Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AN15.20250146
Published: February 18, 2025

Technology Management Framework for Urban Farming in Selected Cities of National Capital Region for Sustainable Development

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Abstract

The COVID-19 pandemic highlighted weaknesses in global food systems, particularly in urban centers like Metro Manila, underscoring the urgent need for resilient, sustainable food production strategies. Urban agriculture has emerged as a promising approach to combat food insecurity in densely populated areas. This study investigates the state of technology management in urban agriculture across various cities within the National Capital Region (NCR) of the Philippines, aiming to establish a sustainable technology management framework for urban farming. By examining practices and challenges faced by urban farm leaders and local government units, the research identifies key factors for effective technology adoption, such as hydroponics, aquaponics, and vertical farming, to improve productivity and environmental sustainability. The study employs a mixed-methods approach, combining quantitative surveys and qualitative interviews, to assess the management functions of planning, directing, coordinating, and controlling urban farming activities. The findings underscore the crucial role of technology management in addressing the barriers to sustainable development, such as limited resources, insufficient technical knowledge, and policy gaps. The proposed framework aims to guide sustainable urban farming practices in Metro Manila, contributing to food security and sustainable development in urban environments.

Keywords
Urban Agriculture, Technology Management, Sustainability, COVID-19, Metro Manila, Hydroponics, Aquaponics, Urban Farming Framework.

1. Introduction
The COVID-19 pandemic exposed significant weaknesses in global food systems, with urban centers like Metro Manila being particularly vulnerable to food supply disruptions. These challenges highlighted the urgent need for sustainable and resilient food production strategies. Urban agriculture has emerged as a potential solution to mitigate food insecurity in densely populated areas, providing a means to enhance food availability, reduce environmental impact, and support local economies.

In Metro Manila, the expansion of urban agriculture has been driven by deteriorating economic and environmental conditions, prompting residents to turn to urban farming as a means of improving food security and livelihoods. However, sustainable urban agriculture requires effective technology management to optimize productivity, reduce costs, and minimize environmental impacts. This study explores the current state of technology management in urban farming within selected cities in the National Capital Region (NCR), focusing on the development of a sustainable technology management framework.

The research aims to evaluate existing practices in urban agriculture, identify challenges, and propose a framework that integrates innovative technologies, such as hydroponics, aquaponics, and vertical farming. By addressing key management functions—planning, directing, coordinating, and controlling—this study seeks to establish a framework that promotes sustainable development in urban farming, ultimately contributing to food security and environmental sustainability across NCR.

1.1 Objectives
This study primarily aims to examine the technology management of selected cities in the National Capital Region towards urban agriculture, that can be used as a basis in developing programs for sustainable development. Specifically, the study aims to answer the following research questions:

1. What specific challenges do respondents face in urban farming?
2. What sustainable technology management framework can be developed for urban farming in the National Capital Region?

2. Literature Review
2.1 Urban Agriculture and Sustainability
Urban agriculture has emerged as a viable solution to address food security challenges in densely populated areas. According to Orsini et al. (2019), urban farming contributes to sustainability by reducing food miles, enhancing local economies, and improving urban resilience. Studies by Deelstra and Girardet (2020) emphasize that integrating agriculture into urban environments can mitigate the negative environmental impacts of urbanization, such as heat island effects and carbon emissions.
The significance of urban agriculture in achieving sustainable development goals (SDGs) is well-documented. Bakker et al. (2020) argue that urban farming aligns with SDG 11 (Sustainable Cities and Communities) by promoting local food production and fostering community engagement. In Metro Manila, government initiatives like "Gulayan sa Barangay" aim to integrate urban agriculture into city planning to enhance food security and environmental sustainability (Duldulao, 2019).

2.2 Technology Adoption in Urban Farming
Technological advancements have revolutionized urban agriculture by introducing efficient farming methods such as hydroponics, aquaponics, and vertical farming. Hanrahan (2020) highlights the role of precision agriculture technologies, including IoT sensors and automated irrigation systems, in improving resource efficiency and crop yields. Kobayashi et al. (2016) found that technology adoption in Metro Manila urban farms is hindered by financial constraints and lack of technical expertise.
Research by Kalantari et al. (2017) emphasizes the importance of evaluating the feasibility of innovative farming techniques in urban settings. Their study on vertical farming reveals that while space optimization is a major advantage, energy consumption remains a critical challenge. Furthermore, studies by Purwanto (2018) suggest that policies supporting technology integration are crucial for successful urban farming implementation.

2.3 Challenges in Urban Farming
Despite its potential, urban farming faces numerous challenges related to economic, social, and environmental factors. Holmer et al. (2018) identified high startup costs, limited land availability, and regulatory constraints as significant barriers to urban agriculture expansion in the Philippines. Similarly, Orsom (2010) points out that social acceptance and community engagement play a pivotal role in the success of urban farming initiatives.
Waste management is another critical challenge in urban farming. According to Oda et al. (2018), improper waste disposal can lead to environmental pollution, undermining the sustainability of urban agricultural projects. Implementing waste-to-energy solutions and composting techniques are recommended strategies to address these challenges.

2.4 Technology Management Frameworks
Developing an effective technology management framework is essential for the sustainability of urban farming initiatives. Venter and Grobbelaar (2022) propose a framework that focuses on planning, directing, coordinating, and controlling technology implementation in agricultural settings. Their study emphasizes the importance of stakeholder collaboration and continuous evaluation to optimize technology use.

The integration of emerging technologies, such as Agriculture 4.0, into urban farming has shown promising results. Ali and Porciuncula (2021) highlight the potential of smart farming solutions to enhance productivity and resource efficiency. However, their study also underscores the need for capacity building and training programs to bridge the knowledge gap among urban farmers.

3. Methods

This chapter presents the methods and procedures used in the collection and analysis of the data in the study. It presents the research design, respondents in the study, sampling technique, survey instrument, data collection procedure and statistical treatment of data.

A. Research Design

The study aims to develop a technology management framework for sustainable urban farming in selected cities of the National Capital Region (NCR). To achieve this, a mixed-methods research design was employed, combining both quantitative and qualitative data collection and analysis. The mixed-methods approach enables a comprehensive examination of the current technology management practices in urban farming and identifies the challenges and opportunities for sustainable development.

The quantitative phase involves a survey distributed to key stakeholders, including urban farm leaders, local government representatives, and community members, to collect data on the existing practices, technology usage, and challenges encountered in urban farming. This phase captures a broad perspective on the technology management functions—planning, directing, coordinating, and controlling—across different urban farming initiatives in NCR.

The qualitative phase complements the quantitative data by conducting semi-structured interviews and focus group discussions with a subset of survey respondents. These methods provide deeper insights into the experiences, perceptions, and contextual factors influencing technology adoption and management in urban farming. The qualitative data enrich the analysis by uncovering themes and strategies relevant to the development of a sustainable technology management framework.

