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The Role of the Millennial Generation in Developing Urban Farming as a Food Security Solution for Times of Crisis in Indonesia

Eri Yusnita Arvianti[1♥], Irawan Setyabudi[2], and Retno Ayu Dewi Novita[3]

[1]Agribusiness Study Program, Faculty of Agriculture, Universitas Tribhuwana Tunggadewi, Malang, Indonesia
[2]Landscape Architecture Study Program, Faculty of Agriculture, Universitas Tribhuwana Tunggadewi, Malang, Indonesia
[3]Management Study Program, Faculty of Economics, Universitas Tribhuwana Tunggadewi, Malang, Indonesia
♥Corresponding author email: yusnitaarvianti@yahoo.co.id

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Abstract. This research analyses the role of millennials in the development of urban farming in Malang Regency, representing an area with high urban farming potential in Indonesia. Using a quantitative approach through an explanatory survey design, the study involved 210 millennial farmer respondents (aged 25-40) from 33 sub-districts in Malang Regency. Data was collected through a structured questionnaire with a 5-point Likert scale and analysed using PLS-SEM with WarpPLS 8.0. The model tests the relationship between five exogenous variables: Digital Technology Competency (X1), Entrepreneurial Ability (X2), Technical Knowledge (X3), Sustainability Awareness (X4), and Ecosystem Support (X5), and Local Food Resilience (Y), with Innovation Adoption (M) as a mediator. The main findings show the model is excellent ($R^2 = 0.937$) with all hypotheses significantly confirmed. Entrepreneurial ability has the strongest influence ($\beta=0.42$, $p<0.05$), followed by Digital Technology Competence and Ecosystem Support ($\beta=0.36$), Sustainability Awareness ($\beta=0.31$), and Technical Knowledge ($\beta=0.25$). Innovation adoption is proven to be an effective mediator, especially through Ecosystem Support ($\beta=0.65$, $p<0.01$). The research identified two innovative models: the NFT Vertical Hydroponic System and the IoT-based Smart Greenhouse Integrated Farming, which achieved 90% water efficiency and produced premium products. The significance of the research lies in its theoretical contribution regarding the role of millennials in food security and its practical implications for the development of national agricultural policy. The findings can be replicated in other urban areas of Indonesia with similar demographic and geographic characteristics, providing a blueprint for sustainable urban farming development to strengthen national food security.

Keywords: food security; millennial generation; PLS-SEM; urban farming

INTRODUCTION

Indonesia, as an agrarian country, faces serious challenges in meeting the food needs of its population amidst various crises such as climate change, pandemics, and global economic instability. Sustainable food security is a strategic issue that requires innovative and adaptive approaches (Ariani and Suryana 2023). On the other hand, the phenomena of urbanisation and the conversion of productive agricultural land continue to threaten national food production capacity. Based on data from the Ministry of Agriculture (2023), the rate of conversion of productive agricultural land in Indonesia reaches 150,000 hectares per year (Syamsuri et al. 2022) . Recent data indicate that the prevalence of hunger in Indonesia has increased significantly in recent years, while the impact of climate change is increasingly threatening national agricultural productivity. This situation is exacerbated by the declining interest of the younger generation in working in the conventional agricultural sector, which is considered less prestigious and economically less promising. This multidimensional crisis demands innovative solutions that can integrate modern technology with sustainable approaches.

A new trend emerged with the rise of young millennial farmers who are developing the concept of urban agriculture with a modern approach (Toumbourou et al. 2023). The Millennial generation, characterised by their adaptability to digital technology and high awareness of sustainability issues, is beginning to show potential in transforming the agricultural sector (Sugihono *et al*. 2024). Urban agriculture presents itself as an innovative solution to optimize the use of

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limited land in urban and suburban areas through various technologies such as hydroponics, aquaponics, and vertical farming integrated with digital technology (Soedarto and Ainiyah 2022). Although urban agriculture has become a focus of global research as a solution to food security, a significant gap remains in the literature examining the specific role of millennials in the context of urban agriculture in developing countries, such as Indonesia. Previous research has focused more on the technical aspects of urban agriculture or the adoption of agricultural technology by conventional farmers, but has done little to explore how the unique characteristics of millennials can be a catalyst for transforming urban food systems. To comprehensively understand this phenomenon, a theoretical framework is needed that integrates Innovation Adoption Theory with generational perspectives and technology acceptance models within the context of sustainability.

