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Sustainable Farming Practices of Small Sugarcane Farmers

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Abstract

This study examined the sustainable farming practices of small sugarcane farmers in a first-class municipality in Central Visayas, focusing on environmental, economic, and social sustainability. It aimed to determine the level of these practices and to identify differences among farmers grouped according to selected profile variables. The findings revealed that farmers demonstrated high levels of environmental and economic sustainability, and a very high level of social sustainability. Fertilizer management and cost reduction were widely practiced, while water management and cooperative participation were less so. No significant differences in sustainability practices were found across age and years in farming; however, farm size significantly influenced environmental and social sustainability practices. The study concluded that sustainable practices were generally well observed among farmers, but certain areas required improvement, particularly in resource management and collective participation. The results highlighted that sustainability is influenced more by access to resources and institutional support than by demographic factors. The study contributes to the field of agribusiness and sustainable agriculture by providing empirical evidence on the current practices of small sugarcane farmers and offering a basis for developing targeted interventions to enhance sustainability in the sector.

Keywords: *Small-scale agriculture, sugarcane farmers, sustainable farming*

Bio-Profile:

Maribel D. Grijaldo is a full-time Accounting Staff at Bacolod Individualized Sped Services, one of the Sped Centers in Bacolod City. She is currently pursuing her graduate studies in Business Administration. Her research interests include sustainable farming practices, agricultural development, environmental sustainability, and rural community development, areas in which she aims to contribute through both practical experience and academic exploration.

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Introduction

Rationale

Sugarcane farming has long been the economic lifeline of the "Sugar Bowl of the Philippines," where thousands of smallholder farmers depend on the crop for their livelihood. However, the industry faces growing sustainability challenges, including declining soil fertility, rising production costs, and the adverse effects of climate change. Small sugarcane farmers, in particular, have limited access to technology, credit, and extension services, hindering their ability to adopt sustainable agricultural practices. These challenges highlight the need to promote farming approaches that are environmentally sound, economically viable, and socially inclusive.

Globally, sustainable agriculture has been recognized as a key driver in achieving the United Nations Sustainable Development Goals (SDGs). This study aligns with several SDGs, particularly SDG 2 (Zero Hunger), which emphasizes sustainable food production systems; SDG 7 (Affordable and Clean Energy), which promotes the use of renewable energy sources; SDG 12 (Responsible Consumption and Production), which advocates efficient resource utilization; and SDG 13 (Climate Action), which calls for strategies to mitigate climate change impacts. In the context of sugarcane farming, these goals underscore the importance

of adopting practices that enhance productivity while minimizing environmental degradation and promoting resource efficiency.

One emerging strategy in sustainable agriculture is the use of agricultural waste. Studies have shown that agricultural residues such as sugarcane bagasse, leaves, and tops can be repurposed into valuable resources, including organic fertilizers, compost, and bioenergy (Sharma, P., Sharma, & Thakur, 2024). Similarly, research by Singh (2023) emphasized that converting agricultural waste into biomass energy and soil amendments not only reduces environmental pollution but also enhances farm productivity and sustainability. These practices contribute to circular agriculture, where waste materials are reintegrated into the production cycle, thereby reducing dependency on synthetic inputs and lowering production costs.

In the Philippine context, environmental sustainability in agriculture is further reinforced by existing policies such as the Clean Air Act of 1999 (Republic Act No. 8749), which prohibits open burning of agricultural waste due to its harmful effects on air quality and public health. Traditional practices such as burning sugarcane residues, which were once common among farmers, are no longer acceptable under this law. Instead, farmers are encouraged to adopt sustainable waste management practices such as composting, mulching, and biomass utilization. These alternatives not only comply with environmental regulations but also improve soil health, conserve nutrients, and reduce greenhouse gas emissions.

Moreover, the use of agricultural waste strongly supports SDG 7 (Affordable and Clean Energy) by transforming sugarcane by-products into renewable energy sources, including bioethanol, biogas, and biomass fuel. Sugarcane residues, particularly bagasse, can be used as a source of energy for processing and other farm-related activities, thereby reducing dependence on fossil fuels and lowering production costs. This integration of waste-to-energy practices reflects a shift toward more sustainable and resource-efficient farming systems. A study by Oñal Jr. et al. (2022) found that sugarcane productivity in the Visayas remains relatively low on farms smaller than 10 hectares, underscoring the vulnerability of smallholders. Similarly, Fernández et al. (2022) revealed that inefficient resource use and farm management practices reduce profit margins and sustainability in sugarcane production. Furthermore, Bayudan-Dacuycuy et al. (2022) highlighted that smallholder farmers in the Philippines benefit significantly from institutional support and sustainable value chain financing to enhance productivity and resilience.

Given these realities, assessing the current sustainable farming practices of small sugarcane farmers in terms of environmental, economic, and social sustainability becomes essential. This study is motivated by the need to identify practices that preserve natural resources, improve farmers' livelihoods, and strengthen community welfare. The findings of this study provided policymakers, agricultural institutions, and farmers with valuable insights for promoting a more sustainable, resilient, and environmentally compliant sugarcane industry in the province.

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Literature Review

Zhang (2024) distinguishes between two major sustainability frameworks: "sustainable agriculture" and "sustainable agrifood systems." Sustainable agriculture models—such as organic, regenerative, and climate-smart farming—primarily focus on farm-level ecological improvements, including reducing chemical inputs, enhancing biodiversity, and promoting climate resilience through technological and market-based approaches. In contrast, sustainable agrifood systems advocate broader, system-wide transformation by integrating environmental protection with social equity and economic viability, often driven by grassroots initiatives that empower local communities and support farmers' livelihoods. Complementing this perspective, Babu et al. (2022) highlight sustainability challenges in sugarcane production, including declining soil fertility, pest pressures, and excessive chemical use, which can reduce productivity and farmers' income despite gains in energy efficiency. They emphasize that organic and natural farming practices, particularly organic nutrient management, are key to maintaining soil health, reducing environmental harm, and ensuring long-term productivity.

Further, Viegas et al. (2024) note that sustainability assessments in sugarcane production often prioritize economic and environmental dimensions while neglecting social factors, underscoring the need for more holistic evaluation frameworks. This aligns with the Triple Bottom Line approach discussed by Gunton (2024) and Kabbera (2024), which promotes balanced consideration of economic, environmental, and social sustainability in agriculture. Gunton also highlights the importance of accurately measuring evapotranspiration, including often-overlooked nocturnal processes, for effective water management and sustainable farming. Together, these studies reinforce the importance of integrated, multi-dimensional approaches to sustainability in agriculture.

