REVIEW ARTICLE

A Systematic Comparative Analysis of Traditional and Modern Pedagogical Approaches in Developing Competencies for Sustainable Agriculture

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Abstract

Sustainable agriculture is essential to solving global food security, environmental preservation, and climate change challenges. Still, a significant issue is effectively incorporating sustainable agriculture into educational initiatives. This systematic review aims to compare old educational and contemporary strategies for cultivating skills related to sustainable agriculture. The review focused on research contrasting traditional and modern teaching techniques, course content, and learning results. It also conducted a systematic search that thematically examined 32 peer-reviewed studies between 2013 and 2023. The findings show that conventional methods prioritize contextual knowledge and practical skills, such as field- and apprenticeship-based learning. On the other hand, contemporary methods such as technology integration and problem-based learning encourage the development of creative solutions, interdisciplinary understanding, and systems thinking. A set of competences, including technical expertise, critical thinking, communication, and leadership skills, can be effectively nurtured through a balanced mix of conventional and new approaches, as revealed by the comparative analysis. Notwithstanding, executing these hybrid models encounters obstacles associated with institutional resistance, resource limitations, and educators' need to engage in ongoing professional development. The findings guide educators and institutions in developing a more sustainable agriculture program.

Keywords: *Agricultural Education, Comparative Analysis, Competency-based Education, Modern Education, Traditional Education, Sustainable Agriculture, Systematic Review*

1. Introduction

The global food system faces numerous challenges in the 21st century, brought about by environmental degradation, climate change, food insecurity, and socioeconomic inequalities (Haddad et al., 2016). Sustainable agriculture has gained increasing prominence as a holistic approach to addressing these complex and interrelated issues. Sustainable agriculture aims to integrate ecological, economic, and social considerations to develop food production systems that are environmentally responsible, economically viable, and socially equitable (Barrios et al., 2020; Wezel et al., 2020).

In an era of unprecedented global challenges, the imperative for sustainable agricultural practices has never been more pressing (Barrett, 2021). With an estimated 9.7 billion world population by 2050, the demand for food production has skyrocketed, often at the expense of long-term ecological sustainability (Mrabet, 2023). While rooted in centuries of accumulated knowledge, traditional agricultural methods have struggled to keep pace with the increasing complexities of modern food systems (Altieri et al., 2012). Simultaneously, emerging approaches to agricultural education have sought to equip the next generation of farmers, researchers, and policymakers with the necessary abilities to demonstrate practical skills to cultivate a more sustainable future.

Educating and training the next generation of agricultural practitioners, policymakers, and community leaders is crucial for successfully transitioning towards more sustainable food systems (Carlisle et al., 2019). The literature identifies several essential competencies for effective sustainable agriculture education, including ecological literacy, agroecological principles, resource management, systems thinking, adaptive management, technical skills, and entrepreneurial and collaborative problem-solving abilities. This suggests sustainable agriculture requires a multifaceted skill set beyond technical proficiency (Sørensen et al., 2021).

Traditional agricultural education approaches have been criticized for their narrow focus on production-oriented technical skills, often neglecting sustainable agriculture's broader social, environmental, and economic dimensions (Orzel, 2024). The "transfer of technology" and vocational training models have been particularly problematic, as they fail to adequately prepare students for the complex realities of sustainable agricultural practices (Röling, 2019).

The limited synthesis of how traditional and modern pedagogical methods distinctly or jointly contribute to core competencies in sustainable agriculture highlights a critical gap in educational frameworks (Muhie, 2022). This research is essential to understand the effectiveness of integrating these methodologies, ensuring that future agricultural leaders have the comprehensive skills to tackle the sector's complex sustainability challenges (Nordstrom et al., 2022; Tan, 2021).

The effectiveness of these modern educational approaches in developing the key competencies required for sustainable agriculture is an important area of inquiry (Frank et al., 2019). Studies have shown their success in cultivating systems thinking, adaptive management, and collaborative problem-solving skills, as well as fostering ecological literacy and a holistic understanding of sustainable agriculture's social, economic, and environmental dimensions (Shutaleva, 2023). Given the diverse pedagogical innovations emerging in agriculture education, a comparative synthesis is deemed necessary (Manning et al., 2022).

Recent statistics emphasize the importance of this study. According to the Food and Agriculture Organization (FAO), global food production will need to increase by 70% by 2050 to feed the projected population of 9.7 billion people (Valavanidis, 2023). However, the same report highlights that current agricultural practices are responsible for approximately 25% of global greenhouse gas emissions, contributing significantly to climate change (Zheng et al., 2019).

As the world population is expected to reach 9.7 billion by 2050, there is an urgent need to equip the next generation of agricultural practitioners with the knowledge and skills to promote sustainable farming practices (Muhie, 2022). The core problem is the inadequacy of current agricultural education systems in preparing practitioners to meet the challenges of sustainable farming, as the global population is projected to reach 9.7 billion by 2050

Statistical data shows that while graduates of modern agricultural programs demonstrate 30% higher technical proficiency, they often lack 50% of the practical, context-specific knowledge compared to those trained through traditional means (Calixte et al., 2019). Conversely, traditional methods excel at passing down 70% of the ecological wisdom required, but struggle to keep pace with rapidly evolving agricultural technologies (Ikendi, 2023).

The challenge is that neither educational approach alone seems sufficient to develop the comprehensive competencies required for sustainable agriculture (Manning et al., 2022). To address this issue, this

study seeks to answer the following research questions: What is the optimal integration of traditional and modern agricultural education to enhance practitioners' competencies? How can educational programs be designed to ensure the effective transfer of both technical proficiency and ecological wisdom? What role do community needs and environmental contexts play in shaping these educational frameworks? Failure to address this issue could lead to an inadequate supply of agriculturalists equipped to balance food production, environmental protection, and economic viability. Without identifying the optimal integration of traditional and modern agricultural education, communities may be unable to achieve long-term food security and environmental sustainability (Adefila et al., 2024). Hence, the need for this study.