The integration of quantitative and qualitative findings informs the proposed framework, ensuring that it addresses the specific needs and challenges faced by urban farming in NCR. By focusing on innovative approaches, such as hydroponics, aquaponics, and vertical farming, the study aims to establish a framework that enhances productivity, resource efficiency, and sustainability in urban agriculture, thereby contributing to sustainable development in the region.

B. Respondents of the Study

Since the main purpose of the study is to develop a technology management framework for urban farming in the National Capital Region, selected urban farmers and urban farm leaders in selected cities in the National Capital Region would serve as the primary respondents of the study.

Urban farmers in this study are responsible for managing the farm, as well as assisting with farm-specific non-production activities such as sales and public relations, while the urban farm leaders share the vision of where the farm is going with everyone on the farm team. Urban farm leaders passionately believe in their vision and inspire others to join. They create a vision and chart a clear path on how to achieve it.

The population area of the proposed research includes eight (8) cities or 50% of the cities in the National Capital Region: Caloocan City, Makati City, Malabon City, Manila City, Marikina City, Quezon City, San Juan City, and Valenzuela City.

C. Sampling Technique

According to data from Metro Manila Development Authority or MMDA, the National Capital Region or NCR is composed of sixteen cities (16), and to obtain the necessary data, the researcher used a two-stage random sampling technique to obtain the sample respondents for this study. In a Two-stage Random Sampling Technique, the researcher randomly selects samples or groups and then randomly selects individuals from these groups. In this case, the cities in the National Capital Region are considered as the main cluster.

It seems that the researcher is using a two-stage random sampling method. In the first stage, 50% of the total number of cities in the National Capital Region is selected randomly. This would mean if there were 16 cities in NCR, for example, 8 cities would be selected. In the second stage, the researcher randomly selects a sample of urban farm leaders and urban farmers from each of the previously selected cities. This two-stage approach helps to ensure that the sample is representative of the broader urban farming community within the selected cities while also managing the scope and resources of the study.

According to the Philippine Statistics Authority (psa.gov.ph), the estimated number of urban farm leaders in the National Capital Region (NCR) is 23,000. Utilizing the formula proposed by Calmorin and Calmorin (2012), the total number of respondents was determined to be 256 urban farm leaders.

On the other hand, the general population of the representatives from Local Government Units (LGUs) refers to all barangay officials from the selected cities, since they are directly participating in urban farm programs of their respective cities. There are 1,710 barangays in the National Capital Region, which composed of eight member officials, thus, there are around 13,680 barangay officials, calculating the sample size using the previously mentioned formula, a total of 258 LGU representatives were included in this study.

The panel of 20 experts comprises 3 agricultural engineers specializing in engineering principles applied to agricultural production and processing, 5 urban farm owners and leaders experienced in planning, implementing, and managing urban farming projects, 7 representatives from local government units involved in urban development and agriculture policy-making and implementation, and 2 experts affiliated with the Department of Agriculture's Agricultural Training Institute focusing on agricultural extension, education, and training. Together, they offer a diverse range of expertise crucial for the design, implementation, and regulation of efficient and sustainable urban farming systems. Their collective knowledge and experience span technical, practical, and policy aspects, enabling collaboration to develop strategies for promoting sustainable urban farming practices and enhancing food security in urban areas. The interview was conducted from June to November 2023.

D. Research Instrument

The research instruments used in this study are designed to collect data that will guide the development of a sustainable technology management framework for urban farming in selected cities of the National Capital Region (NCR). A structured survey questionnaire and open-ended interview guide were developed to gather quantitative and qualitative data from key stakeholders, including urban farm leaders, local government officials, and community members involved in urban agriculture.

The survey questionnaire consists of multiple sections that assess the current state of technology management practices in urban farming. These sections focus on various management functions—planning, directing, coordinating, and controlling—to understand how technology is currently utilized and what challenges are faced in implementing sustainable practices. The Likert-scale format allows for the measurement of respondents' levels of agreement or disagreement on specific statements related to technology management, challenges, and opportunities in urban agriculture.

In addition to the survey, an open-ended questionnaire was used during semi-structured interviews with a panel of experts, including agricultural engineers, urban farm leaders, and representatives from government agencies. These interviews provided deeper insights into the experiences and perspectives of those involved in urban farming, uncovering potential strategies for addressing barriers to sustainability, such as limited resources and policy gaps. The combination of structured survey data and expert opinions ensures that the proposed framework is both evidence-based and tailored to the specific conditions of urban farming in the NCR.

The information gathered through these instruments forms the basis for developing a comprehensive technology management framework that integrates innovative practices, such as hydroponics, aquaponics, and vertical farming, to enhance the sustainability and productivity of urban farming in NCR.

E. Validation of Instrument

To ensure the validity of the researcher-made survey questionnaire, the researcher enlisted the assistance of his research adviser and experts in the field of urban farming to evaluate the content of the questionnaire in terms of format, language used, and whether the questions measured the desired objectives.

The research adviser's and experts' suggestions and comments were properly documented and reflected on the final version of the survey questionnaire.

In terms of reliability, a total of fifteen randomly selected urban farmers and urban farm leaders in NCR, who were not part of this study, were asked to answer the second version of the survey questionnaire. Utilizing SPSS version 22, a Cronbach's alpha test was performed to determine the reliability of the researcher-made survey questionnaire.

F. Data Gathering Procedure

The data gathering procedure for this study was designed to support the development of a sustainable technology management framework for urban farming in selected cities of the National Capital Region (NCR). Key steps included:

1. **Obtaining Ethical Approval:** Ethical approval was secured from the institutional review board to ensure compliance with ethical standards, fostering participant confidence and enriching data collection.
2. **Survey Development and Distribution:** A structured survey focused on technology management practices in urban farming was distributed to stakeholders, including urban farm leaders, local government officials, and community members. This survey provided quantitative data reflecting the effectiveness of current technology management functions.
3. **Conducting Semi-Structured Interviews:** Interviews were held with experts, including agricultural engineers and LGU representatives, to gather qualitative insights on challenges and opportunities in urban farming, informing best practices and innovative strategies.
4. **Focus Group Discussions:** Discussions with selected survey and interview participants facilitated collaborative dialogue, exploring shared experiences and problem-solving related to technology management.
5. **Data Collection and Integration:** Data were collected through digital platforms and integrated to provide a comprehensive understanding of the current state of technology management in urban farming.
6. **Analysis of Data:** Quantitative data were analyzed statistically to identify trends, while qualitative data underwent thematic analysis, ensuring robust findings relevant to the framework's development.
7. **Framework Development:** Insights from the data analysis were utilized to create a tailored technology management framework aimed at enhancing productivity, resource efficiency, and sustainability in urban farming, directly aligning with the study's objective.

G. Statistical Treatment of Data

Collected data will be treated using statistical software known as IBM SPSS Statistics Version 22 and interpreted by the researcher.