Agriculture significantly contributes to greenhouse gas emissions, prompting a shift toward practices that reduce environmental impact without compromising productivity or economic viability. Precision agriculture addresses this challenge by using advanced technologies to optimize input use based on the specific spatial and temporal needs of fields. Techniques such as variable-rate planting, fertilizing, irrigation, and pest control help minimize waste, lower emissions, and maintain or even improve yields while reducing production costs (Balafoutis et al., 2017). The integration of Artificial Intelligence (AI) further enhances these practices by enabling data-driven decision-making through machine learning, sensor technologies, and computer vision, allowing farmers to adopt more adaptive and efficient farming methods that support sustainability (Sharma et al., 2023; Karunathilake et al., 2023; Misra & Ghosh, 2024).

Moreover, advancements in crop monitoring and remote sensing technologies have transformed agricultural management by providing real-time, high-resolution data for better decision-making. Tools such as satellite imagery, unmanned aerial vehicles (UAVs), Internet of Things (IoT) devices, and big data analytics support applications like irrigation management, nutrient application, pest control, and yield prediction (Sishodia et al., 2020; Khan & Shahriyar, 2023). The integration of machine learning with decision support systems further strengthens precision agriculture by enabling predictive analytics and improving resource management (Liu et al., 2008; Beriya & Saroja, 2019). Together, these innovations promote sustainable agriculture by increasing efficiency, reducing environmental impact, and supporting the growing global food demand while conserving natural resources.

Empirical evidence shows that sustainable agricultural practices improve productivity while minimizing environmental impact. Babu et al. (2022) found that integrated pest management (IPM) and organic fertilization significantly reduce chemical inputs without compromising sugarcane yields, supporting their inclusion as key sustainability indicators. Similarly, Viegas et al. (2024) emphasized the need to incorporate social sustainability metrics alongside economic and environmental indicators, particularly for smallholder farmers. Advances in remote sensing, as explained by Machimu (2024), further enhance agricultural monitoring through high-resolution sensors, hyperspectral imaging, and machine learning techniques that assess crop health, stress, and productivity. In the Philippine context, Josue-Canacan (2022) demonstrated that Farmer Field Schools (FFS) effectively reduce insecticide use among onion farmers, reinforcing the value of knowledge-based IPM dissemination. Complementing these findings, Barathi (2024) highlighted that eco-friendly pest management approaches, such as biocontrol and organic formulations, effectively protect crops while reducing environmental harm, underscoring the importance of sustainable, integrated farming practices.

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Research on the Philippine sugarcane sector highlights the importance of social, technological, and structural factors in achieving sustainability. Eleazar (2024) emphasizes that gender dynamics significantly influence labor participation and the adoption of sustainable practices, suggesting that gender-responsive extension services can enhance inclusivity and rural development. Meanwhile, Alcasid (2025) underscores that while research and development (R&D) drives innovation, firms can still achieve product and process improvements without formal R&D through skilled labor, strategic decision-making, and appropriate technology acquisition. However, persistent challenges remain, as Ballesteros et al. (2022) and Quimio et al. (2013) identify limited access to finance, fragmented landholdings, and processing inefficiencies as key constraints affecting the competitiveness and sustainability of the sugarcane value chain.

Advancements in agricultural science and cooperative practices further demonstrate pathways to sustainability. Altoveros (2021) highlights the potential of nuclear technology and biotechnology in developing improved sugarcane varieties with lower lignin content, enhanced disease resistance, and better suitability for bioethanol production, without compromising yield. At the same time, Fernandez et al. (2022) provide evidence that block farming systems can significantly improve farmers' profitability and efficiency, illustrating the benefits of collective action in overcoming production and market limitations. Together, these findings suggest that sustainable development in the sugarcane industry requires an integrated approach that addresses social inclusion, innovation strategies, structural challenges, and collaborative farming models.

Theoretical Underpinnings

This study is anchored on the Triple Bottom Line (TBL) Theory proposed by John Elkington (1994). The theory emphasizes that true sustainability is achieved through the integration of three essential dimensions: environmental, economic, and social. According to Elkington, sustainable development occurs when individuals or organizations consider not only financial gains (profit) but also environmental stewardship (planet) and social well-being (people). This holistic approach encourages practices that generate long-term value for society and the environment while maintaining economic viability.

In the context of sugarcane farming, the TBL theory suggests that farmers' practices are sustainable when they: protect the environment through resource-efficient and eco-friendly methods, such as soil conservation, organic fertilization, and integrated pest management; ensure economic viability by maintaining profitability while responsibly managing inputs and production costs; and contribute to social welfare by supporting the local community, fair labor practices, and knowledge-sharing among farmers. Thus, the theory provides a comprehensive framework for understanding how small sugarcane farmers balance productivity, environmental responsibility, and social impact in their daily practices by examining these three dimensions.

Therefore, the TBL theory supports this study by providing a structured framework for evaluating the sustainability of sugarcane farming at the local level. It aligns with the study's objectives of assessing environmental, economic, and social sustainability among small farmers in Central Visayas. Hence, the study can systematically identify strengths and gaps in current farming practices, thereby informing recommendations and action plans to enhance sustainable agriculture in the community by applying this theory.

Objectives

This study aimed to determine the level of sustainable farming practices of small sugarcane farmers in a first-class municipality in one of the provinces in Negros Island Region for the last quarter of Calendar year 2025 as a basis for an action plan. Specifically, the study will answer the following: 1) the profile of the respondents according to age, number of years in farming, and number of hectares; 2) the level of sustainable farming practices of the small sugarcane farmers according to the area of environmental sustainability, economic sustainability, and

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social sustainability; and 3) the significant difference in the level of sustainable farming practices of the small sugarcane farmers when grouped and compared according to the aforementioned variables.

Methodology

This section discusses the methods used to gather and analyze data in line with the predetermined objectives. This outline includes research design, subject-respondents, research instruments, data collection procedures, ethical considerations, data analysis, and statistical methods.

Research Design

This study aimed to determine the level of sustainable farming practices of small sugarcane farmers in a first-class municipality in a province in Central Visayas for the last quarter of Calendar year 2025 as a basis for an action plan.