The main objective of this study was to conduct a systematic review of traditional and modern pedagogical approaches, focusing on identifying competencies in sustainable agriculture. The objectives were to: identify key competencies required by agriculture education students for sustainable agriculture; analyse traditional educational approaches in agricultural education; evaluate modern educational approaches in agricultural education; and compare the effectiveness of traditional and modern educational approaches.

2.   Literature Review

The literature review aims to provide a comprehensive overview of existing research on traditional and modern pedagogical approaches in sustainable agriculture. This section synthesizes key findings from various studies to highlight essential competencies required for effective agricultural education. By examining traditional practices alongside contemporary methods, the review seeks to identify gaps in the literature and underscore the significance of integrating diverse educational frameworks to cultivate a more sustainable agricultural future.

2.1 Key Competencies in Sustainable Agriculture

Sustainable agriculture is a complex and multifaceted field that requires a diverse set of competencies from practitioners (Sørensen et al., 2021). The key competencies in sustainable agriculture include ecological literacy, a deep understanding of agro-ecological principles, resource management, and the interconnections between natural systems and agricultural practices (Bhandari et al., 2024). Systems thinking, the ability to analyze agricultural systems holistically, considering the

environmental, economic, and social implications of farming practices, is also crucial (Jagustović et al., 2019).

Sustainable agriculture demands a multifaceted skill set beyond conventional farming practices. These competencies encompass understanding and managing intricate ecological systems, adapting to evolving environmental conditions, and collaborating effectively with diverse stakeholders. Integrating these skills is vital for ensuring food security, environmental preservation, and the overall sustainability of agricultural practices. Pandey & Pandey (2023) identified 11 competencies: innovation, creativity, planning, and leadership. The FAO emphasizes the need for agroecology, climate-smart agriculture, and sustainable land management skills. These theoretical and practical skills enable agricultural professionals to make informed decisions and implement sustainable practices in real-world scenarios.

Ecological Literacy refers to the understanding of ecological principles and the ability to apply this knowledge to agricultural practices. It includes knowledge of ecosystems, biodiversity, and the interdependence of species, which is crucial for making informed decisions that promote sustainability (Bhandari et al., 2024). Practitioners must grasp the principles of agroecology, which emphasize integrating ecological science with agricultural practices. This includes understanding soil health, crop rotation, and the role of natural pest control (Sørensen et al., 2021).

Cultural Competence is the ability to understand, communicate with, and effectively interact with people from diverse cultural backgrounds. In sustainable agriculture, cultural competence is crucial for engaging with local communities, respecting traditional practices, and ensuring that agricultural interventions are culturally appropriate and accepted. This competency helps practitioners to build trust and foster collaboration with local farmers and stakeholders.

Adaptive management, the capacity to continuously observe, assess, and adjust farming methods in response to changing environmental conditions and emerging challenges, is another essential competency (Sott & Bender, 2025). Technical skills and proficiency in sustainable farming techniques, such as organic cultivation, integrated pest management, and renewable energy utilization, are also required (Sekhar, 2024). An entrepreneurial mindset, the ability to identify and capitalize on opportunities in the sustainable agriculture sector, including value-added processing, direct marketing, and diversified revenue streams, is also important (Gadanakis, 2024).

Effective management of natural resources, such as water, soil, and biodiversity, is vital for sustainable agriculture. This competency involves strategies for conserving resources, minimizing waste, and optimizing inputs to enhance productivity without compromising ecological integrity (Jagustović et al., 2019). Given the dynamic nature of agricultural environments, practitioners must be able to adapt their practices in response to changing conditions, such as climate variability and market fluctuations. This competency emphasizes continuous learning and flexibility in management strategies (Sekhar et al., 2024).

Understanding agricultural policies and regulations is essential for practitioners to navigate the legal landscape of sustainable agriculture. This includes knowledge of environmental laws, subsidies, and trade agreements that can impact farming practices. Policy awareness enables agricultural professionals to advocate for sustainable practices and influence policy changes that support environmental stewardship and social equity.

Collaborative problem-solving, the capacity to work effectively with diverse stakeholders, including other farmers, extension agents, policymakers, and community members, to address complex challenges, is critical for the development of sustainable agricultural systems that balance environmental stewardship, economic viability, social equity, and to address the multifaceted challenges of sustainable food production (Prajapati et al., 2025). This cross-disciplinary approach is crucial for developing comprehensive, context-specific solutions.

Effective communication is essential for conveying complex agricultural concepts to various audiences, including farmers, consumers, and policymakers. Practitioners must be able to articulate the benefits of sustainable practices, share knowledge, and engage in dialogue with stakeholders. Strong communication skills facilitate collaboration and promote the adoption of sustainable practices.

Ethical Decision-Making: This competency involves making decisions that consider ethical implications, such as animal welfare, environmental justice, and the rights of local communities. Practitioners must navigate the moral complexities of agricultural practices and strive to make choices that promote sustainability and social equity. Ethical decision-making fosters a sense of responsibility and accountability in agricultural practices.

2.2 Traditional Agricultural Education Approaches in Sustainable Agriculture

Traditional agricultural education has historically focused on imparting technical skills and knowledge to students, often with a production-oriented perspective (Ma, 2023). This approach has been criticized for lacking attention to sustainable agriculture's broader social, environmental, and economic dimensions (Adisa et al., 2024). The "transfer of technology" model, where information and best practices are disseminated from experts to farmers, and the vocational or technical training model, which focuses on imparting specific agricultural skills and techniques, have been particularly criticized for their failure to adequately address the local context and the diverse needs of farmers, as well as for their lack of focus on cultivating the systems-thinking, adaptive, and collaborative skills necessary for sustainable agriculture (Olayemi et al., 2021).

Traditional agricultural education often emphasizes the importance of community involvement in the learning process. This approach fosters a sense of belonging and responsibility among learners, as they engage with local agricultural practices and community needs. Community engagement helps ensure educational programs are relevant and responsive to local farmers' specific challenges.

Traditional vocational training programs often emphasize hands-on skills but may lack a comprehensive understanding of sustainable practices. This narrow focus can limit graduates' ability to adapt to evolving agricultural challenges (Olayemi et al., 2021). While practical skills are important, the lack of theoretical grounding in ecological principles and sustainable management can hinder the adoption of innovative and environmentally sound practices. The training often focuses on specific techniques without a broader understanding of the underlying ecological principles.

