RESEARCH ARTICLE

Innovating sustainable agriculture: Perspectives from economy and biology professionals

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Abstract: In the realm of agricultural development, the pursuit of sustainability stands as a paramount objective, necessitating an integration of multifaceted expertise from diverse disciplines. Amidst this pursuit, understanding the perspectives of professionals in both the realms of economy and biology becomes imperative, serving as a cornerstone for innovative strategies. This study examines the viewpoints of economy and biology professionals on multidisciplinary innovations for sustainable agricultural development. Through qualitative analysis of interviews and focus groups, the research identifies key themes and challenges. Participants recognise the need for integrating diverse disciplines to address agricultural sustainability, emphasising the importance of economic viability and technological innovation. However, barriers such as high costs and limited access to resources hinder widespread adoption. Policy recommendations include incentivising sustainable practices and fostering collaboration between stakeholders. The results underscore the significance of multidisciplinary approaches in advancing sustainable agriculture, with implications for policy and practice.

Keywords: biology professionals; economy professionals; multidisciplinary innovations; sustainable agriculture

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Introduction

In contemporary discourse surrounding global sustainability, the agricultural sector stands as a pivotal arena where innovation, efficiency, and sustainability converge (Prost et al., 2017; Velten et al., 2015). As humanity grapples with the challenges posed by climate change, population growth, and dwindling natural resources, the imperative for transformative approaches within agricultural economies becomes increasingly urgent. Against this backdrop, the present study embarks on a comprehensive exploration of multidisciplinary innovations aimed at fostering sustainable agricultural economies. The backdrop against which this research unfolds is characterised by a nexus of pressing environmental, economic, and social concerns. Agricultural systems worldwide face mounting pressure to adapt to changing climatic conditions, mitigate environmental degradation, and meet the growing demand for food, fibre, and bioenergy (Bröring et al., 2020; D'Amato et al., 2017). Concurrently, economic considerations loom large, with the need to ensure the viability and resilience of agricultural enterprises amidst fluctuating market dynamics and resource constraints. In light of these challenges, the imperative for interdisciplinary collaboration and innovation emerges as a linchpin for realising sustainable agricultural futures.

At the heart of this discourse lies the recognition that traditional paradigms of agricultural production and management are no longer tenable in the face of contemporary challenges. Conventional approaches characterised by intensive resource extraction, monoculture cropping, and chemical inputs have come under scrutiny for their adverse environmental impacts and limited long-term viability. Consequently, there is a growing impetus to embrace more holistic and regenerative practices that promote ecological integrity, enhance resource efficiency, and foster socio-economic resilience. Within this context, the role of multidisciplinary innovation assumes paramount importance (Naydenov, 2018; Omariba, 2021). By harnessing insights and methodologies from diverse fields such as biology, economics, management, and finance, agricultural stakeholders can develop novel solutions that transcend traditional disciplinary boundaries. This integrative approach not only holds promise for addressing immediate challenges but also paves the way for transformative shifts towards more sustainable and resilient agricultural systems (Snapp & Pound, 2017; Velten et al., 2015).

The need for such multidisciplinary innovation is underscored by the interconnected nature of contemporary challenges facing agricultural economies. Climate change, for instance, poses multifaceted risks to agricultural productivity, exacerbating factors such as water scarcity, soil degradation, and pest outbreaks. In this context, solutions that combine biological insights with economic strategies hold particular promise, offering pathways for adapting to changing climatic conditions while maximising resource efficiency and economic returns. Moreover, the imperative for sustainable agricultural economies extends beyond environmental considerations to encompass broader socio-economic dimensions (Lewandowski, 2018). Rural livelihoods, food security, and social equity are intricately intertwined with the functioning of agricultural systems, highlighting the need for approaches that simultaneously address economic viability and social welfare. Herein lies the potential of multidisciplinary innovations to foster inclusive growth, empower local communities, and enhance the resilience of agricultural livelihoods in the face of global challenges (Snapp & Pound, 2017; Vanloqueren & Baret, 2017).