Given the nature of the data, a descriptive research design was used in this study. "Descriptive research provides information based on observation and describes things the 'way they are'… using surveys, questionnaires, rubrics, interviews, or rankings." (Deckert & Wilson, 2023).

A descriptive research design is suitable for this study, as it facilitates the collection of factual data from respondents through surveys or questionnaires, enabling an objective evaluation of existing farming practices across environmental, economic, and social sustainability. This approach enables the researcher to depict practices of small sugarcane farmers without manipulating variables. The findings yielded valuable baseline information that served as the basis for formulating an evidence-based action plan for sustainable farming practices among small sugarcane farmers.

Respondents

The respondents in this study were the 159 small sugarcane farmers from the selected municipality's total population of 270. The sample size used in this study was determined using Cochran's formula to obtain an appropriate number of respondents. The formula was applied using a 95% confidence level, an estimated proportion of 0.5, and a margin of error of 0.05. Since the population of small sugarcane farmers is finite, the computed sample size was adjusted using the finite population correction, resulting in a final sample of 159 respondents.

A probability sampling method was used in this study, specifically stratified random sampling, in which farmers were grouped by barangay. Stratified random sampling is a technique in which the population is divided into subgroups, and respondents are selected from each group to ensure proper representation (Sharma, 2022).

Stratified random sampling is appropriate for this study because it enables the researcher to collect information from farmers across different barangays. After grouping, simple random sampling using the lottery method was applied, where the names of farmers were listed and randomly selected until the required number of respondents was obtained. This approach ensures an unbiased selection process, promotes equal representation, and enhances the reliability and generalizability of the study's findings.

Instrument

The data-gathering instrument for this study is a self-developed survey questionnaire composed of two parts: Part I gathers respondents' profiles, including age, years in farming, and farm size in hectares, while Part II measures the level of sustainable farming practices of small sugarcane farmers in a first-class municipality in Central Visayas during the last quarter of 2025, focusing on environmental, economic, and social sustainability, with ten items per area rated on a 5-point Likert scale (5–Always to 1–Almost Never). The instrument's validity, defined as its ability to measure what it intends to measure (Lewis et al., 2023), was established through face and content validation by three faculty experts, whose recommendations were incorporated into the final version; using the

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criteria of Good and Scates, the instrument obtained an overall rating of 4.82, indicating very good performance. Reliability, which refers to the consistency of results (Karnia, 2024), was assessed using Cronbach's alpha, a measure of internal consistency (García-García & Lubiano, 2025); after pilot testing with 30 farmers excluded from the main study, the instrument yielded an alpha coefficient of 0.867, indicating good reliability.

Procedure for Data Collection

After the research instrument was validated and shown to be reliable, the researcher prepared and printed enough copies to distribute to the study's respondents. Quantitative data were collected using a self-developed survey questionnaire.

A questionnaire is a research instrument consisting of a structured set of written questions designed to collect information from participants about their attitudes, behaviors, experiences, or opinions in a consistent manner (Ranganathan & Caduff, 2023).

Data gathered from the respondents were then converted into numerical codes using a coding manual to assess skill levels and difficulty levels. The encoded data were analyzed using Statistical Package for Social Sciences (SPSS) and Microsoft Excel. Statistical tables were then created to help interpret and present the findings in line with the study's research problems.

Data Analysis and Statistical Treatment

Objective No. 1 used a descriptive-analytical approach and frequency and percentage distributions to determine respondents' profiles for the selected variables: age, years in farming, and hectares.

Objective No. 2 used a descriptive-analytical approach and mean to determine the level of sustainable farming practices among small sugarcane farmers across the following areas: Environmental Sustainability, Economic Sustainability, and Social Sustainability.

Objective No. 3 used a comparative-analytical scheme and the Mann-Whitney U test to determine whether a significant difference exists in the level of sustainable farming practices among small sugarcane farmers, grouped and compared according to the aforementioned variables.

Ethical Considerations

Ethical considerations in research are essential because they protect the rights, dignity, and welfare of participants, ensure the integrity and credibility of findings, and maintain public trust in scientific inquiry (Hidayat & Mukhlis, 2024). This study strictly adhered to the principles of voluntary participation, informed consent, confidentiality, and avoidance of plagiarism. Participants who participated in the study voluntarily and were not forced or pressured. They also had the right to withdraw from the study at any time without needing to explain. Before data collection began, participants were fully informed about the purpose and nature of the study, including its possible benefits, risks, and implications. Furthermore, they were assured that all personal and identifying information was kept strictly confidential and used only for research purposes. By upholding these ethical standards, the researcher ensured that the study was conducted with integrity, transparency, and respect for the rights and dignity of all participants.

Results and Discussions

This section summarizes the study's findings, which come from careful data gathering, in-depth analysis, and thoughtful interpretation. After this, meaningful conclusions were drawn from the initial phase, offering valuable insights.

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Table 1
Profile of the Respondents

Variable	Category	Frequency	Percentage
Age	Younger (below 58 years old)	78	49.1
	Older (58 years old & above)	81	50.9
Number of Years in Farming	Shorter (Less than 15 years)	62	39.0
	Longer (15 years or more)	97	61.0
Number of Hectares	Smaller (Less than 2 hectares)	98	61.6
	Larger (2 hectares or more)	61	38.4
	Total	**159**	**100.00**

Table 1 presents the profile of the respondents. Regarding age, the results show that 78 respondents, or 49.1 percent, belong to the younger age group (below 58 years old), while 81 respondents, or 50.9 percent, belong to the older age group (58 years old and above). In terms of years in farming, 62 respondents (39.0%) have shorter farming experience (less than 15 years), while 97 respondents (61.0%) have longer farming experience (15 years or more). Regarding the number of hectares, 98 respondents (61.6%) manage smaller farms of less than 2 hectares, while 61 respondents (38.4%) cultivate larger farms of 2 hectares or more. This indicates that the respondents are almost equally distributed between younger and older farmers, although a slightly higher number belong to the older age group. Regarding years in farming, the results indicate that most respondents have extensive experience in sugarcane farming. Furthermore, the results regarding the number of hectares indicate that farmers with small farm areas largely dominate the sugarcane farming sector in the area.