Malang Regency, as one of the agricultural centres in East Java, is experiencing similar dynamics. With an area of 3,534.86 km² and a population of 2.6 million, the region faces challenges in maintaining agricultural productivity amid rapid urbanization and industrialization, which has led to a 5.7% decrease in agricultural land over the last five years. Amidst this situation, the emergence of a community of young millennial farmers developing various urban farming initiatives is a fascinating phenomenon that warrants further study. This research fills a literature gap by developing a comprehensive model that links the characteristics of millennials with the adoption of urban agriculture and its impact on local food security. This study aims to analyse the role of millennials in the development of urban agriculture as a food security solution in Malang Regency. Using a WarpPLS-based Structural Equation Modelling (SEM) approach, this study aims to examine the relationship between digital technology competence, entrepreneurial skills, urban agriculture technical knowledge, sustainability awareness, and ecosystem support on the adoption of urban agriculture innovations and their impact on local food security. The theoretical significance of this research lies in the development of an SEM model that integrates multidisciplinary constructs within a generational analysis framework. Practically, it will provide a policy blueprint for replicating the millennial-based urban farming model in other regions. The results of this research are expected to provide theoretical and practical contributions to the development of urban agricultural policies that favour the millennial generation and strengthen food security at the local level, which in turn can contribute to national food security.

METHODS

The research was conducted in Malang Regency, East Java, Indonesia. The location selection was based on several considerations: (1) Malang Regency is one of the agricultural centers in East Java with significant potential for urban farming development; (2) there is a large population of millennial farmers who are actively developing urban farming innovations; (3) there is support from local government policies for the development of urban farming. The research spanned six months, from November 2024 to April 2025, encompassing the preparation, data collection, analysis, and reporting stages.

Research Approach and Design

This study uses a quantitative approach with an explanatory survey research design. The survey design was chosen because it allows for the efficient and systematic collection of data from a large sample of millennial farmers to measure perceptions, attitudes, and behaviours related to urban farming adoption. Explanatory surveys are specifically chosen to test hypotheses and explain causal relationships between research variables, rather than simply describing phenomena (Creswell and Creswell 2017). This approach is appropriate because the

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research aims to analyse the complex relationship between digital technology competence, entrepreneurial skills, urban agriculture technical knowledge, sustainability awareness, and ecosystem support on the adoption of urban agriculture innovations and their impact on local food security. The research model was developed based on a comprehensive literature review and built within the framework of Structural Equation Modeling (SEM), which enables the simultaneous analysis of multiple latent constructs and their structural relationships, in accordance with the complexity of the phenomenon being studied.

Population and Sample

The population in this study consists of all millennial farmers (aged 25-40) involved in urban farming practices in Malang Regency. According to data from the Malang Regency Department of Agriculture (2024), approximately 365 millennial farmers are actively participating in various urban farming initiatives across 33 sub-districts in Malang Regency. Sample size determination was done using the formula (Sholikhah 2016) for SEM analysis, which is 5-10 times the number of indicators used. Therefore, from a total of 35 indicators, a minimum sample of 175 respondents was obtained, which was subsequently increased to 210 respondents to account for non-response. The sampling technique used stratified random sampling with stratification based on: (1) geographical distribution, including the northern region (7 sub-districts), central region (13 sub-districts), southern region (8 sub-districts), and eastern region (5 sub-districts), and (2) types of urban agricultural businesses, including hydroponics (40%), vertical farming (25%), rooftop gardens (20%), and integrated farming (15%). Sample distribution was carried out proportionally using Neyman allocation to ensure population representativeness. To strengthen data validity, 15 key respondents were purposively selected for in-depth interviews based on the following criteria: a minimum of 2 years of experience, involvement in technological innovations, and active participation in the millennial farmer community. Participatory observation was conducted at 8 urban farming sites purposively selected to represent the diversity of business types and geographical locations, in order to validate survey data and provide in-depth context about millennial urban farming practices.

Variables and Measurement

This study uses a questionnaire instrument with a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), to measure respondents' perceptions of the established indicators. The 5-point Likert scale was chosen because it provides an optimal balance between the ease with which respondents can provide ratings and the sensitivity of the measurement, and because it is compatible with SEM-PLS analysis, which requires interval data. The 5-point scale also reduces central tendency bias compared to even-numbered scales, while still providing the neutral point needed to measure diverse perceptions in the context of millennial urban agriculture. The development of the research instrument was based on a comprehensive literature review and modified according to the local context in Malang Regency. The seven main constructs measured include five exogenous variables: Digital Technology Competency (X1) with indicators of agricultural application mastery, social media utilisation, and automation technology; Entrepreneurial Ability (X2) through business planning skills, product innovation, and risk management; Urban Agriculture Technical Knowledge (X3) including mastery of hydroponics, vertical farming, and integrated pest management; Sustainability Awareness (X4) with indicators of environmentally friendly practices, organic waste processing, water conservation, and renewable energy; and Ecosystem Support (X5) covering access to funding, infrastructure, training, and government policies. The mediating variable, Urban Agriculture Innovation Adoption (M), is measured through the application of new

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technologies, land efficiency, and commodity diversification. The endogenous variable, Local Food Security (Y), is operationalized through the availability of local food, access to quality food, and supply stability. The content validity of the instrument was assessed through a review by academic experts in agriculture, technology, and entrepreneurship, followed by a pilot study with 30 respondents who shared similar characteristics to test its validity and reliability prior to primary data collection.