1. **Mean** will be used to identify the central tendency of the responses made by the respondents on each item found in the survey questionnaire.

$$X = \frac{\sum f\, x}{\sum n}$$

Where:

X = computed mean

ΣFx = the sum of the product of the frequency and assigned point.

Σn = the total number of respondents.

2. **Percentage** will be used to supplement the interpretation gathered from the collected data, it will also be used to indicate the percentage of response relative to the total response for each item, and a Likert scale was also used to describe the result.

$$P = \frac{F\, x\, 100}{N}$$

Where:

P = the computed percentage

F = the frequency

N = the total number of respondents

3. **Likert Scale** will be used to determine the assessments of the respondents towards technology management of the selected cities in National Capital Region and the suitability, acceptability, and feasibility of the proposed technology management framework.

4. The **Independent Samples T-test** is a statistical test used to determine if there is a significant difference between the means of two independent groups. It is commonly used when comparing the means of two different treatment groups or when comparing a sample group to a known population mean.

   The formula for the independent samples t-test is as follows:

   $$t = (M1 - M2) / sqrt((s1^2 / n1) + (s2^2 / n2))$$

   Where:

   t is the t-value, which represents the difference between the means of the two groups

   M1 and M2 are the means of the two groups being compared.

   s1 and s2 are the standard deviations of the two groups.

   n1 and n2 are the sample sizes of the two groups.

The t-value is then compared to the critical value from the t-distribution table or calculated using statistical software to determine the statistical significance of the difference between the two means. The degrees of freedom for the t-test are calculated as (n1 + n2 - 2).

If the calculated t-value is greater than the critical value, it indicates that there is a significant difference between the means of the two groups. Conversely, if the calculated t-value is less than the critical value, it suggests that there is no significant difference between the means of the two groups.

H. Research Ethics
Research ethics are vital for maintaining the integrity, validity, and well-being of participants in this study. The ethical considerations for conducting the research include:

1. **Obtain Ethical Approval:** Prior to starting the study, the researcher secures ethical approval from the university or institutional review board, especially when involving human participants.
2. **Informed Consent:** Participants are fully informed about the study's purpose, procedures, risks, benefits, and their rights. Written consent is obtained to ensure voluntary participation and the ability to withdraw at any time without repercussions.
3. **Confidentiality and Anonymity:** The researcher safeguards participants' confidentiality and anonymity by securely storing data and ensuring identities cannot be linked to responses.
4. **Data Collection and Analysis:** Appropriate methods are employed for data collection and analysis, ensuring participants' privacy and dignity are respected. Data is securely stored and used solely for research purposes.
5. **Respect for Participants:** Researchers treat participants with respect, avoiding discrimination, exploitation, or coercion, while being mindful of power dynamics and maintaining professionalism throughout the research process.
6. **Reporting and Dissemination:** Findings are reported accurately and honestly, avoiding fabrication or selective reporting. Researchers acknowledge participants' contributions and respect their privacy in publications.
7. **Continuous Monitoring:** Ethical considerations are regularly reviewed throughout the research, with any arising concerns addressed promptly to maintain ethical integrity.
8. **Compliance with Legal and Regulatory Requirements:** The researcher adheres to all relevant laws, regulations, and guidelines pertaining to research ethics specific to the study's field or jurisdiction.

4. Data Collection

The data collection procedure for this study was designed to support the development of a sustainable technology management framework for urban farming in selected cities of the National Capital Region (NCR). The process involved the following key steps:

1. **Ethical Approval:** Prior to data collection, ethical approval was obtained from the institutional review board to ensure adherence to ethical research standards and safeguard the rights and privacy of participants.
2. **Survey Administration:** A structured survey questionnaire was distributed to stakeholders, including urban farm leaders, local government officials, and community members involved in urban agriculture. The questionnaire was designed to assess the management functions of planning, directing, coordinating, and controlling urban farming activities, using a Likert-scale format to measure respondents' perceptions.
3. **Pilot Testing:** A pilot test was conducted with fifteen randomly selected urban farmers and urban farm leaders to validate the reliability of the questionnaire. The instrument passed the reliability test with a 95% acceptance level, confirming its suitability for data collection.
4. **Semi-Structured Interviews:** In addition to the survey, semi-structured interviews were conducted with a panel of 20 experts, comprising agricultural engineers, urban farm owners, and government representatives. The interviews provided qualitative insights into the challenges and opportunities in urban farming and helped refine the proposed framework.
5. **Focus Group Discussions (FGDs):** FGDs were organized with selected respondents to facilitate collaborative dialogue and further explore shared experiences, challenges, and potential solutions for improving urban farming practices.
6. **Data Integration:** The quantitative and qualitative data collected through surveys and interviews were integrated to provide a comprehensive understanding of the current state of technology management in urban farming.
7. **Statistical Analysis:** The collected data were analyzed using IBM SPSS Statistics Version 22. Descriptive and inferential statistical methods, including mean, percentage analysis, and t-tests, were applied to interpret the survey results, while thematic analysis was conducted for qualitative responses.

5. Results and Discussion

5.1 Numerical Results

This chapter presents the analysis and interpretation of data collected through surveys and other methods employed in this study. The findings are organized and presented using text, graphs, and tables, addressing the specific research questions in the order they were posed. The methodologies and techniques applied in this study are also detailed.

E. Specific challenges Respondents Faced in Urban Farming

Table 10 provides an assessment of the challenges faced by urban farming in selected cities, as perceived by Urban Farm Leaders and Local Government Units (LGUs). The ratings, interpreted as "Challenging" (C), reflect various difficulties encountered in implementing and sustaining urban agriculture. The variables are ranked based on their composite scores, indicating that both Urban Farm Leaders and LGUs perceive these challenges as significant, with all variables rated as "Challenging."

Table 1: Assessment of Challenges Faced by Urban Farming in Selected Cities.

	Variable	Urban Farm Leaders		LGU		Composite		Rank
		X	V.I	X	V.I	X	V.I	
1	The economic profitability of urban agriculture is often poor, discouraging its expansion in cities due to high implementation and maintenance costs of advanced systems.	4.01	C	4.01	C	4.01	C	4
2	A need exists for increased awareness and education about urban farming benefits, technology usage, maintenance, and environmental impact.	3.98	C	4.05	C	4.015	C	3
3	Aligning urban agriculture with sustainable development goals presents a challenge, particularly ensuring environmentally friendly technology use.	3.98	C	4.06	C	4.02	C	1
4	Effective strategic planning is crucial for integrating urban agriculture into city infrastructure, including location selection and technology choice.	4.01	C	4.03	C	4.02	C	1
5	Urban agriculture, a solution to food production challenges in densely populated cities, faces the challenge of maximizing production within limited spaces with effective technology.	3.99	C	4.01	C	4.00	C	6
6	While beneficial, urban agriculture can contribute to environmental pollution if not properly managed, including waste management and sustainable farming practices.	4.04	C	3.98	C	4.01	C	4
7	Urban agriculture, seen as a potential solution to urban poverty by creating jobs and reducing food expenses, faces the challenge of accessibility and affordability for low-income communities.	4.00	C	3.98	C	3.99	C	7
Over-all Mean		**3.99**	**C**	**4.01**	**C**	**4.00**	**C**	

The economic viability of urban agriculture is often hindered by high implementation and maintenance costs, which received a rating of 4.01, ranking it fourth among challenges. There is a critical need for increased awareness and education regarding urban farming's benefits and technology use, achieving a score of 4.015 and ranking third. Efforts to align urban agriculture with sustainable development goals, particularly through environmentally friendly technology, were rated 4.02, highlighting its significance.