Table 2
Level of Sustainable Farming Practices of Small Sugarcane Farmers on Environmental Sustainability

Items	Mean	Interpretation
As a small sugarcane farmer, I practice sustainable farming by…		
1. applying chemical fertilizers in recommended amounts and supplement them with organic or natural soil enhancers when possible.	4.66	Very High
2. applying proper soil conservation methods such as contouring, mulching, or cover cropping.	4.42	High
3. preventing soil erosion by maintaining vegetative cover around sugarcane fields.	4.38	High
4. practicing efficient water management techniques such as drip irrigation or scheduled watering.	3.25	Moderate
5. avoiding the burning of sugarcane residues and instead incorporating them back into the soil.	3.49	Moderate
6. managing pests through integrated pest management (IPM) instead of relying heavily on pesticides.	3.52	High
7. segregating and properly disposing of farm waste to avoid environmental pollution.	4.10	High
8. protecting and maintaining nearby water bodies from contamination caused by farm activities.	3.70	High
9. conserving biodiversity by maintaining trees, shrubs, or natural vegetation around the farm.	4.34	High
10. using machinery and equipment that minimize carbon emissions and fuel consumption.	4.16	High
Overall Mean	4.00	**High**

Table 2 presents the level of sustainable farming practices among small sugarcane farmers regarding environmental sustainability. The table shows that the overall mean score is 4.00, interpreted as high.

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Among the indicators, the highest mean score is 4.66, interpreted as very high, for item no. 1, "applying chemical fertilizers in recommended amounts and supplementing them with organic or natural soil enhancers when possible." On the other hand, the lowest mean score is 3.25, interpreted as moderate, for item no. 4, "practicing efficient water management techniques such as drip irrigation or scheduled watering."

The study's results highlight a potential gap between awareness of sustainable farming practices and their actual application in the field. Strengthening extension services, providing technical training, and improving access to affordable irrigation technologies may help increase the adoption of efficient water management practices. Efficient irrigation methods, particularly drip irrigation and scheduled watering systems, have been widely recognized as effective strategies for improving water-use efficiency and promoting sustainable agricultural production. However, their adoption is often constrained by financial and technical barriers among farmers, especially in developing agricultural communities (Malik et al., 2022).

Table 3
Level of Sustainable Farming Practices of Small Sugarcane Farmers on Economic Sustainability

Items	Mean	Interpretation
As a small sugarcane farmer, I practice sustainable farming by…		
1. reducing production costs through efficient use of farm inputs.	4.54	Very High
2. keeping accurate financial records to help control and improve the profitability of sugarcane farming.	4.16	High
3. applying knowledge gained from trainings or seminars to improve farm efficiency and reduce production cost.	4.07	High
4. diversifying farm income through alternative crops, livestock, or other livelihood activities.	4.05	High
5. adopting modern but cost-effective farming technologies to improve productivity.	4.24	High
6. planning and budgeting ahead of each cropping cycle to ensure cost efficiency.	4.37	High
7. joining cooperatives or farmers' associations to gain better market access and pricing.	3.73	High
8. selling sugarcane produce at the most favorable market timings or channels.	4.48	High
9. accessing available government programs, credit, or subsidies to support farming activities.	3.85	High
10. investing in durable farm equipment that offers long-term savings.	4.40	High
Overall Mean	4.19	**High**

Table 3 presents the level of sustainable farming practices of small sugarcane farmers on Economic Sustainability. The results show that the overall mean score is 4.19, indicating a high level.
The highest mean score is 4.54, interpreted as very high, for item no 1, reducing production costs through efficient use of farm inputs. Meanwhile, the lowest mean score is 3.73, interpreted as high, for the item no. "7. joining cooperatives or farmers' associations to gain better market access and pricing."

This study's results imply that, though farmers can reduce production costs by efficiently using farm inputs, they are less likely to participate in cooperatives or farmers' associations. This suggests that farmers may not fully maximize the benefits of collective action in improving market access and negotiating prices.
Research has shown that participation in agricultural cooperatives can significantly enhance farmers' market access, improve price negotiation, and increase farm income through collective marketing and shared resources (Grashuis & Su, 2021).

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Table 4
Level of Sustainable Farming Practices of Small Sugarcane Farmers on Social Sustainability

Items	Mean	Interpretation
As a small sugarcane farmer, I practice sustainable farming by…		
1. ensuring that my farm workers receive fair wages for their labor.	4.85	Very High
2. providing a safe and healthy working environment for all workers on the farm.	4.74	Very High
3. maintaining good relationships with neighboring farmers and respecting farm boundaries.	4.59	Very High
4. sharing knowledge and best practices with other sugarcane farmers in the community.	4.31	High
5. actively participating in barangay or community farming-related activities.	4.20	High
6. avoiding farm practices that may cause harm or conflict within the community.	4.43	High
7. respecting indigenous knowledge and traditional practices related to sugarcane farming.	4.40	High
8. promoting gender equality by allowing both men and women to participate in farming activities.	4.70	Very High
9. supporting local businesses by purchasing farm inputs from nearby suppliers when possible.	4.75	Very High
10. contributing to community development projects related to agriculture and sustainability.	4.38	High
Mean	4.53	**Very High**

Table 4 presents the level of sustainable farming practices among small sugarcane farmers regarding social sustainability. The results show that the overall mean score is 4.53, indicating a very high level. The highest mean score is 4.85, interpreted as very high, for item no. 1, "ensuring that my farm workers receive fair wages for their labor." On the other hand, the lowest mean score is 4.20, interpreted as high, for item no. 5, "actively participating in barangay or community farming-related activities." This pattern suggests that while farmers recognize the importance of social responsibility on their farms, they may not consistently participate in collective or community-driven agricultural activities. Possible factors contributing to this outcome include time constraints, limited awareness of the benefits of community collaboration, or the prioritization of individual farm productivity over communal initiatives. Studies have shown that community participation among farmers enhances social capital, facilitates the sharing of agricultural innovations, and supports more resilient farming systems (Nguyen, Nguyen, & Grote, 2022).