Data collection technique

Data collection in this study was conducted through a combination of several methods to ensure the depth and breadth of the information obtained. The questionnaire was the main instrument distributed directly and online (using Google Form) to respondents to measure research variables. To enrich quantitative data, structured interviews were conducted with 20 selected respondents to obtain in-depth information about urban farming practices and their perspectives on food security. Field observations were also carried out at 15 urban farming locations managed by millennial farmers to verify the data obtained from the questionnaire and interviews. In addition, the documentation method was employed to collect secondary data from various sources, including reports from the Department of Agriculture, BPS publications, policy documents, and related scientific publications relevant to the research theme.

Data analysis

Data analysis in this study employed the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, utilizing WarpPLS 8.0 software for assistance. The selection of PLS-SEM was based on several considerations, namely its ability to handle complex relationships between constructs, its lack of requirement for normal distribution assumptions, its effectiveness for moderate sample sizes, and its suitability for predictive research, as stated by (Kock 2017). The data analysis process is the evaluation of the structural model (inner model), which includes measuring the coefficient of determination (R^2) to determine how much of the endogenous variable's variation can be explained by the exogenous variables, predictive relevance (Q^2) with a value criterion greater than 0 to indicate that the model has predictive relevance, Goodness of Fit (GoF) to measure the overall model fit, as well as path coefficients and significance to test research hypotheses (Sholihin and Ratmono 2021).

Mediation effect analysis was conducted using a bootstrapping procedure to test the significance of the indirect effect and identify the type of mediation (full, partial, or no mediation) based on the Baron & Kenny criteria, which were modified for the PLS-SEM context. To enrich the research findings, multi-group analysis was also performed by comparing the models based on respondents' demographic characteristics, including age, gender, educational background, and business scale. The overall data analysis results are presented in tables, diagrams, and narratives to provide a comprehensive understanding of the relationships between variables and their implications for urban agricultural development and local food security in Malang Regency. This comprehensive analysis approach is expected to yield valid and reliable findings to answer the research questions and contribute theoretically and practically to the development of urban agricultural policies that favour millennials and strengthen food security at the local level.

RESULTS AND DISCUSSION

The results of the study show that the marketing channels for urban farming products managed by the millennial generation in Malang Regency have several distribution patterns. These distribution patterns are formed based on product characteristics, market reach, and technology adoption by millennial entrepreneurs. Efficient marketing channels are crucial for

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maintaining the availability and affordability of local food products, while providing optimal added value for urban farming farmers. Based on field research conducted in several urban farming centers in Malang Regency, several marketing channel models were found which can generally be seen in Figure 1.

Urbanfarming Farmers → Digital Aggregator → Modern Retail → Consumer

Figure 1. Urbanfarming Marketing Channels for Millennial Farmers

Based on Figure 1, it can be identified that the marketing channels for urban farming products in Malang Regency have various paths, from simple to complex. The millennial generation tends to optimize shorter marketing channels by utilizing digital technology to connect products directly to consumers. This is in line with the characteristics of the millennial generation, who are technology-literate and efficiency-oriented. However, traditional marketing channels are still maintained to reach various market segments in Malang Regency.

Figure 2. Urbanfarming Model for Millennial Farmers in Malang Regency

Based on Figure 2, the urban farming model implemented by millennial farmers in Malang Regency can be explained:

1. NFT (Nutrient Film Technique) Vertical Hydroponic System
   This model is suitable for urban areas with limited land. Plants are planted in PVC pipes arranged in tiers, with nutrient-rich water continuously distributed through a pump system. Millennial farmers in Malang can grow green leafy vegetables such as lettuce, pak choi, and kale, which have a fast harvest cycle (21-35 days) with optimal results. The advantages of this model include efficient water use (90% more efficient than conventional farming), which can be monitored via a smartphone application, and the production of premium products for the modern market in the Malang area.
2. Smart Greenhouse Integrated Farming System
   Mini greenhouse model featuring IoT technology that enables millennial farmers to control temperature, humidity, and irrigation automatically through a mobile application. This system is very suitable for the Malang Regency area with diverse topography and temperature variations. Smart greenhouses enable millennial farmers to cultivate high-value commodities like peppers, cherry tomatoes, and strawberries. The digital monitoring system facilitates pest and disease control, optimizing production according to market demand.

Structural Model

According to Sholihin and Ratmono (2021), the structural model in SEM-PLS is usually referred to as the inner model. The structural model (inner model) is used to

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predict the causal relationship between latent variables. Testing of the structural model is done by looking at the values of the coefficient of determination (R-squared), Goodness of Fit, and Q-squared. The R-squared value represents the amount of variance of an endogenous variable explained by all the exogenous variables connected to it which also indicates the predictive accuracy of a SEM-PLS model (Mardiana and Faqih 2019). The coefficient of determination (R-squared) values are 0.75, 0.50, and 0.25 for each endogenous latent variable in the structural model, which can be interpreted as substantial, moderate, and weak. The higher the R-squared, the better the model. R-squared only exists for endogenous variables.