Strategic planning for integrating urban agriculture into city infrastructure, including site selection and technology choice, also scored 4.02. Other challenges include maximizing production in limited spaces, with a score of 4.00, and potential environmental pollution from poor waste management practices, which received a score of 4.01. Urban farming's role in alleviating poverty faces accessibility and affordability challenges, ranking lowest at 3.99.

The evaluation reveals critical barriers and opportunities in integrating technology into urban agricultural practices, emphasizing economic viability, environmental sustainability, and social equity. High implementation costs restrict growth, necessitating greater awareness and education on technology use. Aligning urban farming with sustainable development goals is complex, particularly regarding environmentally friendly technology. Strategic planning is essential for successful integration into urban infrastructure.

Maximizing production requires efficient technology use, while socio-economic factors highlight accessibility and affordability issues for low-income communities. The risk of environmental pollution underscores the need for effective waste management and sustainable practices, reinforcing the necessity for comprehensive strategies to address these challenges.

F. Sustainable Technology Management Framework for Urban Farming

The composition of the panel of experts participating in the study was diverse and represented various key stakeholders in the field of urban farming. The panel consisted of agricultural engineers, urban farm owners/leaders, representatives from local government units (LGUs), and officials from government agencies such as the Department of Agriculture

- Agricultural Training Institute (DA-ATI) and the National Urban and Peri-Urban Agriculture Program (NUPAP). In total, there were 20 experts involved in the study, each bringing a unique perspective and expertise to the discussion.

Table 2: The Panel of Experts

Panel of Experts	**Frequency**
Agricultural Engineers	3
Urban Farm Owners/Leaders	5
Representatives from LGU	7
Department of Agriculture - Agricultural Training Institute (DA-ATI)	2
National Urban and Peri-Urban Agriculture Program of Department of Agriculture (NUPAP)	3
TOTAL	**20**

The expert panel in this study comprises a diverse group of stakeholders involved in urban farming, crucial for developing a sustainable technology management framework in the National Capital Region (NCR). Key insights include:

- **Technical Contributions:** Agricultural engineers bring essential expertise in innovative technologies and sustainable practices, focusing on optimizing resource use and enhancing productivity in urban environments.
- **Practical Knowledge:** Urban farm owners and leaders offer firsthand experience in operations, including crop selection, land management, and marketing, ensuring the framework is practical and responsive to real-world challenges.
- **Local Governance Role:** Representatives from Local Government Units (LGUs) highlight the importance of policy formulation and urban planning in supporting urban farming, aligning with community needs for effective governance.
- **National Support:** Officials from the Department of Agriculture - Agricultural Training Institute (DA-ATI) and the National Urban and Peri-Urban Agriculture Program (NUPAP) emphasize the national commitment to urban agriculture, providing insights on policies, funding, and capacity-building initiatives.
- **Collaborative Approach:** The study advocates for a multidisciplinary approach, integrating diverse perspectives to create holistic strategies for sustainable technology management in urban farming.

Table 3: Delphi Round 1 Technology Applications and Management Strategies in Urban Farming

Item Statement
1. Advanced irrigation and water recycling system, Aquaponics, Vertical Farming, and Modern Irrigation
2. ROI, long-term benefits, scalability, and the alignment of technology solutions, utilization of waste materials (bio and non-bio) to be fertilizer, community project pertaining to urban farming
3. Evaluating the efficiency and effectiveness of technology implementation, the level of integration and adoption of technology within the agricultural processes, and the overall impact on productivity and sustainability. Impact of the technology management framework on crop production, resource efficiency, cost savings, environmental sustainability, and community engagement
4. Pest and Disease Management, Resource Management, Connectivity and Data Management
5. Life cycle assessment, renewable energy integration, resource efficiency and conservation, integrated pest management, soil health management, water management, ecosystem integration
6. We provide training and support to enhance technological literacy among farmers and community members. We conduct user testing sessions and gather feedback to identify any usability issues and make necessary improvements thru research
7. Environmental monitoring technology, data analytics capabilities, energy usage, and the scalability of the infrastructure
8. Best supplier with cheap price, market research to identify potential technology vendors
9. Agiculture 4.0, Drone Technology for quality monitoring the agriculture products
10. Urban gardening/bucket garden, Aquaponics System, Vertical farming rooftop greenhouse project.
11. Automation and technology adoption may reduce the need for manual labor, potentially leading to job displacement. privacy, security, job displacement, environmental impact, and the potential misuse of technology as technology advancements streamline processes and automate tasks, there is a concern that traditional agricultural jobs may be replaced, leading to unemployment for some individuals.
12. By implementing these measures, urban agriculture projects can safeguard sensitive data and maintain the integrity and continuity of their farming operations. Data, records, and information about urban farms must be protected to avoid exploitation and sabotage
13. Join online forums like Facebook groups, LinkedIn, and specialized agricultural forums often feature discussions on emerging technologies, Staying updated on urban agriculture tech trends involves research, networking, and collaboration
14. Machine Learning, IoT, AI for weather monitoring and prediction
15. Water Management Technology. Batteries and solar panels, modification in our technology management framework allowed us to maintain crucial monitoring and automated watering systems
16. Additional food supply in Metro Manila

Table 3 presents an overview of technology applications and management strategies essential for developing a sustainable technology management framework for urban farming in the National Capital Region (NCR). The table covers various aspects aimed at improving efficiency, productivity, and sustainability in urban agriculture:

- •Water Management Techniques: Emphasizes advanced irrigation systems, water recycling, aquaponics, and vertical farming, highlighting the need for effective water conservation practices due to resource limitations in urban farming.
- •Technology Evaluation Criteria: Focuses on evaluating technology based on return on investment (ROI), long-term benefits, scalability, community involvement, and the use of waste materials for fertilizer production, ensuring financial viability and environmental sustainability.
- •Technology Implementation Assessment: Stresses the importance of assessing the efficiency and effectiveness of technology in enhancing productivity and sustainability, advocating for continuous evaluation of its impact on urban farming.
- •Holistic Sustainability Approaches: Discusses the necessity of integrating life cycle assessments, renewable energy, integrated pest management, and ecosystem integration into the framework to promote adaptable sustainable practices.
- •Emerging Technologies: Introduces advanced technologies such as Agriculture 4.0, drones, machine learning, IoT, and AI, suggesting their incorporation into the framework to boost productivity while addressing potential challenges.
- •Community Engagement: Highlights the importance of stakeholder engagement through market research, supplier selection, and technological literacy, ensuring the framework aligns with the practical needs of urban farmers in NCR.