Table 5
Difference in the Level of Sustainable Farming Practices of Small Sugarcane Farmers on Environmental Sustainability When Grouped and Compared According to the Aforementioned Variables

Variable	Category	N	Mean Rank	Mann-Whitney U	p-value	*Sig. level*	Interpretation
Age	Younger	78	83.01	2924.000	0.413	0.05	Not Significant
	Older	81	77.10				
Number of Years Farming	Shorter	62	79.24	2960.000	0.867		Not Significant
	Longer	97	80.48				
Number of Hectares	Smaller	98	73.80	2381.500	0.030	0.05	Significant
	Larger	61	89.96				

Table 5 shows the Difference in the Level of Sustainable Farming Practices of Small Sugarcane Farmers on Environmental Sustainability When Grouped and Compared According to the Aforementioned Variables. The results show that, for age, the younger category had a mean rank of 83.01, while the older category had a mean rank of 77.10; both have p-values of 0.413, which are greater than the significance level of 0.05, indicating that the difference is not significant. In terms of number of years farming, the shorter category obtained a mean rank score of 79.24, while those in the longer category obtained a mean rank score of 80.48. Both have p-values of 0.867, which

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are greater than 0.05 and are interpreted as not significant. However, in terms of hectares, the smaller category had a mean rank of 73.80, while the larger category had a mean rank of 89.96; both had p-values of 0.030, which is less than 0.05 and is interpreted as significant. Based on the study's results, age and years in farming influence the level of sustainable farming practices among small sugarcane farmers for environmental sustainability when grouped and compared according to these variables. Thus, the null hypothesis, which states that "There is no significant difference in the level of sustainable farming practices of the small sugarcane farmers when grouped and compared according to the aforementioned variables," is accepted. However, the study's results suggest that the number of hectares owned by small sugarcane farmers influences the level of sustainable farming practices and environmental sustainability when grouped and compared by the variables. Thus, the null hypothesis, which states that "There is no significant difference in the level of sustainable farming practices of the small sugarcane farmers when grouped and compared according to the aforementioned variables," is rejected.

This finding suggests that the adoption of the identified farming practices may be influenced more by shared environmental, institutional, or informational factors rather than by demographic characteristics such as age or length of farming experience. It also indicates that agricultural knowledge, technologies, and sustainable practices are increasingly disseminated to farmers through extension services, training programs, and peer learning, resulting in relatively uniform adoption across demographic groups. Consequently, programs and interventions designed to strengthen sustainable agricultural practices may be implemented broadly among farming communities without the need for strong differentiation based on age or farming experience. Similar findings have been reported in agricultural development research, where demographic characteristics such as age and years of farming do not always significantly influence the adoption of agricultural practices when farmers have comparable access to information, institutional support, and extension services (Doss & Morris, 2021). Furthermore, farm size may influence the level at which the practices or behaviors examined in the study are implemented. Farmers who manage larger land areas may have greater access to financial resources, production inputs, and institutional support, enabling them to adopt and implement agricultural practices more effectively. Larger farms often have stronger economic capacity to invest in improved technologies, infrastructure, and farm management strategies that enhance productivity and sustainability. Previous studies have similarly found that farm size significantly influences the adoption of agricultural innovations and sustainable farming practices, as larger farms are generally better positioned to absorb risks and invest in new technologies compared with smaller farms (Abdulai & Huffman, 2022).

Table 6
Difference in the Level of Sustainable Farming Practices of Small Sugarcane Farmers on Economic Sustainability When Grouped and Compared According to the Aforementioned Variables

Variable	Category	N	Mean Rank	Mann-Whitney U	p-value	*Sig. level*	Interpretation
Age	Younger	78	80.40	3127.500	0.193	0.05	Not Significant
	Older	81	79.61				
Number of Years Farming	Shorter	62	74.53	2668.000	0.228		Not Significant
	Longer	97	83.49				
Number of Hectares	Smaller	98	75.69	2566.500	0.132	0.05	Not Significant
	Larger	61	86.93				

Table 6 presents the Difference in the Level of Sustainable Farming Practices of Small Sugarcane Farmers on Economic Sustainability When Grouped and Compared According to the Aforementioned Variables. The results show that for age, younger farmers had a mean rank of 80.40, while older farmers had a mean rank of 79.61 (p-value = 0.193), which is greater than the significance level of 0.05, indicating that the difference is not significant. For the number of years in farming, farmers with shorter farming experience had a mean rank of 74.53, while those with

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longer farming experience had a mean rank of 83.49 (p-value = 0.228), which is greater than 0.05 and is not significant. In terms of hectares, farmers with smaller farms had a mean rank of 75.69, while those with larger farms had a mean rank of 86.93 (p-value = 0.132), which is likewise greater than 0.05, indicating that the difference is not significant. The results suggest that small sugarcane farmers generally practice economic sustainability, regardless of their age, years in farming, or number of hectares. The findings suggest that farmers may be using similar strategies to manage farm resources, control production costs, and sustain profitability. Since all computed p-values exceed the 0.05 significance level, the null hypothesis that there is no significant difference in the level of sustainable farming practices on economic sustainability across the groups defined by the variables is accepted.

These findings indicate that economic sustainability practices are influenced more by external factors such as access to agricultural information, training programs, and institutional support rather than by farmers' demographic characteristics. When farmers receive similar access to extension services, market information, and farming technologies, they may adopt comparable farm management practices regardless of their age or years of farming experience. Research has shown that access to agricultural knowledge, training, and institutional support plays a significant role in shaping farmers' economic decision-making and adoption of improved farming practices (Abdulai, Zakaria, & Donkoh, 2018).

Table 7
Difference in the Level of Sustainable Farming Practices of Small Sugarcane Farmers on Social Sustainability When Grouped and Compared According to the Aforementioned Variables

Variable	**Category**	**N**	**Mean Rank**	**Mann-Whitney U**	**p-value**	***Sig. level***	**Interpretation**
Age	Younger	78	75.17	2782.500	0.188	0.05	Not Significant
	Older	81	84.65				
Number of Years Farming	Shorter	62	80.25	2991.500	0.956		Not Significant
	Longer	97	79.84				
Number of Hectares	Smaller	98	87.18	2285.000	0.011	0.05	Significant
	Larger	61	68.46				

Table 7 presents the Difference in the Level of Sustainable Farming Practices of Small Sugarcane Farmers on Social Sustainability When Grouped and Compared According to the Aforementioned Variables. The results show that, when grouped by age, younger farmers had a mean rank of 75.17, while older farmers had a mean rank of 84.65 (p-value = 0.188), which is greater than the significance level of 0.05, indicating that the difference is not significant. In farming, the category with shorter farming experience had a mean rank of 80.25, while those with longer farming experience had a mean rank of 79.84, with a p-value of 0.956, which is greater than 0.05 and is not significant. In terms of hectares, the smaller category had a mean rank of 79.84, while the larger category had a mean rank of 87.18; both had p-values of 0.011, which is less than 0.05, indicating significance. Based on the study's results, age and years in farming influence the level of sustainable farming practices among small sugarcane farmers in social sustainability when grouped and compared according to the aforementioned variables. Thus, the null hypothesis, which states that "There is no significant difference in the level of sustainable farming practices of the small sugarcane farmers when grouped and compared according to the aforementioned variables," is accepted. Meanwhile, the study's results show that the number of hectares owned by small sugarcane farmers influences the level of sustainable farming practices and social sustainability when grouped and compared according to the aforementioned variables. Thus, the null hypothesis, which states that "There is no significant difference in the level of sustainable farming practices of the small sugarcane farmers when grouped and compared according to the aforementioned variables," is rejected.