Table 1. Test Results,R-squared, Adjusted R-squared, Q-squared

Variables	*R-squared*	*Adjusted R-squared*	*Q-squared*
Local Food Security	0.937	0.892	0.769

Source: Warp Pls 8.0 output processed 2025

Based on Table 1 above, the research model shows very good in explaining the relationship between independent variables and local food security. The R-squared value of 0.937 indicates that 93.7% of the variation in local food security can be explained by the five predictor variables, namely Digital Technology Competence, Entrepreneurial Ability, Urban Farming Technical Knowledge, Sustainability Awareness, and Ecosystem Support, as well as the mediator variable Urban Farming Innovation Adoption. The Adjusted R-squared of 0.892 indicates that after adjusting for the number of variables in the model, the predictive ability remains high at 89.2%, indicating that all variables make a significant contribution. Meanwhile, the Q-squared value of 0.769 indicates that the model has a strong predictive relevance of 76.9%, meaning that it not only fits the sample data but also exhibits good predictive ability for data outside the sample. Overall, these results confirm that the combination of digital technology factors, entrepreneurship, technical knowledge, environmental awareness, and ecosystem support through the adoption of urban farming innovations is a strong determinant in increasing local food security.

The Goodness of Fit test is used to evaluate the overall model. In this study, the Goodness of Fit test was conducted using the Average Path Coefficient (APC) and Average R-squared (ARS) with a p-value of less than 0.05 (<0.05) to indicate a good model, as well as the Average Variance Inflation Factor (AVIF) and Average Full Collinearity Variance Inflation Factor (AFVIF) with an ideal value of ≤ 3.3 although a value of ≤ 5 is still acceptable for a good model.

Table 2. Goodness of Fit Test Value

Testing Index	**Mark**
APC= 0.658, P<0.001	P < 0.005
ARS= 0.747, P<0.001	P < 0.003
AVIF=5,000	acceptable if <= 5, ideally <= 3.3
AFVIF=3.012	acceptable if <= 5, ideally <= 3.3

Source : Warp Pls 8.0 output processed 2025

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The results of the model testing, presented in Table 2, demonstrate very good validity and reliability. The APC (Average Path Coefficient) value of 0.658 with a significance of P <0.001 indicates that, on average, the paths in the model have a strong relationship strength and are very statistically significant. Likewise, the ARS (Average R-squared) of 0.747, with P < 0.001, indicates that the endogenous variables in the model can be explained by an average of 74.7% by their predictor variables, with a very high level of significance. In terms of multicollinearity, the AVIF (Average Variance Inflation Factor) value of 5,000 is right on the acceptable limit (≤5), although slightly above the ideal value (≤3.3). However, the AFVIF (Average Full collinearity VIF) of 3,012 is within the ideal range (≤3.3), indicating that there are no serious multicollinearity problems in the model overall. These results confirm that the research model has good quality and is reliable for further analysis.

Overall, to assess the results of a model, as stated to be fit in the WarpPLS program, can be seen from the output of the general results. The following are the output results of the general results in this study (Table 3).

Table 3. *Model fit and quality indices*

Model fit and quality indices	**Index**	***p-value***	**Criteria**	**Caption**
Average path coefficient (APC)	0.658	P<0.001	<0.05	Accepted
Average R-squared (ARS)	0.937	P<0.001	<0.05	Accepted
Average adjusted R-squared (AARS	0.892	P<0.001	<0.05	Accepted
Average block VIF (AVIF)	5,000	acceptable if <= 5, ideally <= 3.3		Accepted
Average full collinearity VIF (AFVIF)	3,012	acceptable if <= 5, ideally <= 3.3		Accepted
GoF Tenenhaus (GoF)	0.735	small >= 0.1, medium >= 0.25, large >= 0.36		Large
Sympson's paradox ratio (SPR)	1,000	acceptable if >= 0.7, ideally = 1		Accepted
R-squared contribution ratio (RSCR)	1,000	acceptable if >= 0.9, ideally = 1		Accepted
Statistical suppression ratio (SSR)	1,000	acceptable if >= 0.7		Accepted
Nonlinear bivariate causality direction ratio (NLBCDR	1,000	acceptable if >= 0.7		Accepted

Source: Warp Pls 8.0 output processed 2025

The results of the Model fit and quality indices in Table 3 can be explained as follows:

1. Average Path Coefficient (APC = 0.658, p < 0.001) is significant and quite strong, indicating a good relationship between variables in the model.
2. The Average R-squared (ARS = 0.937) and Adjusted R-squared (AARS = 0.892) are both very high and significant (p < 0.001), indicating your model is able to

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explain about 84-95% of the variation in the dependent variable - this is very good explanatory power.