Against this backdrop, the present study sets out to investigate the perspectives of key stakeholders within the agricultural and biological industries (Chatterjee & Tandon, 2020; Diagne et al., 2021). By focusing on agricultural professionals, applied biological scientists, and economical farmers, the research aims to elucidate the opportunities and challenges associated with multidisciplinary innovation in sustainable agriculture. Through qualitative research methods and descriptive analysis, the study seeks to uncover insights into the drivers, barriers, and implications of adopting innovative approaches within agricultural economies (Anderson et al., 2016). In doing so, this research not only contributes to the academic discourse on sustainable agriculture but also holds practical implications for policymakers, practitioners, and industry stakeholders. By shedding light on the potential synergies between biological sciences, economics, and management, the study seeks to inform decision-making processes and inspire collaborative efforts towards more sustainable and resilient agricultural futures. In summary, the present study addresses a pressing need for multidisciplinary approaches to innovation in agricultural economies (Antràs & Chor, 2022; Judit et al., 2017). By examining the perspectives of agricultural professionals, applied biological scientists, and economical farmers, the research seeks to uncover insights that can inform transformative strategies for sustainable agricultural development. In doing so, the study contributes to the growing body of knowledge on interdisciplinary approaches to addressing complex socio-environmental challenges, thereby advancing both academic scholarship and practical solutions for sustainable development (Lebeničnik & Starčič, 2020).

In the context of this research on multidisciplinary innovations for sustainable agricultural economies, the literature review explores key themes, theories, and empirical results that inform the research objectives. This section critically evaluates a diverse array of literature spanning disciplines such as agriculture, biology, economics, and management, shedding light on the state of knowledge and identifying gaps that warrant further investigation (Abas, 2021). Central to discussions of sustainable agriculture is the concept of agroecology, which emphasises the ecological principles underlying agricultural systems. Drawing on insights from ecology, agroecological approaches seek to enhance the resilience, productivity, and sustainability of agricultural ecosystems while minimising external inputs and environmental impacts (Notohadiprawiro et al., 2022; Velten et al., 2015). By fostering synergies between biological processes and human activities, agroecology offers a holistic framework for addressing the complex challenges facing agricultural economies.

Complementing the ecological dimension of sustainable agriculture is the economic perspective, which underscores the importance of efficient resource allocation, market dynamics, and policy incentives. Neoclassical economic theory provides a theoretical foundation for understanding the behaviour of agricultural markets, the role of incentives in shaping farmer decision-making, and the implications of government intervention in agricultural policy (Notohadiprawiro et al., 2022). However, critics argue that conventional economic models often overlook important ecological and social dimensions, highlighting the need for interdisciplinary approaches that integrate economic and ecological perspectives (Van der Ryn & Cowan, 2013). Within the realm of agricultural management, the literature highlights the role of innovation, entrepreneurship, and adaptive management in fostering sustainable agricultural practices.

Innovations such as precision agriculture, agroforestry, and organic farming hold promise for enhancing productivity while minimising environmental impacts (Board et al., 2014; Clark et al., 2010). Moreover, the adoption of sustainable agricultural practices is influenced by factors such as farmer attitudes, knowledge networks, and institutional support mechanisms. By examining the drivers and barriers to innovation in agricultural management, researchers can identify strategies for promoting the uptake of sustainable practices at the farm level.

In the context of applied biological sciences, research has focused on enhancing crop productivity, resilience, and nutritional quality through genetic improvement, biotechnology, and crop management strategies. Advances in genomics, molecular breeding, and biotic stress tolerance have the potential to revolutionise agricultural production systems, enabling farmers to adapt to changing environmental conditions and pest pressures (Prost et al., 2017; Snapp & Pound, 2017). However, concerns have been raised regarding the social, ethical, and environmental implications of biotechnological innovations, underscoring the need for careful risk assessment and stakeholder engagement. Beyond the technical dimensions of sustainable agriculture, the literature also explores the socio-economic dimensions of agricultural development, including issues of rural livelihoods, food security, and social equity. Smallholder farmers, who constitute the majority of agricultural producers in many developing countries, face numerous challenges related to access to land, markets, and financial resources. Moreover, gender disparities persist within agricultural systems, with women often facing limited access to land, inputs, and decision-making power (Hardy & Woodcock, 2015). Addressing these socio-economic inequalities is essential for achieving inclusive and sustainable agricultural development.

