective Human Resource Management. Sage Open, 11(2), 21582440211006124. https://doi.org/10.1177/21582440211006124

Misra, S., & Ghosh, A. (2024). Chapter 6 - Agriculture paradigm shift: a journey from traditional to modern agriculture (K. Singh, M. C. Ribeiro, & Ö. B. T.-B. and B. Calicioglu, Eds.; pp. 113–141). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-323-95482-2.00006-7

Neglo, K. A. W., Gebrekidan, T., & Lyu, K. (2021). The role of agriculture and non-farm economy in addressing food insecurity in Ethiopia: A review. Sustainability (Switzerland), 13(7). https://doi.org/10.3390/su13073874

Olofsson, A. D., Fransson, G., & Lindberg, J. O. (2020). A study of the use of digital technology and its conditions with a view to understanding what 'adequate digital competence' may mean in a national policy initiative. Educational Studies, 46(6), 727–743. https://doi.org/10.1080/03055698.2019.1651694

Omulo, G., & Kumeh, E. M. (2020). Farmer-to-farmer digital network as a strategy to strengthen agricultural performance in Kenya: A research note on 'Wefarm' platform. Technological Forecasting and Social Change, 158, 120120. https://doi.org/https://doi.org/10.1016/j.techfore.2020.120120

Said Mohamed, E., Belal, A. A., Kotb Abd-Elmabod, S., El-Shirbeny, M. A., Gad, A., & Zahran, M. B. (2021). Smart farming for improving agricultural management. The Egyptian Journal of Remote Sensing and Space Science, 24(3, Part 2), 971–981. https://doi.org/https://doi.org/10.1016/j.ejrs.2021.08.007

Saiz-Rubio, V., & Rovira-Más, F. (2020). From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. In Agronomy (Vol. 10, Number 2, p. 207). https://doi.org/10.3390/agronomy10020207

Salman, M., Ganie, S. A., & Saleem, I. (2020). The concept of competence: a thematic review and discussion. European Journal of Training and Development, 44(6–7), 717–742. https://doi.org/10.1108/EJTD-10-2019-0171

Salman, Mohammad, Ganie, Showkat Ahmad, & Saleem, Imran. (2020). Employee Competencies as Predictors of Organizational Performance: A Study of Public and Private Sector Banks. Management and Labour Studies, 45(4), 416–432. https://doi.org/10.1177/0258042X20939014

Seyar, M. H., & Ahamed, T. (2024). Optimization of Soil-Based Irrigation Scheduling Through the Integration of Machine Learning, Remote Sensing, and Soil Moisture Sensor Technology BT - IoT and AI in Agriculture: Smart Automation Systems for increasing Agricultural Productivity to Achieve (T. Ahamed, Ed.; pp. 275–299). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-1263-2_18

Singh, R., Singh, R., Gehlot, A., Akram, S. V, Priyadarshi, N., & Twala, B. (2022). Horticulture 4.0: Adoption of Industry 4.0 Technologies in Horticulture for Meeting Sustainable Farming. In Applied Sciences (Vol. 12, Number 24, p. 12557). https://doi.org/10.3390/app122412557

Struik, P. (n.d.). Sustainable Agriculture Education : Integrating Climate- Smart Practices in Farmer Training Programs. (March 2025), 8–20.

Valdes, R., Gómez, D., & Barrantes, L. (2023). Enhancing agricultural value chains through technology adoption: a case study in the horticultural sector of a developing country. Agriculture & Food Security, 12(1), 45. https://doi.org/10.1186/s40066-023-00450-4

Version, P. (2025). Alma Mater Studiorum Università di Bologna Archivio istituzionale della ricerca Smart Farming Technologies adoption : which factors play a role in the digital transition ? Technology in Society, 68(April), 1–40.

Wang, Z., Song, Y., Xie, H., Li, C., Hu, Y., Wu, Z., & Chen, J. (2025). The impact of farmers' digital literacy on farmers' enthusiasm for grain cultivation: Findings from the "Double Hundred and Thousand" farmers in Jiangxi province. PLOS ONE, 20(12), e0334437. https://doi.org/10.1371/journal.pone.0334437

Yoon, C., Lim, D., & Park, C. (2020). Factors affecting adoption of smart farms: The case of Korea. Computers in Human Behavior, 108, 106309. https://doi.org/https://doi.org/10.1016/j.chb.2020.106309

Yuan, Y., Sun, L., She, Z., & Chen, S. (2025). Influence of Digital Literacy on Farmers' Adoption Behavior of Low-Carbon Agricultural Technology: Chain Intermediary Role Based on Capital Endowment and Adoption Willingness. In Sustainability (Vol. 17, Number 5, p. 2187). https://doi.org/10.3390/su17052187