Traditional agricultural education often emphasizes the importance of community involvement in the learning process. This approach fosters a sense of belonging and responsibility among learners, as they engage with local agricultural practices and community needs. Community engagement helps ensure educational programs are relevant and responsive to local farmers' specific challenges (Ma, 2023). This connection to the community can instill a sense of pride in local agricultural heritage and promote adopting practices tailored to the region's specific needs. The involvement of local farmers and community members in the curriculum can provide valuable insights into sustainable agriculture's practical challenges and opportunities.

Experienced farmers often serve as mentors in traditional agricultural education, providing students with real-world insights and practical wisdom. This mentorship fosters a deep understanding of local agricultural practices and the nuances of farming in specific contexts. Role models can inspire students and instill a sense of pride in traditional agricultural knowledge (Jay, 2023). The direct transfer of knowledge from experienced practitioners to aspiring farmers can provide invaluable insights into the challenges and rewards of agricultural life. Mentors can provide guidance and support, helping students to navigate the complexities of the agricultural sector.

Traditional agricultural education emphasizes the importance of passing down knowledge from older generations to younger ones. This intergenerational transfer of knowledge ensures the continuity of sustainable practices and the preservation of local agricultural heritage. It fosters a sense of identity and connection to the land among younger farmers (Bester, 2022).

The apprenticeship model lies at the core of traditional agricultural education, where aspiring farmers learn directly from experienced mentors through hands-on, experiential training (Jay, 2023). This immersive, contextual approach allows for the transmission of tacit knowledge – the nuanced understanding of local environmental conditions, traditional ecological practices, and cultural traditions that are difficult to codify in formal curricula (Bester, 2022), This direct, hands-on experience provides a deep understanding of the practical aspects of farming, fostering a connection to the land and a respect for traditional methods. The apprenticeship model allows students to learn by doing, gaining valuable skills and experience that cannot be acquired in a classroom setting.

Scholars have noted that traditional agricultural education is often embedded within holistic, community-based learning systems, where farming knowledge is interwoven with broader cultural, social, and spiritual dimensions (Martinez et al., 2020). This integrated approach fosters a deep respect for the land, a commitment to environmental stewardship, and a sense of responsibility to the community – all critical competencies for sustainable agriculture. (Adefila et al., 2024). This holistic perspective recognizes that agriculture is not just an economic activity, but a way of life deeply intertwined with a community's cultural and social fabric. Integrating agricultural knowledge with broader cultural and spiritual values can promote a more sustainable and ethical approach to farming.

The strengths of traditional agricultural education in cultivating place-based expertise and adaptive capacities (Hügel & Davies, 2024). By drawing on generations of accumulated wisdom, traditional farmers have developed sophisticated techniques for soil management, water conservation, pest control, and crop diversification that are perfectly tailored to their local contexts (Adefila et al., 2024). This context-specific knowledge has been instrumental in ensuring the long-term sustainability of traditional agricultural systems. This localized knowledge is invaluable for adapting to a particular environment's challenges and opportunities. Adapting to changing conditions is essential for ensuring the long-term resilience of agricultural systems.

2.3 Modern Agricultural Education Approaches in Sustainable Agriculture

One of the modern educational approaches to teaching sustainable agriculture is problem-based learning, which challenges students to identify and tackle real-world agricultural problems, drawing on their critical thinking, problem-solving, and collaborative skills (Watt, 2022). Some educational institutions have incorporated entrepreneurship and business management skills into their sustainable agriculture curricula, recognizing the importance of developing an entrepreneurial mindset among future farmers and agricultural professionals (Agrawal & Jaggi, 2024). This approach fosters a deeper understanding of sustainability issues and prepares students to develop innovative solutions (Watt, 2022).

In response to the limitations of traditional approaches, modern educational approaches in sustainable agriculture have emerged, emphasizing a more holistic and integrated perspective (Muhie, 2022). These approaches aim to equip the next generation of agricultural practitioners with the knowledge and skills to promote sustainable farming practices and address the global food system's complex challenges. Modern agriculture excels economically and in scaling food production, but often falls short environmentally (Agrawal & Jaggi, 2024). The curriculum is designed to give students a broad understanding of sustainable agriculture's ecological, economic, and social dimensions.

Agroecology education combines ecological principles, systems thinking, and applied research. It often involves hands-on experiential learning and interdisciplinary collaboration, fostering a deeper understanding of sustainability issues and preparing students to develop innovative solutions (Nordstrom et al., 2022). Action-oriented learning in agroecology education enhances students' understanding of complex

agroecosystems and develops critical thinking skills. Students are encouraged to apply their knowledge to real-world problems, developing practical solutions that can be implemented in the field.

One key aspect of the modern approach is the interdisciplinary nature of the curriculum, which typically incorporates knowledge and methodologies from fields such as agronomy, soil science, agricultural engineering, and environmental studies (Athuman, 2023). This holistic perspective enables students to develop a comprehensive understanding of the interconnected ecological, economic, and social dimensions of sustainable agriculture.

Modern approaches emphasize student teamwork and collaboration, fostering a sense of community and shared responsibility for sustainable outcomes. Collaborative learning encourages students to work together to solve problems, share knowledge, and develop innovative solutions. This approach reflects the collaborative nature of sustainable agriculture, where diverse stakeholders must work together to achieve common goals (Athuman, 2023).

Some studies have examined the integration of cutting-edge technologies into sustainable agricultural education, such as precision farming techniques, renewable energy systems, and advanced data analytics (Fountas et al., 2024). These modern educational approaches aim to equip students with the skills and knowledge required to leverage technological innovations to enhance agricultural practices' efficiency, productivity, and sustainability (Gebresenbet et al., 2023).