Method

The research employs a qualitative descriptive approach, aiming to capture the nuanced perspectives and experiences of agricultural professionals, applied biological scientists, and economical farmers (Creswell & Clark, 2011; Lee et al., 1999; Padgett, 2016). This methodological choice is grounded in the nature of the research questions, which seek to explore the lived realities and perceptions of these stakeholders regarding multidisciplinary innovations for sustainable agricultural economies (Altieri, 2018; Deguine et al., 2023). The research design is informed by a phenomenological framework, which prioritises the subjective experiences and interpretations of participants. Through in-depth interviews and focus group discussions, the research seeks to elicit rich, detailed narratives that shed light on the complexities of sustainable agricultural practices and innovations (Anderson et al., 2016). Participants are selected using a purposive sampling technique, ensuring representation from diverse backgrounds and experiences within the agricultural and biological industries. The sample size is determined by the principle of saturation, whereby data collection continues until no new themes or insights emerge from the analysis, ensuring the richness and depth of the data collected. Data collection procedures involve semi-structured interviews and focus group discussions conducted with the selected participants (Archibald et al., 2019). These sessions are designed to encourage open-ended discussions and reflections, allowing participants to express their thoughts, opinions, and experiences freely. The researcher adopts a participatory approach, actively engaging with participants to co-create knowledge and meaning throughout the research process (Archibald et al., 2019; Vanloqueren & Baret, 2017).

Interviews and focus group discussions are audio-recorded and transcribed verbatim to ensure accuracy and fidelity to participants' voices. The data analysis process follows a thematic analysis approach, whereby the researcher identifies, codes, and organises patterns and themes within the data. This iterative process involves constant comparison and reflection, allowing for the development of rich, nuanced insights into the research questions. The validity and reliability of the research results are ensured through several strategies (Castleberry & Nolen, 2018; H. Kim et al., 2017). Firstly, the researcher adopts a reflexive stance, acknowledging and addressing their own biases, assumptions, and preconceptions throughout the research process. Secondly, member checking is conducted, whereby participants are invited to review and validate the results, ensuring that their perspectives are accurately represented (Domingues, 2013; Fischer & Miller, 2017). The research method employs a qualitative descriptive approach, leveraging interviews and focus group discussions to explore multidisciplinary innovations for sustainable agricultural economics from the perspectives of agricultural professionals, applied biological scientists, and economical farmers (Barrios et al., 2020). Through a phenomenological lens, the research seeks to uncover the underlying meanings and experiences that shape these stakeholders' perceptions of sustainable agriculture, ultimately contributing to a deeper understanding of the complexities of agricultural sustainability.

Results and Discussion

Several Key Themes

The results of the research reveal several key themes that emerged from the analysis of interviews and

focus group discussions with agricultural professionals, applied biological scientists, and economical farmers. One of the predominant themes is the importance of adopting a multidisciplinary approach to agriculture. Participants highlighted the value of integrating various disciplines, such as biology, economics, and management, to develop innovative and sustainable farming practices. This holistic approach was seen as essential for addressing the complex challenges facing agricultural economies (Table 1).

Table 1. Key themes

Theme	Description	Participants
Multidisciplinary Approach	Participants highlighted the importance of integrating various disciplines in agriculture	90% of participants
Sustainable Practices	Emphasis was placed on the adoption of sustainable farming practices	85% of participants
Economic Viability	The need for economic incentives to promote sustainable agriculture was emphasised	75% of participants
Technological Innovation	Participants expressed interest in technological innovations for agricultural sustainability	70% of participants

The results of the research reveal several key themes that emerged from the analysis of interviews and focus group discussions with agricultural professionals, applied biological scientists, and economical farmers. One of the predominant themes is the importance of adopting a multidisciplinary approach to agriculture. Participants highlighted the value of integrating various disciplines, such as biology, economics, and management, to develop innovative and sustainable farming practices. This holistic approach was seen as essential for addressing the complex challenges facing agricultural economies.

Sustainable practices emerged as another key theme, with participants emphasising the need to adopt environmentally friendly and resource-efficient farming methods. Strategies such as crop rotation, agroforestry, and organic farming were cited as examples of sustainable practices that can enhance soil health, biodiversity, and overall ecosystem resilience. Participants expressed a strong commitment to promoting sustainability in agriculture, recognising it as a key factor in ensuring long-term food security and environmental stewardship.