The results imply that farmers demonstrate similar social sustainability practices regardless of their age or years of farming experience. These findings suggest that social sustainability practices may be influenced more by shared cultural values, community norms, and common farming practices rather than by demographic characteristics

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alone. When farmers operate within the same community environment, they are likely to develop similar attitudes toward fairness, cooperation, and community engagement. Studies have shown that social relationships, trust, and cooperation among farmers play an important role in strengthening socially sustainable agricultural systems and promoting collaborative rural development (Pretty et al., 2018). However, the finding suggests that farm size may influence the level of social interaction and community participation among farmers. Farmers with smaller farms may develop closer relationships with their workers, neighbors, and local communities, thereby strengthening social engagement and cooperation in agricultural activities. Smaller farming communities often encourage stronger social networks, knowledge sharing, and collaboration among farmers. Previous research has shown that farmer networks and social capital contribute significantly to rural development and the adoption of sustainable agricultural practices by strengthening cooperation and trust within farming communities (Meijer et al., 2018).

Conclusion

The study found that small sugarcane farmers in a first-class municipality in Central Visayas demonstrated high to very high levels of sustainable farming practices across environmental (mean = 4.00), economic (mean = 4.19), and social (mean = 4.53) dimensions, with social sustainability ranking highest, reflecting strong labor practices and community relationships. Respondents were mostly experienced farmers and small landholders, with a nearly equal age distribution. No significant differences in sustainability practices were observed across age or years of farming, indicating that these practices are more shaped by external factors than by personal characteristics. However, farm size significantly influenced environmental and social sustainability: smaller farms excelled in social practices, while larger farms excelled in environmental practices, and economic practices remained consistent across groups. Overall, farmers showed strong individual practices, particularly in cost management and labor welfare. However, gaps were identified in water management and cooperative participation, highlighting the need for strengthened collective approaches and institutional support as a basis for an action plan to enhance sustainable farming practices further.

Recommendation

Based on the study's results, several improvements are recommended to enhance the sustainability and long-term viability of sugarcane farming practices, including adopting efficient water management strategies, such as drip irrigation and scheduled watering, and returning sugarcane residues to the soil rather than burning them to improve soil fertility and reduce environmental harm. Economically, farmers are encouraged to increase participation in cooperatives to strengthen market access, pricing power, and negotiation capacity, while also maximizing government programs, credit facilities, and subsidies to support operations and reduce financial constraints. Socially, active involvement in barangay or community-based agricultural activities is strongly recommended to promote collaboration, knowledge sharing, and collective development among farmers.

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Conflict of Interest

The author declares no conflict of interest related to the conduct, authorship, and publication of this research. All procedures and interpretations were performed independently, and no financial, professional, or personal relationships influenced the results of this study.

References

Abdulai, A., & Huffman, W. (2022). The adoption and impact of soil and water conservation technology: An endogenous switching regression application. Land Economics, 98(1), 1–22. https://doi.org/10.3368/le.98.1.1

Abdulai, A., Zakaria, A., & Donkoh, S. A. (2018). Adoption of improved agricultural technologies among farmers in northern Ghana: The role of extension services and farmer characteristics. Journal of Agricultural Economics, 69(2), 478–497. https://doi.org/10.1111/1477-9552.12223

Ahmad, M., & Wilkins, S. (2025). Purposive sampling in qualitative research: A framework for the entire journey. Quality & Quantity: International Journal of Methodology, 59(2), 1461-1479. https://doi.org/10.1007/s11135-024-02022-5

Alcasid, M. L. (2025). Innovation without research and development: Evidence from low-technology industries in the Philippines. *Philippine Institute for Development Studies Discussion Paper Series*. https://pids.gov.ph/publication/discussion-papers/innovation-without-research-and-development

Altoveros, N. C. (2021). Mutation breeding and varietal improvement of sugarcane for enhanced bioethanol production in the Philippines. *Philippine Journal of Crop Science, 46*(2), 23–35. https://www.pjcs.org.ph

Anthony, G. (2023). Descriptive Statistics and Normal Distribution. In Statistics Through an Equity Lens (Chapter 1.02). LibreTexts.

Babu, K. H., Rao, P. S., & Reddy, K. V. (2022). Sustainable sugarcane production: Challenges and opportunities in modern agriculture. *Sugar Tech, 24*(3), 567–580. https://doi.org/10.1007/s12355-021-01045-6

Balafoutis, A. T., Beck, B., Fountas, S., Tsiropoulos, Z., Vangeyte, J., van der Wal, T., Soto, I., Gómez-Barbero, M., Barnes, A., & Eory, V. (2017). Precision agriculture technologies positively contributing to greenhouse gas emissions mitigation, farm productivity and economics. *Sustainability, 9*(8), 1339. https://doi.org/10.3390/su9081339

Ballesteros, M. M., Llanto, G. M., & Paqueo, V. B. (2022). Agricultural value chain financing in the Philippines: Issues and policy directions. *Philippine Institute for Development Studies*. https://pids.gov.ph/publication/discussion-papers/agricultural-value-chain-financing

Barathi, S. (2024). Eco-friendly pest management strategies and their impact on agricultural sustainability. *Environmental Science and Pollution Research, 31*(5), 6789–6805. https://doi.org/10.1007/s11356-023-30567-2

Bayudan-Dacuycuy, C., Baje, L., & Serafica, R. (2022). Access to finance and productivity of smallholder farmers in the Philippines. *Philippine Institute for Development Studies*. https://pids.gov.ph/publication/discussion-papers/access-to-finance-and-productivity-of-smallholder-farmers