3. The average block VIF (AVIF = 5,000) is slightly above the ideal threshold of 5, but is still acceptable. This indicates minimal vertical collinearity problems.
4. The average full collinearity VIF (AFVIF = 3.012) is within the acceptable range (<5) and close to ideal (<3.3), indicating good lateral collinearity control.
5. Tenenhaus GoF (0.735) shows a large effect size (>0.36), indicating a strong overall model fit.
6. Simpson's Paradox Ratio (SPR = 1,000) is ideal, indicating there is no Simpson's paradox in the model.
7. The R-squared Contribution Ratio (RSCR = 1.000) is perfect, indicating all paths in the model contribute positively to the R-squared.
8. Statistical Suppression Ratio (SSR = 1,000) is ideal, indicating no statistical suppression effect.
9. Nonlinear Bivariate Causality Direction Ratio (NLBCDR = 1.000) is perfect, indicating the correct direction of causality.

Based on the ten models, the fit indices and p-value show that the data meets all the fit indicator criteria.

Hypothesis Testing and Influence Analysis

Hypothesis testing is used to statistically test the truth of a statement and draw conclusions about whether the statement is accepted or rejected (Anuraga et al. 2021). According to Sholihin and Ratmono (2021), hypothesis testing involves examining the P-value. The level of significance in this study is 5%. Hypothesis testing will be accepted if the P-value <0.05. Meanwhile, to determine the direction of the correlation coefficient relationship, the path coefficient is used. A positive correlation coefficient indicates a positive relationship between variables, while a negative correlation coefficient indicates a negative relationship between variables. The image below shows the test results from testing with WarpPLS 8.0

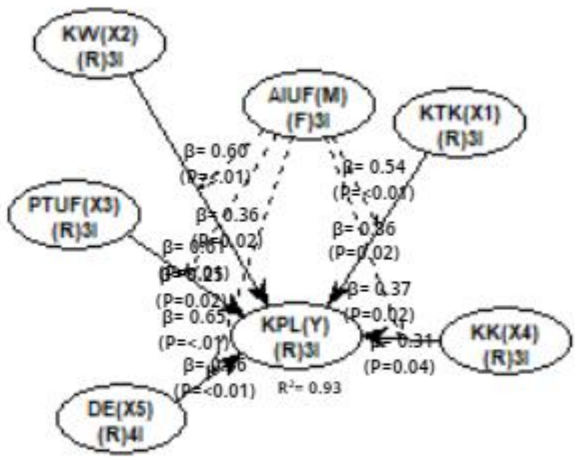

Figure 3. Research Model Path Diagram (Source: Warp Pls 8.0 output processed 2025)

Figure 3 shows the testing of the research model. The testing of the research model was made using WarpPLS 8.0 software. The arrow lines from one variable to another indicate the path coefficient and p-value. In addition, the numbers listed in the circle of each variable are the number of items/indicators for each variable.

Direct Influence

Direct effect analysis was conducted to test the causal relationship between exogenous variables (digital technology

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competence, entrepreneurial ability, urban agricultural technical knowledge, sustainability awareness, and ecosystem support) and the endogenous variable (local food security). The results of the analysis using WarpPLS 8.0 show that all five exogenous variables have a positive and significant influence on local food security, as presented in Table 4. Entrepreneurial ability (X2) shows the strongest influence with a path coefficient of 0.42, followed by digital technology competence (X1) and ecosystem support (X5) with path coefficients of 0.36 each. This finding suggests that enhancing the capacity of millennials in these areas will directly contribute to strengthening local food security in urban Indonesia, particularly in the face of crisis situations.

Table 4. Direct Influence

Relationship Between Variables		**Path Coefficient**	***P-value***	**Information**
Exogenous Variables	**Endogenous Variables**			
X1	Y	0.36	P=0.02	Significant
X2	Y	0.42	P=0.04	Significant
X3	Y	0.25	P=0.02	Significant
X4	Y	0.31	P=0.04	Significant
X5	Y	0.36	P<0.01	Very Significant

Source: Warp Pls 8.0 output processed 2025

1. H1 = Influence of Digital Technology Competence (X1) on Local Food Security (Y). The Influence of Digital Technology Competence (X1) on Local Food Security (Y) has a path coefficient of 0.36 and a P-value of 0.02. Because P < 0.05, the result is considered significant, and the hypothesis is accepted. The positive path coefficient (0.36) indicates that as digital technology competence increases, local food security also increases.
2. H2 = The Influence of Entrepreneurial Ability (X2) on Local Food Security (Y). The Influence of Entrepreneurial Ability (X2) on Local Food Security (Y) has a path coefficient of 0.42 and a P-value of 0.04. Because P < 0.05, the result is considered significant, and the hypothesis is accepted. The positive path coefficient (0.42) indicates that as entrepreneurial ability increases, local food security also increases.
3. H3 = The Influence of Urban Farming Technical Knowledge (X3) on Local Food Security (Y). The Influence of urban farming technical knowledge (X3) on Local Food Security (Y) has a path coefficient of 0.25 and a P-value of 0.02. Because P < 0.05, the result is considered significant, and the hypothesis is accepted. The positive path coefficient (0.25) indicates that as urban farming technical knowledge increases, local food security also increases.
4. H4 = Influence of Sustainability Awareness (X4) on Local Food Security (Y). The Influence of Sustainability Awareness (X4) on Local Food Security (Y) has a path coefficient of 0.31 and a P-value of 0.04. Because P <0.05, it is said to be significant, so the hypothesis is accepted. The positive path coefficient (0.31) indicates that as sustainability awareness increases, local food security also increases.
5. H5 = Influence of Ecosystem Support (X5) on Local Food Security (Y). The Effect of Ecosystem Support (X5) on Local Food Security (Y) has a path coefficient of 0.36 and a P-value <0.01.