Economic viability was also a recurring theme in the results, with participants highlighting the importance of economic incentives to encourage the adoption of sustainable farming practices (Small, 2013; "Social Infrastructure Needs: Financing Through Digital Platform," 2019). Many participants noted that while they were committed to sustainability, economic constraints often limited their ability to invest in new technologies or practices. They called for government support, such as subsidies or tax incentives, to help offset the costs of sustainable agriculture and make it more financially viable for farmers. Technological innovation emerged as a key enabler of sustainable agriculture, with participants expressing interest in new technologies such as precision farming, biotechnology, and digital agriculture. These technologies were seen as valuable tools for improving efficiency, reducing resource inputs, and minimising environmental impacts (Jagannathan et al., 2021; S.-K. Kim, 2020). However, participants also noted the importance of ensuring that technological innovations are accessible and affordable for smallholder farmers, who may lack the resources to invest in expensive equipment or technologies.

The results of the research underscore the complex interplay between ecological, economic, and social factors in shaping sustainable agricultural economies. The emphasis on multidisciplinary approaches highlights the need for collaboration and knowledge-sharing across disciplines to develop innovative solutions to agricultural challenges. Sustainable practices are seen as central to achieving environmental sustainability and resilience, while economic viability is crucial for ensuring the adoption and long-term success of sustainable agriculture. Technological innovation offers promising opportunities for enhancing agricultural productivity and sustainability, but must be accompanied by policies and initiatives that promote equitable access and affordability. The results of the research point to a growing recognition among agricultural stakeholders of the importance of sustainability in agriculture. By highlighting the perspectives and experiences of agricultural professionals, applied biological scientists, and economical farmers, this research contributes to a deeper understanding of the challenges and opportunities facing sustainable agricultural economies. It underscores the need for continued research, innovation, and collaboration to ensure the long-term viability and resilience of agricultural systems.

Multidisciplinary Innovations for Sustainable Agricultural Economies

The results regarding multidisciplinary innovations for sustainable agricultural economies reveal a strong interest among participants in adopting innovative technologies and practices (Table 2). Precision agriculture emerged as a widely acknowledged innovation, with 80% of participants recognising its potential to improve resource efficiency and crop yields. Precision agriculture encompasses a range of technologies, such as GPS-guided machinery, drones, and sensors, that enable farmers to precisely monitor and manage their crops, reducing inputs such as water, fertilisers, and pesticides. Agroecology was also highlighted as a promising approach, with 75% of participants expressing interest in adopting agroecological practices. Agroecology focuses on integrating ecological principles into agricultural systems, emphasising the importance of biodiversity, soil health, and ecosystem resilience. Practices such as crop rotation, agroforestry, and integrated pest management are central to agroecological approaches, which aim to enhance sustainability by mimicking natural ecosystems (Altieri, 2018; Vanloqueren & Baret, 2017).

Table 2. Respondents of multidisciplinary innovations

Innovation	Description	Participants
Precision Agriculture	80% of participants acknowledged the benefits of precision agriculture in improving resource efficiency and crop yields	80% of participants
Agroecology	75% of participants expressed interest in adopting agroecological practices for sustainable agriculture	75% of participants
Biotechnology	60% of participants highlighted the potential of biotechnology in enhancing crop resilience and productivity	60% of participants
Digital Agriculture	70% of participants expressed interest in digital agriculture technologies for farm management and decision-making	70% of participants

Biotechnology emerged as another area of interest, with 60% of participants highlighting its potential to enhance crop resilience and productivity. Biotechnological innovations such as genetically modified crops, gene editing, and biofortification offer promising solutions for addressing agricultural challenges such as pests, diseases, and climate change. However, participants also expressed concerns about the social, ethical, and environmental implications of biotechnology, underscoring the need for careful regulation and oversight. Digital agriculture technologies were also seen as valuable tools for improving farm management and decision-making, with 70% of participants expressing interest in adopting such technologies. Digital agriculture encompasses a range of technologies, including farm management software, weather forecasting tools, and remote sensing technologies, that enable farmers to make informed decisions and optimise their operations. These technologies can improve efficiency, reduce waste, and enhance sustainability by providing real-time data and insights.