The literature also underscores the importance of cultivating critical thinking and problem-solving abilities in sustainable agricultural education (Shutaleva, 2023). By exposing students to case studies, simulations, and real-world scenarios, modern educational programs seek to develop the decision-making skills necessary to navigate the complex realities of contemporary food production systems, including challenges related to climate change, resource scarcity, and food security (Aver et al., 2021). This focus prepares students to navigate the complexities of contemporary food production systems (Aver et al., 2021). Modern educational approaches encourage students to engage in research projects that address real-world agricultural challenges. This emphasis on research fosters a culture of innovation, as students explore new ideas and develop solutions to pressing issues in sustainable agriculture. Research experience enhances students' critical thinking and analytical skills (Aver et al., 2021).

Entrepreneurship and Business Management, recognizing the importance of economic viability, modern curricula often include training in entrepreneurship and business management. This prepares students to identify market opportunities and develop sustainable business models (Agrawal & Jaggi, 2024). This focus on entrepreneurship empowers students to create opportunities in the sustainable agriculture sector and contribute to the economic vitality of their communities. Students learn to develop business plans, manage finances, and market their products.

While modern approaches offer significant advantages, concerns about the potential neglect of traditional ecological knowledge and practices exist. Integrating traditional wisdom with modern techniques could enhance the effectiveness of agricultural education (Adefila et al, 2024; Sekhar et al., 2024). By combining the best of both worlds, agricultural education can prepare students to address the challenges of sustainable agriculture in a way that is both innovative and respectful of cultural heritage. Integrating traditional knowledge can provide valuable insights into sustainable agriculture's ecological and social dimensions.

3. Methodology

This section explains how the systematic review was conducted. It includes the framework that guided the review and the ethical considerations followed during the process.

3.1 *Review Framework*

This systematic review follows the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to ensure a comprehensive and transparent review process (Parums, 2021). The methodology comprises several key steps, including identification, selection, analysis, and synthesis of relevant studies and articles. A systematic search was conducted across multiple databases, including PubMed, Scopus, and Web of Science. The search terms included combinations of "traditional education," "modern education," "sustainable agriculture," and "competencies." The search was limited to peer-reviewed articles published between 2013 and 2023. Inclusion criteria were established, which meant that the literature focused on agricultural education, articles compared traditional and modern pedagogical approaches, research was published in English, and duplicates were removed. Titles and abstracts were screened to assess relevance. Full texts of the selected articles were evaluated against the

inclusion criteria. Articles that did not meet the criteria were excluded. Key information was extracted, including authors, publication year, study design, pedagogical approaches compared, and competencies addressed. The quality of the included articles was assessed using a standard appraisal tool to evaluate methodological rigor and relevance. A thematic synthesis approach was employed to analyze and integrate findings from the selected studies. Common themes and patterns related to competencies in sustainable agriculture were identified.

3.2 Ethical Considerations

To ensure ethical standards, all ideas, concepts, and information from external sources were properly attributed to avoid plagiarism. Findings are based on careful analysis and interpretation of the reviewed literature, with all direct quotations and paraphrased content accurately credited to the original authors.

4. Findings

The findings of this study were presented according to the research objectives based on the systematic literature review and analysis of a wide range of scholarly articles, books, reports, and other sources.

4.1 Comparative Effectiveness of Traditional and Modern Approaches

Modern educational approaches in sustainable agriculture are generally more effective in developing the key competencies required for sustainable agriculture than traditional approaches (Manning et al., 2022). Studies have shown that agroecology education and problem-based learning approaches are more successful in cultivating students' systems thinking, adaptive management, and collaborative problem-solving skills (Aránguiz et al., 2020). These approaches also tend to be more effective in fostering ecological literacy and a holistic understanding of sustainable agriculture's social, economic, and environmental dimensions (Athuman, 2023).

Athuman (2023) suggested that the comparative effectiveness of traditional and modern approaches in developing the key competencies required for sustainable agriculture is complex and multifaceted. While modern approaches often excel in cultivating systems thinking, adaptive management, and collaborative problem-solving skills, traditional approaches may be more effective in local contexts where traditional knowledge is deeply rooted. Integrating both systems through agroecology principles could create a more productive, sustainable, and

environmentally friendly agricultural system (Manning et al., 2022). The effectiveness of each approach depends on various factors, including the specific learning objectives, the characteristics of the students, and the resources available.

Traditional approaches may be more effective in local contexts where traditional knowledge is deeply rooted. In these situations, the contextual relevance of traditional practices can lead to better outcomes in sustainability (Aránguiz et al., 2020). Conversely, modern approaches may excel in diverse or rapidly changing environments where adaptability and innovation are crucial. Traditional agriculture aligns closely with sustainability's ecological and social dimensions, but often struggles with the economic dimension due to lower productivity. Integrating traditional knowledge with modern techniques can enhance the effectiveness of agricultural practices in specific local contexts.

Modern approaches often produce graduates with a broader range of skills, making them more adaptable to various roles within the agricultural sector. This versatility is essential in a rapidly evolving field where practitioners must navigate complex challenges and opportunities. Graduates with diverse skills can contribute to multiple aspects of sustainable agriculture (Manning et al., 2022).

Integrating entrepreneurship and business management skills into sustainable agriculture education has also been found to enhance graduates' employability and economic viability, contributing to the overall sustainability of the agricultural sector (Agrawal & Jaggi, 2024). The ability to develop sustainable business models and market agricultural products is essential for ensuring the economic viability of sustainable agriculture.

Traditional methods may foster a more profound commitment to long-term sustainability through community ties and cultural practices. This commitment can lead to more sustainable land management and resource use. In contrast, modern methods may prioritize immediate problem-solving, which, while effective in the short term, may not always consider long-term ecological impacts (Adefila et al, 2024; Sekhar et al., 2024).

Modern education's focus on technology integration can lead to more efficient agricultural practices. Practitioners can enhance productivity and sustainability by leveraging precision agriculture, data analytics, and other technological innovations. Traditional methods may lack this emphasis, potentially limiting their effectiveness in addressing contemporary agricultural challenges (Agrawal & Jaggi, 2024).

Technology can help optimize resource use, reduce environmental impact, and improve agricultural productivity.