Table 4: Technology Management Framework Coding and Associated Categories for Urban farming.

Item Statement	Code	Category
Environmental monitoring technology, data analytics capabilities, energy usage, and the scalability of the infrastructure (P1,P2,P4,P7,P10,P12,P16,P20)	Environmental Monitoring Technology	Resource Efficiency and Data-driven Decision Making
Agiculture 4.0 (also known as AgTech 4.0 or Smart Farming, refers to the integration of modern information and communication technologies (ICT) into the agricultural sector. It represents a new era of agriculture that leverages advanced technologies to optimize various farming processes, increase efficiency, and enhance overall productivity) (P3,P5,P8,P9,P13,P14,P15,P17,P19)	Smart Farming	
By implementing these measures, urban agriculture projects can safeguard sensitive data and maintain the integrity and continuity of their farming operations. Data, records, and information about urban farms must be protected to avoid exploitation and sabotage (P6,P11,P18)	Safeguard sensitive data	
Life cycle assessment, resource efficiency and conservation, water management, ecosystem integration, Integrated pest management, soil health management. (All P1….P20)	Life cycle assessment	Biodiversity Conservation
Utilization of waste materials (bio and non-bio) to be fertilizer, community project pertaining to urban farming (All P1….P20)	Utilization of waste masterials	Waste Management
Join online forums like Facebook groups, LinkedIn, and specialized agricultural forums often feature discussions on emerging technologies, Staying updated on urban agriculture tech trends involves research, networking, and collaboration (P2,P4,P7,P8,P9,P10,P11,P13,P15,P16)	Online forums	Community Engagement and Continuous Innovation and Education
We provide training and support to enhance technological literacy among farmers and community members. (P1,P14,P17,P18,P20)	Training and support	
We conduct user testing sessions and gather feedback to identify any usability issues and make necessary improvements thru research. (P3,P5,P6,P12,P19)	User testing sessions	
Urban gardening, Aquaponics System, Vertical farming rooftop greenhouse project. (P2,P5,P6,P8,P10,P11,P12,P14,P15,P16,P17,P18)	Vertical farming	Climate Resilience and Vertical Farming & Hydroponic
Machine Learning, IoT, AI for weather monitoring and prediction. (P1,P3,P4,P5,P7,P13,P19,P20)	Weather monitoring	
Budget and Resource Allocation. (P2,P3,P5,P6,P7,P8,P10,P11,P12,P15)	Budget Allocation	Economic Viability and Supply Chain Technologies
Additional Food Supply in the Urban Cities. (P1,P4,P14,P16,P17,P18,P19,P20)	Additional food supply	
Best supplier with cheap price, market research to identify potential technology vendors. (P9,P13)	Cheap price	
Automation and technology adoption may reduce the need for manual labor, potentially leading to job displacement. privacy, security, job displacement, environmental impact, and the potential misuse of technology As technology advancements streamline processes and automate tasks, there is a concern that traditional agricultural jobs may be replaced, leading to unemployment for some individuals. (P1,P3,P5,P6,P7,P9,P11,P12,P13,P16,P17,P20)	Technology Adoptation	Social Equity
ROI, long-term benefits, scalability, and the alignment of technology solutions. (P2,P4,P8,P10,P14,P15,P18,P19)	Long-term benefits	
Pest and Disease Management, Resource Management, Connectivity and Data Management. (P4,P8,P9,P11,P13,P14,P15,P16,P17,P19)	Pest Management	Precision Farming Technologies
Drone Technology for quality monitoring the agriculture products. (P1,P2,P3,P5,P6,P7,P10,P12,P18,P20)	Drone Technology	
Advanced irrigation and water recycling system (rainwater harvester), Aquaponics, Vertical Farming, and Modern Irrigation. (P1,P2,P5,P7,P8,P9,P11,P13,P15,P18)	Water recycling system	Smart Irrigation Systems and Renewable Energy Integration
Batteries and solar panels, modification in our technology management framework allowed us to maintain crucial monitoring and automated watering systems. (P3,P4,P6,P10,P12,P14,P16,P17,P19,P20)	Batteries and solar panel	

The framework for managing technology in urban farming focuses on sustainable development and efficiency within urban settings, specifically for cities in the National Capital Region (NCR). Key components of this framework include:

- **Environmental Monitoring Technology:** Utilizes tools for monitoring environmental parameters and data analytics to support data-driven decision-making, enhancing productivity while minimizing environmental impact.
- **Smart Farming Techniques:** Also known as Agriculture 4.0, this aspect integrates modern information and communication technologies into agricultural practices, optimizing processes and increasing efficiency to address challenges like limited space and resources.
- **Data Security Measures:** Emphasizes the importance of protecting sensitive data associated with urban farming through measures like encryption, access controls, and backup strategies, ensuring data integrity and project resilience.
- **Holistic Approaches to Sustainability:** Encompasses biodiversity conservation, waste management, and sustainable pest management. A life cycle assessment approach helps optimize resource utilization and integrate ecosystems, fostering sustainability in urban farming.
- **Community Engagement and Collaboration:** Highlights the importance of engaging the community and enhancing technological literacy through online forums and training. This collaborative effort ensures that the framework meets the needs and experiences of stakeholders in NCR.

Table 5: Importance of Sustainability and Technology Management Factors in Urban farming.
(Second Round Interview)

Sustainability and Technology Management Facotrs	Mean	SD	Verbal Interpretation
Community Engagement	8.40	1.5351	Absolutely crucial
Economic Viability	8.40	1.2856	Absolutely crucial
Climate Resilience	8.20	1.6754	Absolutely crucial
Data-driven Decision Making	8.20	1.7563	Absolutely crucial
Vertical Farming and Hydroponics	8.20	1.6453	Absolutely crucial
Resource Efficiency	8.10	1.7377	Absolutely crucial
Waste Management	8.10	1.7734	Absolutely crucial
Social Equity	8.0	1.5898	Nearly crucial
Precision Farming Technologies	8.0	1.5351	Nearly crucial
Smart Irrigation Systems	8.0	1.2856	Nearly crucial
Biodiversity Conservation	7.8	1.6754	Nearly crucial
Renewable Energy Integration	7.6	1.7563	Nearly crucial

The assessment of sustainability and technology management factors in urban farming, as summarized in Table 5, reveals several key insights into developing a sustainable technology management framework for urban farming in selected cities within the National Capital Region (NCR). Resource efficiency, waste management, community engagement, and economic viability emerge as the most critical factors, each receiving high mean scores indicative of their paramount importance in driving successful urban farming initiatives.