The results regarding multidisciplinary innovations for sustainable agricultural economies underscore the importance of adopting a holistic approach to agricultural innovation. Precision agriculture, agroecology, biotechnology, and digital agriculture offer promising solutions for enhancing productivity, efficiency, and sustainability in agriculture. However, their adoption requires careful consideration of social, economic, and environmental factors to ensure equitable and sustainable outcomes (Fiksel, 2009; McKinley et al., 2020). Precision agriculture stands out as a particularly promising innovation, offering tangible benefits in terms of resource efficiency and crop yields. By enabling farmers to precisely manage their inputs, precision agriculture can reduce costs, minimise environmental impacts, and improve overall farm profitability. However, its widespread adoption may be hindered by factors such as cost, access to technology, and technical know-how, highlighting the need for supportive policies and initiatives. Agroecology also offers promising solutions for sustainable agriculture, emphasising the importance of working with nature rather than against it. By enhancing biodiversity, soil health, and ecosystem resilience, agroecological practices can improve long-term sustainability and resilience in agricultural systems. However, the adoption of agroecology may require changes in farming practices, knowledge systems, and policy frameworks, which could pose challenges for some farmers. Biotechnology presents both opportunities and challenges for sustainable agriculture. While biotechnological innovations have the potential to enhance crop resilience and productivity, they also raise concerns about safety, ethics, and equity. The adoption of biotechnology in agriculture must be accompanied by robust regulatory frameworks, stakeholder engagement, and careful risk assessment to ensure that its benefits are realised without compromising safety or sustainability.

Digital agriculture technologies offer valuable tools for enhancing farm management and decision-

making, enabling farmers to optimise their operations and improve efficiency. By providing real-time data and insights, digital agriculture technologies can help farmers make informed decisions about planting, irrigation, fertilisation, and pest management, leading to more sustainable and productive farming practices (Singh et al., 2020; Zakaria, 2017). However, the adoption of digital agriculture technologies may require investment in infrastructure, training, and technical support, particularly for smallholder farmers and those in developing countries. The results regarding multidisciplinary innovations for sustainable agricultural economies highlight the importance of adopting a holistic approach to agricultural innovation. Precision agriculture, agroecology, biotechnology, and digital agriculture offer promising solutions for enhancing productivity, efficiency, and sustainability in agriculture. However, their adoption must be carefully managed to ensure that they contribute to sustainable development goals and benefit all stakeholders in the agricultural value chain.

Perspectives of Agricultural Professionals, Applied Biological Scientists, and Economical Farmers

The results regarding the perspectives of agricultural professionals (Table 3), applied biological scientists, and economical farmers highlight several key themes related to sustainability, adoption of sustainable practices, barriers to adoption, support for innovation, and policy recommendations. The majority of participants across all three groups demonstrated a high level of awareness of the importance of sustainability in agriculture, with 85% indicating that they recognise the need for sustainable practices. This awareness is particularly strong among applied biological scientists, with 90% indicating awareness, followed by agricultural professionals (80%) and economical farmers (80%). Despite the high level of awareness, the adoption of sustainable practices varied among the groups, with 70% of participants overall indicating that they have adopted sustainable farming practices. Applied biological scientists showed the highest adoption rate at 80%, followed by agricultural professionals at 60% and economical farmers at 50%. The results also reveal common barriers to the adoption of sustainable practices, including the high cost of implementation and a lack of access to information and resources. Participants highlighted the need for financial support, technical assistance, and training to overcome these barriers and transition to more sustainable farming practices. Participants expressed strong support for the adoption of innovative technologies and practices, with 65% indicating support overall. Agricultural professionals showed the highest level of support at 70%, followed by economical farmers at 70% and applied biological scientists at 60%. Participants emphasised the potential of innovation to enhance productivity, efficiency, and sustainability in agriculture.

Table 3. Respondents of the research

Theme	Description	Agricultural Professionals	Applied Biological Scientists	Economical Farmers
Awareness of Sustainability	85% of participants are aware of the importance of sustainability in agriculture	80%	90%	80%
Adoption of Sustainable Practices	70% of participants have adopted sustainable farming practices	60%	80%	50%
Barriers to Adoption	High cost of sustainable practices and lack of access to information are major barriers	75%	70%	80%
Support for Innovation	65% of participants support the adoption of innovative technologies and practices	70%	60%	70%
Policy Recommendations	Participants suggest the need for government support, subsidies, and incentives for sustainable agriculture	80%	75%	85%

The results regarding the perspectives of agricultural professionals, applied biological scientists, and economical farmers highlight both opportunities and challenges in the transition to sustainable agriculture. While there is a high level of awareness of the importance of sustainability, there is variation in the adoption of sustainable practices among the groups. This variation may be attributed to factors such as access to resources, technical knowledge, and institutional support. The results also underscore the importance of addressing barriers to adoption, such as the high cost of sustainable practices and a lack of access to information. Participants highlighted the need for government support, subsidies, and incentives to facilitate the transition to sustainable agriculture. Policy recommendations include the

development of supportive policies, capacity-building initiatives, and knowledge-sharing platforms to promote sustainable practices. Overall, the results suggest that there is a strong foundation for promoting sustainability in agriculture among agricultural professionals, applied biological scientists, and economical farmers. By addressing barriers to adoption and fostering a supportive policy environment, stakeholders can work together to drive innovation and enhance the sustainability of agricultural systems.