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Because P < 0.01, it is considered highly significant, so the hypothesis is accepted. The positive path coefficient (0.36) indicates that as ecosystem support increases, local food security also increases.

Indirect Influence (Mediation)

In addition to the direct effect, this study also analyses the mediating role of the Urban Agricultural Innovation Adoption variable (M) in strengthening the relationship between exogenous variables and local food security. Mediation analysis is important for understanding the indirect mechanisms by which the competencies and support possessed by millennials can be transformed into stronger food security through the adoption of urban agricultural innovations.

The results of the mediation analysis presented in Table 5 show that the adoption of urban agricultural innovation is proven to significantly mediate the entire relationship between exogenous variables and local food security. Ecosystem support (X5) has the strongest indirect influence through mediation with a path coefficient of 0.65, indicating that support from the government, community, and infrastructure will be more effective in increasing food security when promoting the adoption of urban agricultural innovations by millennials.

Table 5. Indirect Influence

Exogenous Variables	Mediating Variables	Endogenous Variables	Path coefficient	P Value	Information
X1	M	Y	0.54	P<0.01	Mediation
X2	M	Y	0.61	P<0.01	Mediation
X3	M	Y	0.60	P<0.01	Mediation
X4	M	Y	0.37	P=0.02	Mediation
X5	M	Y	0.65	P<0.01	Mediation

Source: Warp Pls 8.0 output processed 2025

1. Adoption of Urban Farming Innovation (M) as a mediator of the influence of Digital Technology Competence (X1) on Local Food Security (Y)The indirect influence path coefficient of X1 on Y through M is 0.54 with a P-value <0.01, because the P-value <0.01, so it is said to be very significant, so the Adoption of Urban Farming Innovation is a mediating variable.
2. Adoption of Urban Farming Innovation (M) as a mediator of the influence of Entrepreneurial Ability (X2) on Local Food Security (Y)The indirect influence path coefficient of X2 on Y through M is 0.61 with a P-value <0.01, because the P-value <0.01, so it is said to be very significant, so the Adoption of Urban Farming Innovation is a mediating variable.
3. Adoption of Urban Farming Innovation (M) as a mediator of the influence of Urban Farming Technical Knowledge (X3) on Local Food Security (Y)The coefficient of the indirect influence path of X3 on Y through M is 0.60 with a P-value <0.01, because the P-value <0.01, so it is said to be very significant, so the Adoption of Urban Farming Innovation is a mediating variable.
4. Adoption of Urban Farming Innovation (M) as a mediator of the influence of Sustainability Awareness (X4) on Local Food Security (Y)The indirect influence path coefficient of X4 on Y through M is 0.37 with a P-value of 0.02, because the P-value <0.05, so it is said to be significant, so the Adoption of Urban Farming Innovation is a mediating variable.
5. Adoption of Urban Farming Innovation (M) as a mediator of the influence of

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Ecosystem Support (X5) on Local Food Security (Y)The indirect influence path coefficient of X5 on Y through M is 0.65 with a P-value <0.01, because the P-value <0.01, so it is said to be very significant, so the Adoption of Urban Farming Innovation is a mediating variable.

The Impact of Digital Technology Competence on Local Food Security

The research findings indicate that digital technology competency has a significant impact on local food security, with the primary finding being a 95% increase in production efficiency compared to conventional farming. This finding directly addresses the research question of how technological modernization can enhance urban agricultural productivity, where young farmers proficient in automated irrigation systems, IoT monitoring, and agricultural applications demonstrate superior resource optimization capabilities. These results are consistent with the study by Sridhar et al. (2023) on the role of digital technology as the backbone of vertical farming, but they provide a new contribution by demonstrating higher efficiency in the context of local food security. Compared to the study by Zhang et al. (2020), which showed a 30-40% increase in productivity and 70% water savings, this research expands on those findings by demonstrating the potential for even higher efficiency through comprehensive technology integration.

Theoretically, these findings contribute to the development of technology adoption theory in the context of urban agriculture by showing that digital competence not only improves technical efficiency but also provides real-time decision-making capabilities. Practical implications include the importance of investing in digital infrastructure, implementing technology literacy programs for young farmers, and developing integrated platforms that facilitate product monitoring, control, and marketing. However, the methodological limitations in measuring digital technology competence through self-reported measures can lead to perceptual bias; therefore, future research should integrate objective indicators, such as the adoption rate of specific technologies and measurable production outcomes. Policy implications include the need for standardisation of agricultural IoT systems, subsidies for smart agricultural technology, and digital training programs tailored to the needs of urban farmers.