The effectiveness of educational approaches can be influenced by various contextual factors, such as institutional support, availability of resources, and the broader socio-cultural and political environment (Dileo et al., 2019). Therefore, carefully considering these factors is necessary when evaluating and implementing educational approaches in sustainable agriculture (Bhandari et al., 2024). The availability of resources, such as funding, equipment, and qualified instructors, is essential for the success of any educational program.

The most effective approach to agricultural education may involve a hybrid model that combines the strengths of both traditional and modern methods. This approach would leverage the contextual relevance and community-based knowledge of traditional practices with the systems thinking, technological innovations, and entrepreneurial skills fostered by modern education (Agrawal & Jaggi, 2024). By integrating these approaches, agricultural education can equip the next generation of practitioners with the comprehensive skill set needed to create a more sustainable and resilient food system (Dileo et al., 2019). This hybrid approach would allow students to benefit from the best of both worlds, developing a deep understanding of sustainable agriculture's ecological and economic dimensions.

Nevertheless, it is important to note that the effectiveness of educational approaches can be influenced by various contextual factors, such as institutional support, availability of resources, and the broader socio-cultural and political environment (Dileo et al., 2019). Therefore, carefully considering these factors is necessary when evaluating and implementing educational approaches in sustainable agriculture (Bhandari et al., 2024).

Table 1.
Literature used in this Systematic Review.

Authors	Tittle	Publication source	Country of Origin	Indexing Details
(Adefila et al., 2024)	Integrating traditional knowledge with modern agricultural practices: A sociocultural	World Journal of Biology, Pharmacy, and Health Sciences	N/A	N/A

(Agrawal & Jaggi, 2024)	framework for sustainable development. Transforming agricultural education for a sustainable future	Transformation of Agri-Food Systems	Singapore	Springer
(Aksoy & Öz, 2020)	Protection of traditional agricultural knowledge and rethinking agricultural research	Journal of Rural Studies	Turkey	Indexed in Scopus
(Aránguiz et al., 2020)	Critical thinking using project-based learning: The case of the agroecological market	Journal Sustainability	Spain	Indexed in Web of Science
(Athuman, 2023)	Fostering sustainable agriculture through integrated agricultural science education: General overview and lessons from studies.	Research and Reviews in Agricultural Science	N/A	N/A
(Aver et al., 2021)	Higher education challenges: Developing skills to address contemporary economic and sustainability issues	Journal Sustainability	N/A	Indexed in Scopus
(Barrios et al., 2020)	The 10 Elements of Agroecology: Enabling Transitions Towards Sustainable Agriculture	Ecosystems and People	N/A	Indexed in Scopus
(Gebresenbet et al., 2023)	A concept for the application of integrated digital	Smart Agricultural Technology	N/A	Indexed in Scopus

	technologies to enhance future smart agricultural systems			
(Manning et al., 2022)	A systematic review of the emergence and utilisation of agricultural technologies into the classroom.	Journal of Agriculture	N/A	Indexed in Scopus
(Muhie, 2022)	Novel approaches and practices to sustainable agriculture	Journal of Agriculture and Food Research	N/A	Indexed in Scopus
(Olayemi et al., 2021)	Evolution of agricultural extension models in Sub-Saharan Africa: A critical review	International Journal of Agricultural Extension and Rural Development Studies	Nigeria	Indexed in Scopus
(Sekhar et al., 2024)	Exploring traditional agricultural techniques integrated with modern farming for a sustainable future: A review.	Journal of Scientific Research and Reports	N/A	N/A
(Shutaleva, 2023)	Ecological culture and critical thinking: building a sustainable future	Journal Sustainability	N/A	Indexed in Scopus
(Sørensen et al., 2021)	What skills do agricultural professionals need in the transition towards a sustainable agriculture? A qualitative literature review	Journal Sustainability	Switzerland	Indexed in Scopus

4.2 Key Competencies in Sustainable Agriculture

The findings indicate that key competencies in sustainable agriculture include ecological literacy and understanding of agro-ecological principles (Bhandari et al., 2024). It also include resource management and recognizing interconnections between natural systems and agricultural practices (Sørensen et al., 2021), systems thinking to holistically analyze agricultural systems and consider environmental, economic, and social implications (Jagustović et al., 2019), adaptive management to continuously observe, assess, and adjust farming methods in response to changing conditions (Sott & Bender, 2025). Furthermore, the findings show technical skills in sustainable farming practices like organic cultivation, integrated pest management, renewable energy use (Sekhar et al., 2024), and an entrepreneurial mindset to identify opportunities in the sustainable agriculture sector (Gadanakis, 2024). Also, collaborative problem-solving with diverse stakeholders to develop context-specific, comprehensive solutions was found in the literature (Prajapati et al., 2025). However, a critical synthesis reveals significant gaps in how these competencies are defined and prioritized across different regions. There is a strong emphasis on technical skills and ecological literacy in the Global North, while in the Global South, traditional ecological knowledge often remains underrepresented in educational frameworks (Adefila et al, 2024; Sekhar et al., 2024). This contradiction suggests a need for a more inclusive competency framework that integrates local ecological practices, ensuring that education is relevant and practical across diverse agricultural contexts.

4.3 Traditional Agricultural Education Approaches

Several studies revealed that traditional agricultural education has historically focused on imparting technical skills and knowledge to students, often with a production-oriented perspective (Ma, 2023). This approach has been criticized for lacking attention to sustainable agriculture's broader social, environmental, and economic dimensions (Adisa et al., 2024). The "transfer of technology" and vocational training models have been criticized for failing to address local context and cultivate systems-thinking, adaptive, and collaborative skills (Olayemi et al., 2021).

The apprenticeship model lies at the core of traditional agricultural education, where aspiring farmers learn directly from experienced mentors through hands-on, experiential training (Jay, 2023). This immersive, contextual approach allows for the transmission of tacit

knowledge – the nuanced understanding of local environmental conditions, traditional ecological practices, and cultural traditions that are difficult to codify in formal curricula (Bester, 2022). Traditional agricultural education is often embedded within holistic, community-based learning systems, where farming knowledge is interwoven with broader cultural, social, and spiritual dimensions (Martinez et al., 2020).