Integrating Multidisciplinary Innovations for Sustainable Agricultural Economies

The findings of this study provide valuable insights into the viewpoints of agricultural professionals, applied biological scientists, and economical farmers regarding multidisciplinary innovations for sustainable agricultural economies. These findings are congruent with the literature, which underscores the necessity of embracing holistic approaches to agricultural innovation, integrating ecological, economic, and social perspectives. A consensus emerges among participants regarding the significance of a multidisciplinary approach to agriculture, echoing the literature's emphasis on the value of integrating diverse disciplines such as biology, economics, and management to foster innovative and sustainable farming practices. Moreover, the results reinforce the importance of sustainable practices in agriculture, with participants expressing a resolute commitment to adopting environmentally friendly and resource-efficient farming methods (Altieri, 2018; Barrios et al., 2020). This sentiment resonates with the literature's advocacy for agro-ecological approaches aimed at enhancing sustainability by emulating natural ecosystems and promoting biodiversity and soil health.

Economic viability emerges as a pivotal consideration in driving the adoption of sustainable practices, as participants underscore the necessity for economic incentives to incentivise sustainability, aligning with the literature's acknowledgment of the economic dimensions of agricultural sustainability (Giller et al., 2021). Moreover, participants' interest in technological innovation, including precision agriculture, biotechnology, and digital agriculture, underscores the potential of technological advancements to bolster productivity, efficiency, and sustainability in agriculture, mirroring the literature's recognition of this potential. However, amidst the enthusiasm for sustainable practices and technological advancements, several barriers to adoption come to the fore. These barriers include the prohibitive cost of sustainable practices and limited access to information and resources, aligning with existing literature that acknowledges obstacles such as cost, technological accessibility, and technical expertise that can impede the uptake of innovative practices. Participants advocate for policy interventions to address these barriers, including government support, subsidies, and incentives for sustainable agriculture, consistent with literature emphasising the importance of supportive policies and initiatives to foster innovation and sustainability in agriculture. The implications of this research for sustainable agricultural development are profound. By shedding light on the perspectives and experiences of key stakeholders, namely agricultural professionals, applied biological scientists, and economical farmers, this study contributes to a deeper understanding of the challenges and opportunities confronting sustainable agricultural economies. Moreover, the findings underscore the imperative of adopting a holistic approach to agricultural innovation, integrating ecological, economic, and social considerations to bolster sustainability and resilience in agricultural systems. Addressing barriers to adoption and cultivating a conducive policy environment are pivotal steps towards driving innovation and enhancing the sustainability of agricultural systems. Consequently, this research adds to the growing body of knowledge on sustainable agriculture, furnishing valuable insights into the perspectives and experiences of critical stakeholders in the agricultural and biological sectors.

Conclusion

This research has provided valuable insights into the perspectives of agricultural professionals, applied biological scientists, and economical farmers regarding multidisciplinary innovations for sustainable agricultural economies. The results highlight a strong consensus among participants regarding the importance of adopting a holistic approach to agriculture, integrating ecological, economic, and social perspectives. Participants expressed a commitment to adopting sustainable practices and embracing technological innovations to enhance productivity, efficiency, and sustainability in agriculture. Despite the enthusiasm for sustainable practices and innovation, the research also identified barriers to adoption, such as the high cost of sustainable practices and a lack of access to information and resources. Participants highlighted the need for supportive policies, subsidies, and incentives to overcome these barriers and facilitate the transition to sustainable agriculture. This research contributes to a deeper understanding of the challenges and opportunities facing sustainable agricultural economies. By addressing barriers to adoption and fostering a supportive policy environment, stakeholders can work together to drive innovation and enhance the sustainability of agricultural systems. The results of this research have implications for sustainable agricultural development, highlighting the importance of

collaborative efforts and multidisciplinary approaches to address the complex challenges facing agricultural economies.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

AL. G. Malau: methodology, writing original draft preparation, review and editing. **AP. G. Malau**: writing original draft preparation, review and editing. **M. B. Simanjuntak:** methodology, analysis, review and editing.

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