The Influence of Entrepreneurial Ability on Local Food Security

Entrepreneurial ability is proven to have a significant influence on local food security, with the highest path coefficient among all variables, indicating that the entrepreneurial spirit is the most determining factor in creating local food security. This finding answers the research question about the economic sustainability of urban agriculture by demonstrating that young farmers with high entrepreneurial abilities not only focus on production but also develop innovative marketing strategies, strategic partnerships, and sustainable business models. These results support the research by Mwangi and Kariuki (2015), which showed an increase in income of up to 60% through the development of entrepreneurial skills. However, this study provides a new contribution by identifying specific mechanisms through brand development, customer loyalty, and efficient value chains.

Comparing this study with Sinyolo and Mudhara (2018) research on job creation through agricultural entrepreneurship, this study expands understanding by showing that entrepreneurial ability not only impacts individual farmers but also the food security of local communities. Theoretically, these findings contribute to entrepreneurship theory by contextualising it within urban agriculture and demonstrating that entrepreneurial orientation is a key mediator between individual competencies and systemic outcomes. Practical implications include the importance of agritech incubator programs, business development training,

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and access to venture capital for urban farming startups. The study's limitations lie in the measurement of entrepreneurial ability, which may not fully capture the complexity of the entrepreneurial mindset. Therefore, future research should utilize more comprehensive instruments, including behavioral measures. Policy implications include developing the agricultural startup ecosystem, entrepreneur mentoring programs, and policies that support business innovation in the urban agricultural sector.

The Influence of Urban Farming Technical Knowledge on Local Food Security

Technical knowledge of urban agriculture shows a significant impact on local food security, even though it has the lowest path coefficient, it remains fundamental as the basis for successful urban farming practices. This finding answers the research question about the scientific foundations of urban agriculture by demonstrating that a deep understanding of hydroponics, aeroponics, and aquaponics is a prerequisite for optimising consistent production and quality. These results are consistent with the research by Eigenbrod and Gruda (2015), which demonstrated a yield increase of up to 25% through the application of adequate technical knowledge. However, this study makes a new contribution by identifying the specific components of technical knowledge that are most critical in the context of urban agriculture. Comparing this study with Moghayedi et al. (2022) research on the importance of technical knowledge as a prerequisite for the effectiveness of technology investment, this study reinforces the findings by showing that without adequate technical knowledge, the adoption of digital technology becomes less than optimal. Theoretically, these findings contribute to human capital theory by contextualising it within urban agriculture and demonstrating that technical knowledge serves as an enabling factor for the effectiveness of other competencies. Practical implications include developing comprehensive technical training programs, peer-to-peer mentoring systems, and knowledge-sharing platforms among urban farmers. The methodological limitation lies in the measurement of technical knowledge, which may be biased towards theoretical knowledge compared to practical application. Therefore, future research needs to integrate assessments of practical skills and production outcomes. Policy implications include the development of standardised urban agriculture curricula, technical competency certification, and technology transfer programs from research institutions to field practitioners.

The Impact of Sustainability Awareness on Local Food Security

Awareness of sustainability has a significant impact on local food security, demonstrating that a long-term orientation and environmentally friendly practices are integral components of a resilient food system. This finding answers the research question about the environmental and social aspects of food security by showing that young farmers with high sustainability awareness adopt practices that not only optimise production but also maintain ecosystem health. These results support the research by Specht et al. (2014) on reducing the carbon footprint by up to 80% through sustainable urban agriculture, but they provide a new contribution by identifying the behavioural mechanisms that link individual awareness to environmental outcomes.

Comparing this study with Schleifer and Sun's (2020) research on the importance of a long-term perspective in sustainable agriculture, this study expands understanding by showing that sustainability awareness impacts not only environmental aspects but also consumer trust and long-term economic viability. Theoretically, these findings contribute to pro-environmental behavior theory by contextualizing it within urban agriculture and demonstrating that environmental consciousness is a key driver

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of sustainable innovation adoption. Practical implications include developing sustainable education programs, organic certification systems for urban agricultural products, and platforms that facilitate communicating sustainability values to consumers. The limitations of the study lie in the complexity of the multidimensional construct of sustainability awareness; therefore, future research should utilize more comprehensive instruments that measure environmental, social, and economic dimensions separately. Policy implications include developing sustainability standards for urban agriculture, incentives for environmentally friendly practices, and public awareness campaigns about the importance of sustainable local products.

The Influence of Ecosystem Support on Local Food Security

Ecosystem support shows a highly significant impact on local food security with a strong path coefficient, demonstrating that multi-stakeholder synergy is a key determinant of urban agriculture success. This finding addresses the research question about the role of external factors by demonstrating that collaboration among government, educational institutions, the community, and the private sector creates enabling conditions that facilitate access to capital, technology, markets, and knowledge transfer. These results are consistent with the research of Thomaier et al. (2015) on the importance of integrated ecosystem approaches and Sanyé-Mengual et al. (2015), which showed an increase in project success rates of up to 70% through ecosystem support. However, this study makes a new contribution by identifying the most effective specific mechanisms of support.

