The Promotion of Sustainable Agricultural Practices

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Abstract

Minimizing the ecological footprint created by agriculture is crucial, as it enables future generations to thrive in an environment that sustains a food supply, both in quality and quantity. Current agricultural practices are polluting the environment through the use of fertilizers and greenhouse gas emissions, significantly contributing to climate change and biodiversity loss. Both issues contribute to a large ecological footprint, which can be defined as the amount of materials required to support an individual's lifestyle. However, agricultural practices are advancing, aiming to decrease our ecological footprint and mitigate environmental impacts. Modern, sustainable agricultural practices have a positive impact on the environment by reducing pollution in the air, water, and soil. The goal of this review is to analyze strategies for promoting sustainable agriculture practices that minimize the ecological footprint. Technological innovations promote sustainable agriculture by providing methods to combat the globe's growing ecological footprint. Education about sustainable agriculture is crucial for ensuring food security for future generations, aligning with the United Nations' (UN) Sustainable Development Goal (SDG) of achieving Zero Hunger. Likewise, when education promotes experimental learning, it enables individuals to learn more about the impact of humans on the environment. Without food security, consumers would likely face struggles, including health concerns and higher prices. Policy makers draft laws to ensure the SDG of Responsible Consumption and Production of food for years to come. Economic incentives further encourage the implementation of said laws. The UN's SDGs of Climate Action, Zero Hunger, and Responsible Consumption and Production are common themes found in the literature. Throughout this review, researchers gained a deeper understanding of the numerous factors that influence agricultural sustainability.

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The Promotion of Sustainable Agricultural Practices

This review aims to answer the question: What roles do technological innovation, education initiatives, economic incentives, and policies play in advancing sustainable agricultural practices and reducing the ecological footprint? Sustainable agriculture is an approach that meets current food needs without harming the environment, depleting resources, or compromising the ability of future generations to farm (Doval, 2023). Promoting sustainable agriculture encompasses the technologies, education, policies, and economic incentives that encourage the adoption of sustainable practices. Sustainable agriculture is crucial for ensuring food security, economic stability, and environmental health. Innovative technologies—including precision agriculture, automation, and climate-smart tools—promote sustainable agriculture by increasing efficiency and minimizing the ecological footprint of agriculture through the mitigation of fertilizer runoff and greenhouse gas emissions. Through education, individuals can learn about how to promote sustainable agricultural practices that address the environmental issues facing society, specifically through experiential learning. This will, in turn, bridge the knowledge gaps, reconnect humans with the environment, and enable them to adopt sustainable practices. Policy and economic incentives promote environmentally friendly agriculture by supporting farmers who implement sustainable practices.

The negative impact of agricultural practices on the ecological footprint is a global issue that various countries and organizations, including the United Nations (UN), are attempting to remedy through the promotion of sustainable agriculture. The UN promotes sustainable agriculture through its Sustainable Development Goals (SDGs) of Climate Action, Zero Hunger, and Responsible Consumption and Production.

Problem Statement

Agriculture is one of the largest contributors to environmental degradation worldwide, accounting for nearly one-third of global greenhouse gas emissions, while also causing soil depletion, water pollution, and biodiversity loss (Doval, 2023). Small-scale farmers, who make up a large portion of global agricultural producers, often lack the financial resources, technical training, and policy support necessary to adopt sustainable methods. The minimal implementation of innovative technologies is due to high upfront costs, technical expertise requirements, and data concerns. These challenges create a wide gap between current practices and the urgent need for sustainable food systems. Without clear strategies to promote technology adoption, expand agricultural education, and restructure economic incentives, food security and environmental health will continue to be at risk for future generations.

Methods

In accordance with the rules of the Virginia Governor’s School of Agriculture (VGSA) and parameters agreed upon by group members, no sources were used before 2015. Academic research websites, including JSTOR and Google Scholar, were key tools throughout our research process. Information was categorized into four groups: technology, education, economics, and policies, to fully and effectively answer the research question.

Background

Agriculture significantly contributes to environmental degradation and increases the ecological footprint. Rising food demands due to population growth put pressure on farmers to prioritize short-term yield over long-term sustainability. In Virginia and beyond, traditional farming practices rely heavily on synthetic fertilizers, pesticides, and excessive tilling, which creates runoff, eutrophication, and climate instability (Water Resources Mission Area, 2019). When fertilizer runoff enters streams and rivers, the nitrogen and phosphorus it contains cause eutrophication (Water Resources Mission Area, 2019). The lack of dissolved oxygen suffocates plants and animals, hurting biodiversity (Water Science School, 2018). Excess nitrogen, while vital for farming, can pollute the environment (Shibata et al., 2017).