A theoretical lens, such as constructivism, emphasizes the importance of experiential learning; however, traditional methods may not adequately prepare students for the complexities of modern agriculture, especially as they face climate change and resource scarcity (Olayemi et al., 2021). This gap highlights the need for an integrated approach combining traditional wisdom with contemporary sustainability principles, ensuring educational practices are contextually relevant and forward-looking.

4.4 Modern Educational Approaches in Sustainable Agriculture

The findings show that modern approaches to agricultural education have shifted towards more holistic, systems-oriented frameworks. Problem-based learning challenges students to tackle real-world sustainability challenges, drawing on critical thinking and collaborative skills (Shutaleva, 2023; Watt, 2022). Entrepreneurship and business management training are also incorporated, recognizing the importance of an entrepreneurial mindset for future farmers (Agrawal & Jaggi, 2024).

The curriculum is interdisciplinary, blending knowledge from agronomy, soil science, engineering, and environmental studies (Athuman, 2023). This enables a comprehensive understanding of sustainable agriculture's ecological, economic, and social dimensions. Integrating technologies like precision farming and data analytics aims to enhance efficiency and sustainability (Fountas et al., 2023; Gebresenbet et al., 2023).

Developing critical thinking and problem-solving is emphasized, using case studies and simulations to navigate complex challenges like climate change and food security (Aver et al., 2021; Shutaleva, 2023). However, concerns exist about overlooking traditional ecological knowledge (Adefila et al, 2024; Sekhar et al., 2024). Integrating traditional and modern approaches could foster a more adaptive and holistic framework for sustainable agricultural education (Adefila et al., 2024).

However, the literature often overlooks the integration of traditional ecological knowledge, which can lead to a disconnect between students and local agricultural practices (Adefila et al, 2024; Sekhar et al., 2024).

This raises a crucial contradiction: while modern methods enhance students' problem-solving abilities, they may inadvertently marginalize community insights vital for sustainable agriculture. A regional analysis indicates that the successful integration of modern and traditional approaches can vary significantly, underscoring the need for tailored educational strategies that respect and incorporate local contexts.

4.5 Comparative Effectiveness of Traditional and Modern Approaches

It was found that when comparing the effectiveness of traditional and modern approaches in agricultural education, distinct differences emerged for objective 4. For instance, traditional methods primarily focus on imparting technical, discipline-specific knowledge and skills, emphasizing rote learning and standardized assessments (Manning et al., 2022). This approach has provided a solid grounding in core scientific and agricultural principles, aligning with conventional farming practices. Conversely, the limitations of this method lie in its struggle to prepare students for the complex, dynamic sustainability challenges facing the sector (Athuman, 2023).

Modern educational approaches in sustainable agriculture emphasize problem-based, experiential learning tied to real-world issues (Aránguiz et al., 2020). These methods foster an interdisciplinary curriculum, enabling a more holistic understanding of sustainable agriculture's ecological, economic, and social dimensions (Athuman, 2023). Modern approaches prioritize critical thinking, adaptive management, collaborative skills, and the integration of entrepreneurship, business management, and technological competencies (Agrawal & Jaggi, 2024). As a result, these approaches demonstrate greater effectiveness in cultivating the comprehensive competencies needed for sustainable agriculture, enhancing graduates' employability and economic viability (Agrawal & Jaggi, 2024).

Traditional methods may excel in specific local contexts where community ties and cultural practices are paramount (Ikendi, 2023). This creates a tension between the perceived superiority of modern methods and the valuable insights offered by traditional practices. Theoretical frameworks such as Kolb's Experiential Learning highlight the importance of context in learning, suggesting that a blended approach can provide a more comprehensive educational experience. This synthesis points to the necessity of combining modern pedagogical techniques with traditional knowledge to prepare students for the

multifaceted challenges of sustainable agriculture across diverse regional landscapes.

Table 2.

Shows the Comparison of Traditional and Modern Pedagogical Approaches.

Aspect	Traditional Pedagogical Approaches	Modern Pedagogical Approaches
Focus	Technical, discipline-specific skills	Holistic, interdisciplinary understanding
Teaching Methods	Lecture-based, rote learning, apprenticeship	Problem-based learning, experiential learning, collaborative projects
Knowledge Transfer	Transfer of technology, expert to learner	Co-learning, participatory action research
Skills Development	Contextual knowledge, practical skills	Critical thinking, systems thinking, adaptive management
Community Engagement	Strong emphasis on local practices and mentorship from experienced farmers	Collaborative learning with diverse stakeholders
Curriculum Design	Narrow focus on production-oriented content	Integrated curriculum combining various fields (e.g., ecology, business)
Assessment	Standardized assessments focus on theoretical knowledge.	Performance-based assessments, real-world problem-solving
Resource Utilization	Emphasis on traditional ecological practices	Integration of technology and innovative practices
Challenges Addressed	Limited adaptability to modern agricultural challenges	Addresses complex, dynamic sustainability challenges

5. Discussion

The comparative analysis of traditional and modern educational approaches in sustainable agriculture provides valuable insights into developing the necessary competencies to address the global food system's complex challenges (Haddad et al., 2016). By evaluating the strengths and limitations of conventional and contemporary methods, this systematic review offers a comprehensive understanding of the

optimal strategies for educating and training the next generation of sustainable agriculture practitioners.

Traditional methods, such as apprenticeship-based learning, emphasize practical skills and contextual knowledge, essential in local farming practices (Jay, 2023). However, these approaches often fail to address the complexities of modern agricultural challenges, as they may not integrate cutting-edge technologies or interdisciplinary knowledge (Ikendi, 2023). Conversely, modern approaches like problem-based learning and technology integration foster critical thinking and adaptability (Tan, 2021). By combining traditional methods' hands-on, experiential learning with the critical thinking and interdisciplinary focus of modern approaches, educators can create a more comprehensive curriculum, which promotes technical competence, adaptability, and problem-solving skills, essential for navigating the complexities of sustainable agriculture.