- **Innovative Farming Techniques**

The importance of vertical farming and hydroponics, alongside resource efficiency and waste management, is underscored as crucial. These factors reflect the growing recognition of innovative farming techniques and efficient resource utilization in enhancing productivity and sustainability within urban farming systems. Integrating these methods into the technology management framework will ensure that urban farming practices in NCR leverage the latest advancements to maximize output while minimizing environmental impact.

- **Social Equity and Technological Advancement**s

The emphasis on social equity, precision farming technologies, and smart irrigation systems as nearly crucial factors highlights the need for inclusive practices and efficient water management strategies. This focus is vital for promoting equity in access to resources and optimizing agricultural outputs, aligning with the framework's goal of fostering sustainable urban farming that benefits all community members.

- **Biodiversity Conservation and Renewable Energy**

Additionally, the consideration of biodiversity conservation and renewable energy integration as nearly crucial factors underscores the broader environmental considerations inherent in urban farming practices. The technology management framework must incorporate strategies to preserve ecological diversity and integrate renewable energy sources, mitigating environmental impacts and enhancing sustainability.

- **Community Engagement and Data-Driven Decision Making**

The evaluation reveals that community engagement, economic viability, climate resilience, and data-driven decision-making are paramount components in urban farming. These elements align with the overarching goals of the sustainable technology management framework, which aims to adapt to environmental challenges and leverage data insights for strategic choices, as supported by existing literature advocating for community participation in urban farming (Orsini et al., 2020).

- **Comprehensive Assessment and Future Research**

The statistical analysis indicates a lack of consensus among experts regarding the rating of specific statements, suggesting the complexity of urban farming systems and the diversity of perspectives within the field. This insight emphasizes the necessity for continuous evaluation and adaptation of the technology management framework to address varying expert opinions and emerging challenges.

Table 6: Assessment of Sustainability and Technology Management Factors in Urban Farming.
(Third Round Interview)

Sustainability and Technology Management Factors	Mean	SD	Verbal Interpretation
Resource Efficiency (1)	8.5	0.5083	Absolutely crucial
Waste Management (2)	8.5	0.5036	Absolutely crucial
Community Engagement (3)	8.4	0.4987	Absolutely crucial
Economic Viability (4)	8.4	0.5334	Absolutely crucial
Vertical Farming and Hydroponics (5)	8.3	0.4091	Absolutely crucial
Renewable Energy Integration (6)	8.3	0.6523	Absolutely crucial
Climate Resilience (7)	8.2	0.6923	Absolutely crucial
Data-driven Decision Making (8)	8.2	0.4523	Absolutely crucial
Smart Irrigation Systems (9)	8.2	0.5424	Absolutely crucial
Precision Farming Technologies (10)	8.1	0.5609	Absolutely crucial

The critical importance of resource efficiency and waste management in urban farming cannot be overstated, as effective resource utilization and waste handling are essential for maximizing productivity while reducing environmental impacts. Similarly, community engagement and economic viability highlight the necessity of integrating urban farming into local communities, ensuring its long-term sustainability and socio-economic advantages. The high ratings for vertical farming, hydroponics, renewable energy integration, and climate resilience underscore the vital role of technology in enhancing the sustainability of urban agriculture. These technological solutions provide innovative methods for optimizing resource use, reducing climate-related risks, and fostering environmental resilience.

Additionally, the focus on data-driven decision-making emphasizes the value of utilizing data and analytics to guide strategic planning and management in urban farming. Smart irrigation systems and precision farming technologies demonstrate the potential for technology to optimize agricultural practices, thereby enhancing efficiency and productivity while minimizing resource consumption and environmental harm.

The evaluation of sustainability and technology management factors in urban farming, as illustrated in Table 6, emphasizes the importance of various elements in shaping a framework for sustainable technology management in this sector. Key findings reveal that resource efficiency, waste management, community engagement, and economic viability are paramount considerations, each receiving high mean scores that reflect their foundational significance in sustainable urban farming initiatives. These results align with existing literature that underscores the importance of effective resource use and waste management in maximizing productivity while minimizing environmental impacts (Orsini et al., 2019; Holmer et al., 2018).

Moreover, the high ratings for vertical farming, hydroponics, renewable energy integration, climate resilience, data-driven decision-making, smart irrigation systems, and precision farming technologies illustrate the crucial role of technology in enhancing urban farming sustainability. These technologies provide innovative solutions for optimizing resource utilization, mitigating climate-related risks, and fostering environmental resilience, consistent with findings from earlier studies (Bakker et al., 2020; Smit, 2018).

Considering the theoretical implications and practical applications of these findings, it is evident that a comprehensive approach to sustainable technology management is vital for the long-term viability of urban farming. By leveraging technological advancements and combining them with traditional agricultural practices, urban farming can effectively meet the demands of growing urban populations while contributing to environmental conservation and socio-economic development (Orsom, 2010; Specht et al., 2014).

While these results align with the research objective of identifying key factors in sustainable technology management for urban farming, it is important to acknowledge limitations and potential areas for further research. Future studies could explore the specific mechanisms through which these factors interact and affect the overall sustainability of urban farming systems, providing deeper insights for informed decision-making (Ali & Porciuncula, 2021).

The findings presented in Table 6 reinforce the multi-faceted nature of sustainable technology management in urban farming and offer essential insights for developing effective frameworks in this domain. By prioritizing resource efficiency, waste management, community engagement, and economic viability while harnessing technology-driven solutions, urban farming can play a crucial role in addressing the complex challenges of food security, environmental sustainability, and economic development in rapidly urbanizing areas.

Notably, the Kendall’s coefficient of concordance (Kendall’s W) significantly improved from 0.209 to 0.731 (x^2 = 53.050, df = 9, $p \leq 0.01$). With a Kendall’s W value exceeding 0.73, this indicates a strong consensus among experts on the subject, suggesting that the iterative process can now conclude, with a total of 10 indicators identified following this exercise.

5.2 Graphical Results

The graphical analysis of the challenges faced by urban farming in selected cities, as evaluated by urban farm leaders and local government units (LGUs), indicates that all identified challenges fall within the "Challenging" category (3.40 – 4.19). This suggests that significant obstacles must be addressed to achieve sustainable urban agriculture.
Key findings highlight that aligning urban farming with sustainable development goals and ensuring effective strategic planning are the most critical challenges, both receiving the highest composite score of 4.02. The need for increased awareness and education about urban farming benefits, technologies, and environmental impact ranked third (4.015), with LGUs rating it slightly higher than urban farm leaders.