Our findings indicate that achieving sustainable agriculture is a process that requires innovative technology, experiential education, economic incentives, and effective policy. Collectively, these strategies reduce the environmental impact of agriculture, improve the welfare of small-scale farmers, and help achieve SDG goals.

Technology

Promoting the adoption of agricultural technology is an impactful strategy for reducing the ecological footprint of agriculture while also increasing crop yields. New technologies—like precision agriculture, automation, and climate-smart systems—help farmers effectively increase the input-to-output ratio. However, promoting these tools requires more than showcasing their benefits; it also means addressing the barriers that prevent the adoption of these practices. Practices like cooperative extension services and cooperative investments can accelerate the promotion of smart farming systems, overcoming these barriers. These systems reduce emissions, improve soil and water health, and prepare agriculture for the future.

To explore how these technologies can be promoted, it is important to explore how they work in practice. Precision agriculture is one of the most effective technologies for sustainability. It uses Geographic Information Systems (GIS), sensors, and data analytics to guide agricultural decisions. In Argentina, farmers use GIS software to monitor soil moisture and determine the optimal fertilizer type and amount for higher crop yields and less pollution (Young, 2020). Farmers were able to reduce fertilizer runoff, but they still had the same crop yield. Automation and robotics also play a critical role in minimizing the ecological footprint. China's smart farm pilot programs use AI-driven robots to plant, harvest, and manage crops with minimal human labor, lowering energy and water use while increasing productivity. Energy use is reduced because machines don't need to waste fuel or electricity by running inefficiently; water use is reduced by using sensors and data to apply irrigation only where and when crops actually need it. These examples illustrate how government-backed pilot programs and infrastructure investments can promote adoption by reducing the operational burden on farmers. Similarly, climate-smart technologies, such as hyperspectral drones and AI-powered weather models, help farmers efficiently manage crops and reduce resource waste at the risk of crop loss (Walter et al., 2017). Public investment, data platforms, and extension training are essential tools used globally to promote innovative technologies. These tools enable sustainable intensification by improving output without expanding farmland, which protects forests and biodiversity.

Figure 1:

Precision Agriculture Technology

Note: Precision agriculture technologies, such as GPS, help farmers analyze data and increase crop yields while using less effort (Young, 2020).

Despite their promising results and benefits, these technologies also face key adoption barriers that must be addressed through targeted promotion. First, the high upfront costs of precision tools and robotics prevent many small-scale farmers from investing in them. Second, few farmers have the technical expertise necessary to operate or maintain advanced automation systems (Lifestyle Sustainability, 2025). Third, the use of digital data in these automation tools raises concerns about privacy and ownership. Farmers worry about how their production data might be used by governments or corporations against them (Walter et al., 2017). These barriers show that promoting adoption requires a system that reduces costs, builds technical capability, and ensures data protection. These findings reinforce the idea that to reduce adoption barriers for best management practices (BMPs), tools must be accessible, trusted, and aligned with the needs of farmers and other stakeholders.

BMPs, agriculture practices that producers can take to reduce the amount of fertilizer, waste, and pollutants entering bodies of water, are essential for reducing these adoption barriers (Florida Department of Agriculture and Consumer Services, 2025). One method of promoting

BMPs is expanding cooperative extension programs that train farmers on how to use and maintain smart technologies. Extension services not only educate farmers but also build trust in the technologies being newly introduced (Langemeier & Shockley, 2021). Another BMP is promoting shared access to technology through cooperatives. In rural villages, for instance, drones and sensors can be jointly owned by multiple farms, spreading the cost while also increasing access (Walter et al., 2017). This model suggests that collaboration and community-based resource management can be powerful strategies for the widespread adoption of sustainable practices. Additionally, government incentives such as cost-sharing programs or tax credits can help mitigate financial risks for early adopters. Ensuring clear rules on data ownership, privacy, and what to share and what not to share also helps build confidence and trust in digital tools. These combined BMPs demonstrate that addressing adoption barriers requires not just individual effort, but a coordinated, combined system of education, investment, and regulation.