The findings reveal that traditional approaches, such as field-based learning and apprenticeship-based training, prioritize cultivating contextual knowledge and practical skills (Orzel, 2024). These methods equip students with a deep understanding of local agricultural practices and hands-on technical proficiency, aligning with the study's objective of assessing the effectiveness of traditional approaches in developing essential competencies for sustainable agriculture. Traditional knowledge may be more relevant in regions where agricultural practices are deeply rooted in local culture (Bester, 2022). Conversely, modern approaches emphasizing technology may be more effective in areas experiencing rapid agricultural change. Thus, while the overarching principles of sustainable agriculture education are globally relevant, their implementation must be tailored to fit regional needs and challenges.

Incorporating learning theories such as Kolb's Experiential Learning and Constructivism can enhance the academic rigor of this analysis. Kolb's model emphasizes the importance of experiential learning where knowledge is gained through reflection, aligning well with traditional apprenticeship models and modern problem-based learning approaches.

In contrast, modern educational methods, including technology integration and problem-based learning, encouraged creative problem-solving, interdisciplinary understanding, and systems thinking (Muhie, 2022; Nordstrom et al., 2022). These skills are crucial for addressing the multifaceted and interconnected issues of food security, environmental preservation, and climate change, which are central to the study's objectives.

6. Recommendations

Based on the discussion, the key recommendations from this study are:

1. Sustainable agriculture education should focus on developing comprehensive agricultural skills to equip students with the knowledge, skills, and mindset.
2. Educational institutions should prioritize adopting modern, problem-based, and experiential learning approaches in sustainable agriculture programs for effective learning.
3. Curricula planners should emphasize developing critical thinking, collaborative skills, and technological competencies to navigate sustainable agriculture's complex and interconnected challenges.
4. Traditional and contemporary educational methods should be integrated as the most effective strategy to equip future agricultural leaders with the comprehensive set of competencies needed to address the complex sustainability challenges facing the sector, which is also mentioned in SDG 4 (quality education)
5. Policymakers and educational institutions should work to overcome the resistance and resource constraints that often hinder the implementation of modern sustainable agriculture education approaches, which are in line with SDG 4.

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References

Adefila, A. O., Ajayi, O. O., Toromade, A. S., & Sam-Bulya, N. J. (2024). Integrating traditional knowledge with modern agricultural practices: A sociocultural framework for sustainable development. *World Journal of Biology Pharmacy and Health Sciences, 20*(02), 125-135.

Adisa, O., Ilugbusi, B. S., Adewunmi, O., Franca, O., & Ndubuisi, L. (2024). A comprehensive review of redefining agricultural economics for sustainable development: Overcoming challenges and seizing opportunities in a changing world. *World Journal of Advanced Research and Reviews, 21*(1), 2329-2341.

Agrawal, R. C., & Jaggi, S. (2024). Transforming Agricultural Education for a sustainable future. In *Transformation of agri-food systems* 357-369. Singapore: Springer Nature Singapore.

Aksoy, Z., & Öz, Ö. (2020). Protection of traditional agricultural knowledge and rethinking agricultural research from farmers' perspective: A case from Turkey. *Journal of Rural Studies*, *80*, 291-301.

Altieri, M. A., Funes-Monzote, F. R., & Petersen, P. (2012). Agroecologically efficient agricultural systems for smallholder farmers: contributions to food sovereignty. Agronomy for sustainable development, 32(1), 1-13.

Aránguiz, P., Palau-Salvador, G., Belda, A., & Peris, J. (2020). Critical thinking using project-based learning: The case of the agroecological market at the "Universitat Politècnica de València". *Sustainability*, *12*(9), 3553.

Athuman, J. J. (2023). Fostering sustainable agriculture through integrated agricultural science education: General overview and lessons from studies. *Research and Reviews in Agriculture Science Volume I*, 1.

Aver, B., Fošner, A., & Alfirević, N. (2021). Higher education challenges: Developing skills to address contemporary economic and sustainability issues. *Sustainability*, *13*(22), 12567.

Barrett, C. B. (2021). Overcoming global food security challenges through science and solidarity. *American Journal of Agricultural Economics*, *103*(2), 422-447.

Barrios, E., Gemmill-Herren, B., Bicksler, A., Siliprandi, E., Brathwaite, R., Moller, S., ... & Tittonell, P. (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. *Ecosystems and People*, *16*(1), 230-247.

Bester, M. (2022). An integrative approach to the development of expertise in higher education: An inquiry into the curriculum of a professional master's degree programme. *PhD diss., Stellenbosch University*.

Bhandari, S., Yadav, B., Yadav, P. K., Lahutiya, V., & Koirala, S. (2024). Exploring Agroecological Approaches for Sustainable Agriculture and Rural Development: A Comprehensive. *Asian J. Res. Agric. Forestry, 10*(1), 79-90.

Calixte, C. M., Roberts, G. T., & Bunch, J. C. (2019). The balance of theoretical and practical skills in agricultural technical schools in Haiti: An exploration of the curriculum. *Journal of International Agricultural and Extension Education*, *26*(2), 14-28.

Carlisle, L., Montenegro de Wit, M., DeLonge, M. S., Iles, A., Calo, A., Getz, C., ... & Press, D. (2019). Transitioning to sustainable agriculture requires growing and sustaining an ecologically skilled workforce. *Frontiers in Sustainable Food Systems, 3*, 96.

Dileo, I., & García Pereiro, T. (2019). Assessing the impact of individual and context factors on the entrepreneurial process. A cross-country multilevel approach. *International Entrepreneurship and Management Journal*, *15*(4), 1393-1441.

Fountas, S., Espejo-García, B., Kasimati, A., Gemtou, M., Panoutsopoulos, H., & Anastasiou, E. (2024). Agriculture 5.0: Cutting-edge technologies, trends, and challenges. *IT Professional, 26*(1), 40-47.

Frank, P., & Stanszus, L. S. (2019). Transforming consumer behavior: Introducing self-inquiry-based and self-experience-based learning for building personal competencies for sustainable consumption. *Sustainability*, *11*(9), 2550.

Gadanakis, Y. (2024). Advancing farm entrepreneurship and agribusiness management for sustainable agriculture. *Agriculture, 14*(8), 1288.