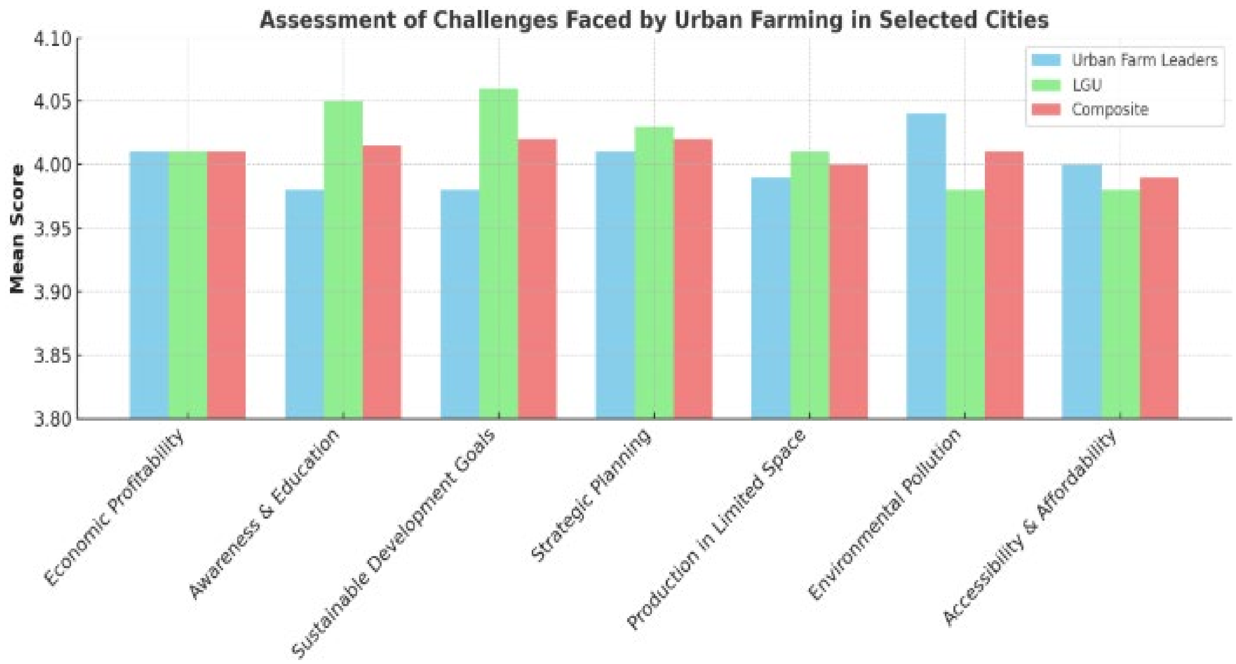

Figure 1. **Assessment of Challenges Faced by Urban Farming in Selected Cities**

Economic profitability, rated at 4.01, emerged as a major concern due to the high costs of implementing and maintaining advanced technologies, posing barriers to expansion. Similarly, concerns related to environmental pollution (4.01) underline the importance of proper waste management and sustainable farming practices.
Challenges associated with maximizing production in limited urban spaces were rated at 4.00, indicating that space constraints remain a significant issue. The lowest-rated challenge, accessibility and affordability (3.99), suggests that while important, it may be less urgent compared to other challenges.

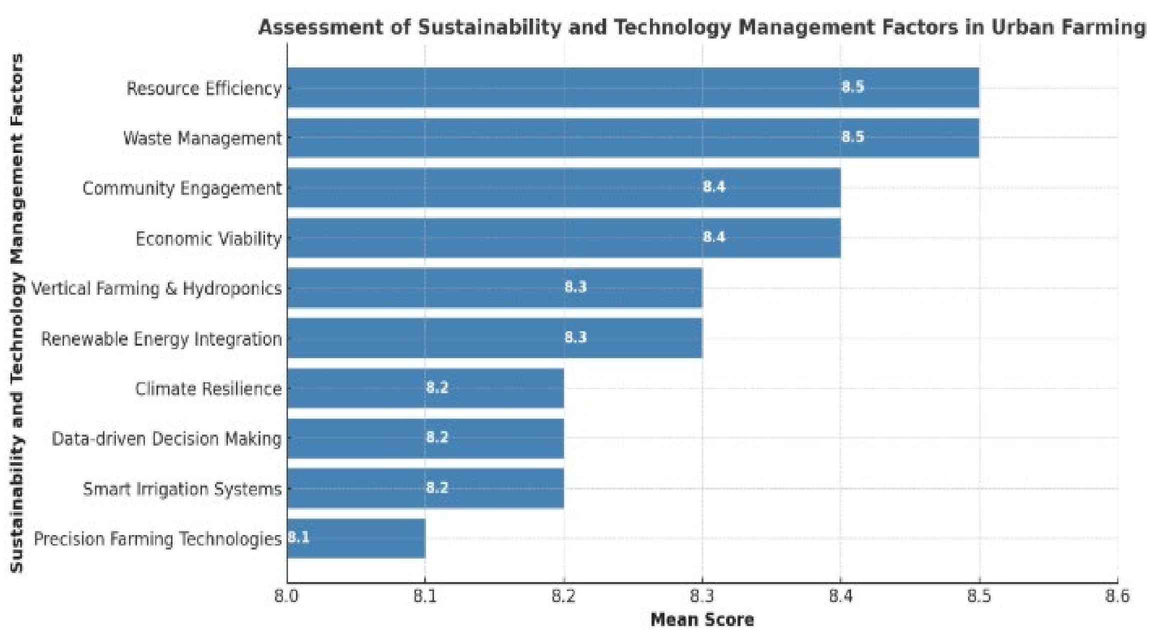

Figure 2. **Assessment of Sustainability and Technology Management Factors in Urban Farming**

Figure 2 illustrates the assessment of sustainability and technology management factors in urban farming, based on expert evaluations. All factors were rated as "Absolutely Crucial," with mean scores ranging from 8.1 to 8.5, emphasizing their importance in ensuring the sustainability of urban agriculture.
Resource efficiency and waste management received the highest ratings (8.5), highlighting their critical role in optimizing productivity and minimizing waste. Community engagement and economic viability (8.4) were also identified as essential for fostering stakeholder involvement and financial sustainability. Technological integration, particularly through vertical farming and renewable energy (8.3), was recognized as vital for enhancing efficiency and addressing space constraints in urban settings.

Climate resilience and data-driven decision-making (8.2) were deemed crucial for adapting to environmental challenges and optimizing farming operations. Smart irrigation systems and precision farming technologies (8.1–8.2) were also noted as key elements in improving resource utilization and operational efficiency.