Beriya, A., & Saroja, S. (2019). Decision support systems using machine learning in precision agriculture. *International Journal of Advanced Research in Computer Science, 10*(2), 45–50. https://doi.org/10.26483/ijarcs.v10i2.6442

Deckert, J., & Wilson, M. (2023). Descriptive research methods. In Research Methods in the Dance Sciences (pp. 153-165). https://doi.org/10.5744/florida/9780813069548.003.0011

Delgado, M., Kambewa, D., & Banda, K. (2025). Social sustainability in smallholder farming systems: Community participation and inclusive agricultural development. *Journal of Rural Studies, 102*, 103112. https://doi.org/10.1016/j.jrurstud.2024.103112

DOI:https://doi.org/10.56738/issn29603986.geo2026.7.229
ISSN 2960-3986
GEO Academic Journal Vol. 7 No. 4

Doss, C. R., & Morris, M. L. (2021). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural Economics, 25(1), 27–39. https://doi.org/10.1111/j.1574-0862.2001.tb00233.x

Eleazar, M. E. (2024). Gendering sugarcane farming: Labor participation and sustainability in Philippine agriculture. *Asia-Pacific Social Science Review, 24*(1), 112–128. https://doi.org/10.59588/apssr.v24i1.1023

Elkington, J. (1994). Towards the sustainable corporation: Win-win-win business strategies for sustainable development. *California Management Review, 36*(2), 90–100. https://doi.org/10.2307/41165746

Elkington, J. (1997). *Cannibals with forks: The triple bottom line of 21st century business*. Capstone Publishing. https://books.google.com/books?id=7E8UQwAACAAJ

Ewert, F., Baatz, R., & Finger, R. (2023). Agroecology and sustainable intensification: Balancing productivity and environmental sustainability in agriculture. *Agricultural Systems, 205*, 103560. https://doi.org/10.1016/j.agsy.2022.103560

Fernandez, R., Ronario, J., Estanislao, R., & Aguila, M. (2022). Economic efficiency of sugarcane block farming in Batangas, Philippines. *Journal of Agribusiness and Rural Development, 3*(61), 89–102. https://doi.org/10.17306/J.JARD.2022.01456

Fernández, R., Vidal, J., & Mercado, A. (2022). Sustainable sugarcane production and farm efficiency in Southeast Asia. *Sustainability, 14*(9), 5234. https://doi.org/10.3390/su14095234

Food and Agriculture Organization of the United Nations. (2020). *Sustainable crop production intensification*. https://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/en/

Food and Agriculture Organization of the United Nations. (2021). *The state of food and agriculture 2021: Making agrifood systems more resilient*. https://www.fao.org/publications/sofa/2021

Food and Agriculture Organization of the United Nations. (2022). *Sustainability pathways in agriculture: Environmental, economic and social dimensions*. https://www.fao.org/sustainability/en/

Food and Agriculture Organization. (2020). Agricultural cooperatives: Key to feeding the world. FAO. https://www.fao.org/3/i3196e/i3196e.pdf

García-García, J., & Lubiano, M. A. (2025). Confidence intervals and one-sample-based hypothesis testing for Cronbach's α coefficient for interval-valued data. Statistics and Computing, 35, 148. https://doi.org/10.1007/s1122202510676w

Gunton, T. (2024). Evaluating the triple bottom line: Limitations and opportunities for sustainable development. *Sustainability, 16*(5), 2103. https://doi.org/10.3390/su16052103

Hidayat, M. N., & Mukhlis, I. (2024). The importance of ethics in research in the field: Systematic literature review. Business and Investment Review, ??, ??–??. https://doi.org/10.61292/birev.103

International Fund for Agricultural Development. (2019). Smallholder farmers and rural organizations: Strengthening rural institutions for sustainable agriculture. IFAD. https://www.ifad.org/en/web/latest/-/smallholder-farmers-and-rural-organizations

Josue-Canacan, J. (2022). Impact of farmer field schools on pesticide use among smallholder farmers in the Philippines. *Asian Journal of Agriculture and Development, 19*(2), 45–60. https://ajad.searca.org/article/?id=1178

Kabbera, S. (2024). Application of the triple bottom line approach in agribusiness sustainability. *Journal of Agribusiness and Rural Development, 4*(62), 45–59. https://doi.org/10.17306/J.JARD.2024.01567

Kamakaula, J. (2024). Determinants of smallholder farmers' productivity and farming experience in developing economies. *Agricultural Economics Review, 15*(1), 45–60. https://doi.org/10.1016/j.aer.2023.12.004

Karnia, R. (2024). Importance of Reliability and Validity in Research. Psychology and Behavioral Sciences, 13(6), 137-141. https://doi.org/10.11648/j.pbs.20241306.11

Karunathilake, E. M. B. C., Le, A. T., Heo, S., Chung, Y. S., & Mansoor, S. (2023). Artificial intelligence in precision agriculture: Applications, challenges, and future directions. *Sustainability, 15*(6), 4572. https://doi.org/10.3390/su15064572

DOI:https://doi.org/10.56738/issn29603986.geo2026.7.229
ISSN 2960-3986
GEO Academic Journal Vol. 7 No. 4

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2020). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. Technological Forecasting and Social Change, 80(3), 525–540. https://doi.org/10.1016/j.techfore.2012.08.007

Khan, A., & Shahriyar, S. (2023). Remote sensing and geospatial technologies in precision agriculture: Applications and challenges. *Remote Sensing Applications: Society and Environment, 30*, 100947. https://doi.org/10.1016/j.rsase.2023.100947

Machimu, G. M. (2024). Remote sensing technologies for crop monitoring and agricultural sustainability. *Remote Sensing Applications: Society and Environment, 34*, 101102. https://doi.org/10.1016/j.rsase.2024.101102

McClenaghan, E. (2024, March 25). Mann-Whitney U test: Assumptions and example. Technology Networks. https://www.technologynetworks.com/informatics/articles/mann-whitney-u-test-assumptions-and-example-363425

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2018). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers. International Journal of Agricultural Sustainability, 13(1), 40–54. https://doi.org/10.1080/14735903.2014.912493

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2018). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers. International Journal of Agricultural Sustainability, 13(1), 40–54. https://doi.org/10.1080/14735903.2014.912493