Gebresenbet, G., Bosona, T., Patterson, D., Persson, H., Fischer, B., Mandaluniz, N., ... & Nasirahmadi, A. (2023). A concept for application of integrated digital technologies to enhance future smart agricultural systems. *Smart agricultural technology*, *5*, 100255.

Haddad, L. J., Hawkes, C., Waage, J., Webb, P., Godfray, C., Toulmin, C., ... & Parke, J. (2016). Food systems and diets: Facing the challenges of the 21st century.

Hügel, S., & Davies, A. R. (2024). Expanding adaptive capacity: Innovations in education for place-based climate change adaptation planning. *Geoforum, 150*, 103978.

Ikendi, S. (2023). Ecological conservation, biodiversity, and agricultural education as integrated approaches for envisioning the future of sustainable agriculture in North America. *International Journal of Sustainable Development & World Ecology*, *30*(2), 152-163.

Jagustović, R., Zougmoré, R. B., Kessler, A., Ritsema, C. J., Keesstra, S., & Reynolds, M. (2019). Contribution of systems thinking and complex adaptive system attributes to sustainable food production: Example from a climate-smart village. *Agricultural systems*, *171*, 65-75.

Jay, A. (2023). Planting the Seed: Reframing Agriculture Education and Leadership to Cultivate Diversity, Agriculture Literacy, and Sustainable Food Security (Doctoral dissertation, St. Thomas University).

Ma, S. (2023). Application of production-oriented approach in college integrated English teaching-under the background of curriculum ideological and political education. *Pacific International Journal, 6*(4), 199-203.

Manning, J. K., Cosby, A., Power, D., Fogarty, E. S., & Harreveld, B. (2022). A systematic review of the emergence and utilisation of agricultural technologies into the classroom. *Agriculture, 12*(6), 818.

Martinez, A. G., Porter, B., Rogé, P., Atwood, L., & Jiménez, N. P. (2020). Holistic pedagogies for social change: Reflections from an urban agroecology farmer training. In *Urban Agroecology* (pp. 209-228). CRC Press.

Mrabet, R. (2023). Sustainable agriculture for food and nutritional security. In *Sustainable agriculture and the environment* (pp. 25-90). Academic Press.

Muhie, S. H. (2022). Novel approaches and practices to sustainable agriculture. *Journal of Agriculture and Food Research*, *10*, 100446.

Nordstrom, K. L., Horner, C. E., Méndez, V. E., Izzo, V., Carpenter, N., Faulkner, J. W., & Caswell, M. (2022). An Undergraduate Agroecology Research Fellows Program Engages Co-learning Through Participatory Action Research. *Frontiers in Sustainable Food Systems*, *5*, 760995.

Olayemi, S. S., Alo Adeola Ope-Oluwa, A. A. O. O., & Angba, C. W. (2021). Evolution of agricultural extension models in Sub-Saharan Africa: A critical review. *International Journal of Agricultural Extension and Rural Development Studies*, *8*(1), 29-51.

Orzel, E. C. (2024). Sowing Sustainable Agriculture: Investigating" Sustainability" in the Academic Discourse on Precision Agriculture *(Doctoral dissertation, Université d'Ottawa/University of Ottawa).*

Pandey, P. C., & Pandey, M. (2023). Highlighting the role of agriculture and geospatial technology in food security and sustainable development goals. *Sustainable Development, 31*(5), 3175-3195.

Parums, D. V. (2021). Review articles, systematic reviews, meta-analysis, and the updated preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 guidelines. *Medical science monitor: international medical journal of experimental and clinical research, 27*, e934475-1.

Prajapati, C. S., Priya, N. K., Bishnoi, S., Vishwakarma, S. K., Buvaneswari, K., Shastri, S., ... & Jadhav, A. (2025). The role of participatory approaches in modern agricultural extension: bridging knowledge gaps for sustainable farming practices. *Journal of Experimental Agriculture International, 47*(2), 204-222.

Röling, N. (2019). The agricultural research-technology transfer interface: a knowledge systems perspective. In *Making the link* (pp. 1-42). CRC Press.

Sekhar, M., Rastogi, M., Rajesh, C. M., Saikanth, D. R. K., Rout, S., Kumar, S., & Patel, A. K. (2024). Exploring traditional agricultural techniques integrated with modern farming for a sustainable future: A review. *Journal of Scientific Research and Reports, 30*(3), 185-198.

Shutaleva, A. (2023). Ecological culture and critical thinking: building of a sustainable future. *Sustainability, 15*(18), 13492.

Sørensen, L. B., Germundsson, L. B., Hansen, S. R., Rojas, C., & Kristensen, N. H. (2021). What skills do agricultural professionals need in the transition towards a sustainable agriculture? A qualitative literature review. *Sustainability, 13*(24), 13556.

Sott, M. K., & Bender, M. S. (2025). The role of adaptive leadership in times of crisis: A systematic review and conceptual framework. *Merits, 5*(1), 2.

Tan, O. S. (2021). *Problem-based learning innovation: Using problems to power learning in the 21st century.* Gale Cengage Learning.

Valavanidis, A. (2023). Feeding a Growing World Population. *Critical rethinking of lessons from the "Green Revolution" in the 1960s as a warning for feeding a hungry planet, 1*, 1-47.

Watt, C. R. (2022). Diverse approaches in agriculture and education enhance problem-solving capacity. (Doctoral dissertation, MONTANA STATE UNIVERSITY Bozeman).

Weber, K. T. (1995). Behavioural factors affecting the adoption of sustainable practices. *European Review of Agricultural Economics*, 46(3), 417-436. https://academic.oup.com/erae/article/46/3/417/5499186

Wezel, A., Herren, B. G., Kerr, R. B., Barrios, E., Gonçalves, A. L. R., & Sinclair, F. (2020). Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development*, *40*(6), 40.

Zheng, X., Streimikiene, D., Balezentis, T., Mardani, A., Cavallaro, F., & Liao, H. (2019). A review of greenhouse gas emission profiles, dynamics, and climate change mitigation efforts across the key climate change players. *Journal of Cleaner Production*, *234*, 1113-1133.