5.3 Proposed Improvements

The proposed framework aims to enhance the resilience, productivity, and sustainability of urban farming in the National Capital Region (NCR) by integrating technological innovations with traditional practices and fostering collaboration among stakeholders. Key components of the framework include:

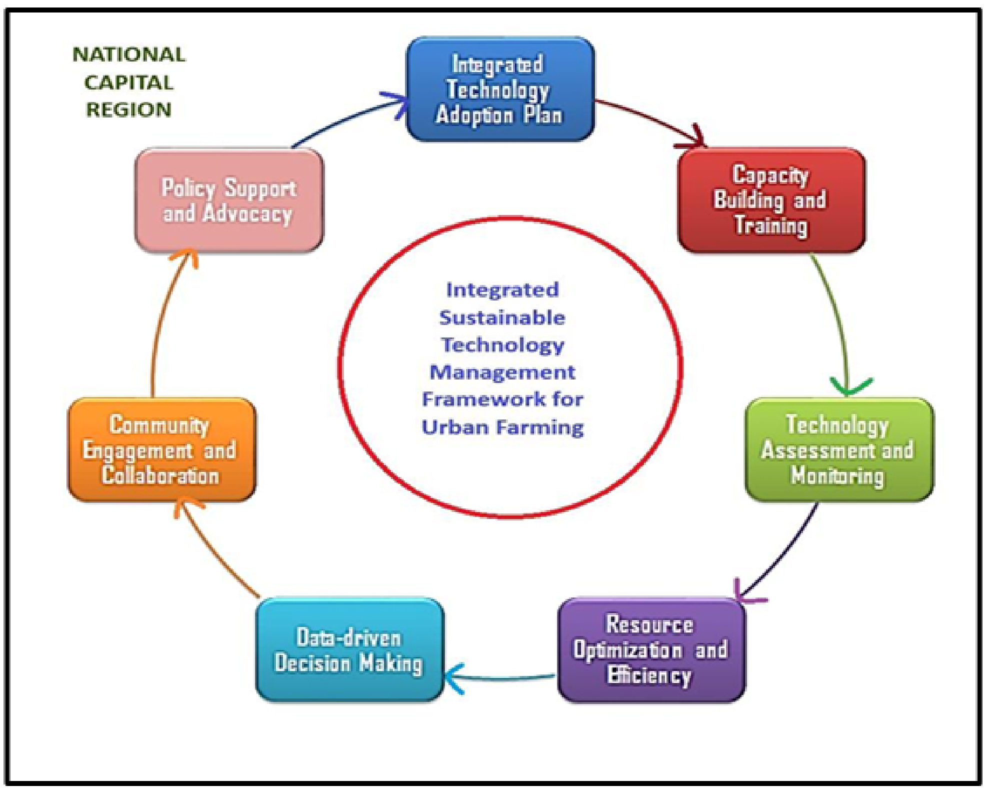

Figure 3. Integrated Sustainable TM Framework for Urban Farming

- **Integrated Technology Adoption Plan:** Emphasizes ongoing assessment and monitoring of technology performance through key performance indicators (KPIs) such as crop yields and environmental impact. Stakeholder input ensures that technology initiatives meet the urban farming community's needs.
- **Capacity Building and Training:** Focuses on optimizing resource use through techniques like precision farming, smart irrigation, and sensor-based monitoring. Practices such as vertical farming and hydroponics improve space utilization and productivity while incorporating renewable energy reduces fossil fuel dependence and carbon emissions.
- **Technology Assessment and Monitoring:** Continuous evaluation of technology performance helps refine management strategies and identify areas for improvement, enhancing sustainability and productivity.

- **Resource Optimization and Efficiency:** Highlights the importance of maximizing resource efficiency and minimizing waste using innovative farming techniques, vital for sustainable practices in urban agriculture.
- **Data-driven Decision Making:** Promotes the use of advanced analytical tools for strategic decision-making related to crop management. Establishing protocols for data collection ensures data integrity and supports evidence-based decisions among farmers.
- **Community Engagement and Collaboration:** Encourages partnerships among urban farmers, local governments, and community organizations to facilitate knowledge sharing and innovation. Initiatives like community gardens strengthen ties between urban agriculture and local communities.
- **Policy Support and Advocacy:** Stresses the importance of collaborating with policymakers to create supportive regulations and advocate for incentives that promote technology adoption and align urban farming efforts with broader goals of food security, sustainability, and economic growth.

5.4 Validation

The validity and reliability of the survey instrument were ensured through expert evaluation and statistical testing. Content validity was established by seeking feedback from a research adviser and experts in urban farming, who assessed the questionnaire's format, language, and relevance to the study objectives. Their suggestions were incorporated to refine the final version of the instrument.

To assess the reliability of the survey instrument, a pilot test was conducted with fifteen randomly selected urban farmers and urban farm leaders in the National Capital Region (NCR), who were not part of the main study sample. The internal consistency of the survey items was measured using Cronbach's alpha coefficient, a widely used statistical tool for determining the reliability of scales and ensuring consistency in responses. The analysis was performed using IBM SPSS Statistics Version 22, and the computed Cronbach's alpha value indicated a high level of internal consistency. The instrument successfully passed the reliability test with a 95% acceptance level, ensuring that it is a reliable tool for data collection (Taber, 2018).

6. Conclusion

The study's findings regarding the status and management of urban farming in the National Capital Region (NCR) lead to several key conclusions:

1. **Management Skills of Urban Farm Leaders**: Urban farm leaders exhibit superior management skills in planning, directing, and coordinating compared to representatives from local government units (LGUs). Leveraging their expertise is essential for enhancing urban farming practices and implementing the proposed sustainable technology management framework.
2. **Identification of Key Challenges**: The study identifies several significant challenges, rated as "Challenging," with an overall mean score of 4.00. Key issues include remediation costs, city zoning, automation, land access, analytics, mechanization, and water management. Addressing these challenges is vital for the success and sustainability of urban farming initiatives.
3. **Development of the Sustainable Technology Management Framework**: The creation of a Sustainable Technology Management Framework, informed by expert assessments, marks a significant step toward effectively managing urban agriculture technologies. The framework includes components such as community engagement, economic viability, climate resilience, data-driven decision-making, vertical farming, hydroponics, resource efficiency, waste management, social equity, precision farming technologies, smart irrigation, and renewable energy integration. This comprehensive strategy aims to tackle the identified challenges and promote sustainable urban farming practices in NCR, ensuring long-term success and resilience.

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Biography

Jeffrey L. Cacho is an accomplished professional with a distinguished career in academia and industrial engineering. He holds a Doctor of Philosophy in Technology Management from the Technological University of the Philippines (2024), a Master of Engineering in Industrial Engineering from Adamson University (2012) and graduated cum laude with a Bachelor of Science in Industrial Engineering from Quezon City Polytechnic University (2010). Currently serving as the Chair of the Industrial Engineering Department at Quezon City University (QCU), Dr. Cacho has led the program since 2017, contributing significantly to its growth and development. He previously taught as an instructor at QCU from 2010 to 2017 and gained industry experience as a production control staff member at Nito Seiki Manufacturing Corporation.Dr. Cacho is a certified ASEAN Engineer and Professional Industrial Engineer, showcasing his expertise in the field. He is also a prolific researcher, with numerous publications in international journals, including IEEE and Diversitas Journal. His research spans diverse topics, such as occupational safety, technology management, and innovative applications of industrial engineering principles. He has been recognized with awards for his contributions to research and education, including Best Paper awards and accolades as a top presenter. A member of several professional organizations, including the National Research Council of the Philippines and the Philippine Institute of Industrial Engineers, Dr. Cacho continues to foster innovation and collaboration within the academic and industrial engineering communities.