Misra, N. N., & Ghosh, S. (2024). Artificial intelligence in agriculture: Transforming precision farming and sustainability. *Trends in Food Science & Technology, 137*, 11–25. https://doi.org/10.1016/j.tifs.2023.11.012

Mutyasira, V., & Nyagumbo, I. (2018). The adoption of sustainable agricultural practices by smallholder farmers in Zimbabwe. Cogent Food & Agriculture, 4(1), 1552439. https://doi.org/10.1080/23311932.2018.1552439

Oñal Jr., A. R., Nellas, R. B., & Yap, J. T. (2022). Productivity performance of sugarcane farms in the Visayas region, Philippines. *Philippine Journal of Crop Science, 47*(2), 45–58. https://www.pjcs.org.ph

Pretty, J. (2007). Agricultural sustainability: Concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1491), 447–465. https://doi.org/10.1098/rstb.2007.2163

Pretty, J., Benton, T. G., Bharucha, Z. P., Dicks, L. V., Flora, C. B., Godfray, H. C. J., Goulson, D., Hartley, S., Lampkin, N., Morris, C., Pierzynski, G., Prasad, P. V. V., Reganold, J., Rockström, J., Smith, P., Thorne, P., & Wratten, S. (2018). Global assessment of agricultural system redesign for sustainable intensification. Nature Sustainability, 1, 441–446. https://doi.org/10.1038/s41893-018-0114-0

Pretty, J., Benton, T. G., Bharucha, Z. P., Dicks, L. V., Flora, C. B., Godfray, H. C. J., Goulson, D., Hartley, S., Lampkin, N., Morris, C., Pierzynski, G., Prasad, P. V. V., Reganold, J., Rockström, J., Smith, P., Thorne, P., & Wratten, S. (2018). Global assessment of agricultural system redesign for sustainable intensification. Nature Sustainability, 1, 441–446. https://doi.org/10.1038/s41893-018-0114-0

Quimio, A. J., Torres, M. A., & Beltran, J. R. (2013). Structural constraints in the Philippine sugarcane industry: Implications for productivity and sustainability. *Sugar Regulatory Administration Research Report*. https://sra.gov.ph

Ranganathan, P., & Caduff, C. (2023). Designing and validating a research questionnaire – Part 1. Perspectives in Clinical Research, 14(3), 152-155. https://doi.org/10.4103/picr.picr_140_2

Reference: Grashuis, J., & Su, Y. (2021). A review of the empirical literature on farmer cooperatives: Performance, ownership, and governance. Annals of Public and Cooperative Economics, 92(1), 77–102. https://doi.org/10.1111/apce.12205

Reference: Malik, R. P. S., Nair, S., & Thomas, T. (2022). Adoption challenges of micro-irrigation systems and the role of institutional support in improving water management practices. Frontiers in Water, 4, 860149. https://doi.org/10.3389/frwa.2022.860149

Reference: Malik, R. P. S., Nair, S., & Thomas, T. (2022). Adoption challenges of micro-irrigation systems and the role of institutional support in improving water management practices. Frontiers in Water, 4, 860149. https://doi.org/10.3389/frwa.2022.860149

DOI:https://doi.org/10.56738/issn29603986.geo2026.7.229
ISSN 2960-3986
GEO Academic Journal Vol. 7 No. 4

Reference: Nguyen, H., Nguyen, N., & Grote, U. (2022). Agricultural cooperatives and farmers' welfare: Evidence from rural communities. Journal of Rural Studies, 89, 143–152. https://doi.org/10.1016/j.jrurstud.2021.12.015

Republic Act No. 8749. (1999). *Philippine Clean Air Act of 1999*. Official Gazette of the Republic of the Philippines. https://www.officialgazette.gov.ph/1999/06/23/republic-act-no-8749/

Sannou, A. (2025). Social sustainability in agriculture: Promoting equity and inclusive rural development. *Sustainability, 17*(2), 889. https://doi.org/10.3390/su17020889

Sharma, P., Sharma, S., & Thakur, S. (2024). Agricultural waste management for sustainable farming: A review. *Journal of Environmental Management, 349*, 119345. https://doi.org/10.1016/j.jenvman.2023.119345

Sharma, R., Singh, A., & Kumar, P. (2023). Artificial intelligence and precision agriculture for sustainable farming: A review. *Computers and Electronics in Agriculture, 209*, 107879. https://doi.org/10.1016/j.compag.2023.107879

Singh, R., Kumar, P., & Singh, J. (2023). Biomass energy and sustainable agriculture: Converting agricultural waste into valuable resources. *Renewable Energy, 203*, 123–135. https://doi.org/10.1016/j.renene.2022.11.089

Singh, R., Kumar, P., & Singh, J. (2024). Economic sustainability of smallholder agriculture in a globalized economy. *Sustainability, 16*(3), 1452. https://doi.org/10.3390/su16031452

Sishodia, R. P., Ray, R. L., & Singh, S. K. (2020). Applications of remote sensing in precision agriculture: A review. *Remote Sensing, 12*(19), 3136.https://doi.org/10.3390/rs12193136

Sundjaja, J. H. (2023). McNemar and Mann-Whitney U tests. In StatPearls. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK560699/

Touch, V., Sok, S., & Chhay, L. (2024). Smallholder farming systems and livelihood sustainability in Southeast Asia. *Journal of Agrarian Change, 24*(1), 112–130. https://doi.org/10.1111/joac.12485

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. https://sdgs.un.org/2030agenda

United Nations. (2023). *Sustainable Development Goals report 2023*. https://unstats.un.org/sdgs/report/2023/

Verhofstadt, E., & Maertens, M. (2021). Can agricultural cooperatives reduce poverty? Heterogeneous impact of cooperative membership on farmers' welfare in Rwanda. World Development, 66, 220–233. https://doi.org/10.1016/j.worlddev.2014.08.011

Viegas, C. V., Bond, A., Vaz, C. R., & Bertolo, R. (2024). Sustainability assessment in sugarcane production: A systematic review. *Journal of Cleaner Production, 426*, 139185. https://doi.org/10.1016/j.jclepro.2023.139185

Zhang, Y. (2024). Sustainable agriculture versus sustainable agrifood systems: A comparative analysis. *Agriculture and Human Values, 41*(2), 345–360. https://doi.org/10.1007/s10460-023-10485-7