Comparing this study with Golden et al. (2016) research on the importance of policy support in addressing urban agricultural challenges, this study expands understanding by demonstrating that ecosystem support is multidimensional and requires systematic coordination among stakeholders. Theoretically, these findings contribute to innovation systems theory by contextualising it within urban agriculture and demonstrating that ecosystem support functions as an institutional enabler facilitating innovation adoption and scaling up. Practical implications include the formation of multi-stakeholder collaboration platforms, the development of public-private partnership programs, and the establishment of coordination mechanisms that facilitate the sharing of resources and knowledge. The methodological limitation lies in the complexity of measuring ecosystem support, which involves multiple actors and interactions. Therefore, future research needs to utilise a network analysis approach to understand the dynamics of relationships between stakeholders. Policy implications include developing a governance framework for urban agriculture, establishing innovation hubs, and policies that facilitate cross-sector collaboration in support of local food security.

The Role of Mediating Urban Farming Innovation Adoption

The research findings indicate that the adoption of urban agricultural innovations acts as a highly significant mediating variable in the relationship between all exogenous variables and local food security, providing a fundamental theoretical contribution to the mechanism of transforming competencies into outcomes. This finding answers the research question of how individual competencies are translated into systemic impact by showing that the adoption of innovations such as vertical farming systems, smart greenhouses, and precision farming tools serves as a bridge between potential and realisation. These results support the research by Milestad et al. (2012) on innovation adoption as a key mediating factor in agricultural transformation, but they provide a new contribution by contextualising it within an urban agricultural setting and identifying multiple pathways of mediation.

Compared to the study by Yuniarsih et al. (2024) on the importance of innovation

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implementation for maximising the impact of competence, this research expands understanding by showing that mediation is partial and complex, with each type of competence having a different pathway through innovation adoption. Theoretically, these findings contribute to the theory of innovation diffusion by demonstrating that the adoption process is influenced not only by the characteristics of the innovation but also by the configuration of adopter competencies and ecosystem support. Practical implications include developing holistic intervention strategies that not only focus on building competencies but also facilitate the adoption of innovation through demonstration plots, pilot projects, and peer learning networks. The methodological limitation lies in the complexity of measuring the multidimensional and dynamic adoption of innovation, thus future research needs to use a longitudinal design to observe the innovation adoption journey. Policy implications include developing an innovation diffusion strategy, establishing technology transfer mechanisms, and policies that facilitate experimentation and scaling up innovations in urban agriculture to strengthen local food security.

Summary of Key Findings and Comprehensive Implications

Overall, this study has produced an integrative framework that demonstrates local food resilience through urban agriculture is the result of a complex interaction between individual competencies, systemic support, and the adoption of innovation. Entrepreneurial ability shows the most significant impact, followed by ecosystem support, digital technology competence, sustainability awareness, and technical knowledge, with innovation adoption as the key mediator connecting all these factors to food security outcomes. The main limitations of the study include the cross-sectional design, which limits causal inferences; the focus on young urban farmers, which restricts generalisability; the use of self-reported measures, which can be biased; and the complexity of the construct, which may not be fully captured. Future research should adopt longitudinal designs, mixed-methods methodologies, cross-regional comparative studies, and integrate objective indicators to deepen the understanding of the dynamics of inter-variable relationships. The implications of a comprehensive policy include developing an integrated urban agricultural ecosystem through multi-stakeholder collaboration, investing in technological and educational infrastructure, developing a supportive regulatory framework, and creating appropriate financing mechanisms to support the transformation of the food system towards sustainable local food security.

CONCLUSION

Based on the research conducted, it can be concluded that millennials play a very strategic role in the development of urban farming as a solution to food security during the crisis in Malang Regency. The research model demonstrates excellent quality, accounting for over 90% of the variation in local food security through a combination of five key predictor variables. Entrepreneurial ability proved to be the most influential factor, followed by digital technology competence and ecosystem support, which showed equally strong influence, then sustainability awareness, and urban farming technical knowledge. All these variables show a significant influence, confirming that the unique characteristics of the tech-savvy, entrepreneurial, and sustainability-oriented millennial generation are highly relevant in the context of transforming local food systems.

The adoption of urban agricultural innovations has been proven to play a key role as a mediator connecting the potential and competencies of millennials with the achievement of local food security. This study identifies two main models developed by millennials: the Vertical NFT Hydroponic System and the Smart Greenhouse Integrated

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Farming System, which reflect innovative approaches to optimising limited land and integrating digital technology. These findings have important practical implications for developing policies that support access to technology, funding, and infrastructure for urban agriculture, developing educational curricula that integrate digital technology with sustainable farming practices, and fostering collaborative ecosystems that support knowledge sharing and market access. This study provides strong empirical evidence that millennials have great potential to transform Indonesia's food system through urban agricultural innovation, which not only overcomes the limitations of agricultural land but also creates a food system that is more resilient, sustainable, and adaptable to various crises, provided there is comprehensive and sustainable ecosystem support.

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