Overall, both the invention and its implementation, are essential for the promotion of sustainable agricultural technology. Precision tools, automation, and climate-smart systems can transform agriculture into a more efficient, eco-friendly system. This is only possible if farmers are supported with education, funding, and clear regulations on data privacy. As global temperatures rise and food security becomes more urgent, these tools offer the most optimal path towards a sustainable environment. This directly connects to the UN SDG 12, Responsible Consumption and Production, as these technologies help reduce waste, increase the output ratio, and manage resources more efficiently across farming systems. These innovations also directly align with the USDA's Agriculture and Food Research Initiative (AFRI) goal of Agriculture Systems and Technology, which focuses on developing tools and systems to improve productivity and efficiency of farms, while also prioritizing sustainability. By connecting Virginia's efforts in sustainable technology with this national priority, the state not only supports local farmers but also advances the USDA's mission of resource-efficient food production.

Education

Educating individuals on sustainable agricultural practices that minimize their ecological footprint is essential for the reconnection of individuals with nature, the increase of knowledge of the environments in which we reside, and the encouragement of collegiate students to further explore agriculture. Many collegiate students at land-grant universities, such as Virginia Tech, become engaged in real-world struggles and find active ways to address environmental degradation (Krebs et al., 2021). Many Americans are depriving themselves of living in harmony with their natural environment, as only 14% of the United States population resides in rural areas, according to data from 2020 (Krebs et al., 2021). Being out of touch with our environment can be detrimental to sustainability, as people will often inadvertently engage in actions that harm it. This disconnect can be resolved by integrating hands-on learning agricultural courses in schools. Instead of memorizing a handful of facts, individuals in urban and suburban areas can learn by experiencing the impact of ecological systems and current agricultural practices. As a result, the knowledge gap between individuals in urban and rural communities will be minimized. Examples of environmental challenges that sustainable agriculture education could address include climate change, water quality issues, concerns about water availability, depletion of natural resources, and the sudden loss of biodiversity (Krebs et al., 2021). By educating ourselves and others on sustainable agricultural practices, we help preserve resources such as water, minerals, and overall ecosystems, all through the process of hands-on, engaged learning.

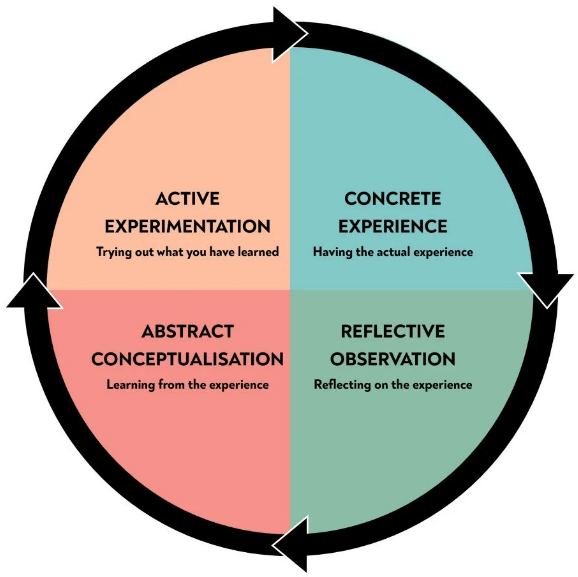
A major benefit of promoting sustainable agricultural practices is that it will address SDG 2, an initiative to end global hunger, as well as improve food nutrition and security. Without nutritious food, students will not have enough sustenance, physically or mentally, to make it through the day. Around 800 million people globally are experiencing malnourishment, leaving 95 million children under five years old underweight. Another 165 million are affected by undernutrition, which results in stunted growth. Children who experience stunted growth often face setbacks reaching their cognitive and developmental milestones (Baye, 2017). Unsustainable agricultural practices contribute to global poverty, educational failures, and gender inequality, which all contribute to the cause of hunger, malnutrition, and excess weight. During the UN's Sustainable Development Summit in New York the 25th of September, 2015, the SDGs addressed improving nutrition and sustainable agriculture without committing detrimental acts to the ecosystems around them (Baye, 2017).

Experiential learning is important in the context of sustainable agriculture because it enables students to develop technical knowledge and acquire practical life skills. Experiential learning, specifically utilized in agricultural land-grant institutions, is more accessible for students in interactive fields because it promotes the mission of cooperative extension, an overarching term for what happens as a result of experiential learning, and education through student-centered learning, personalized learning styles, and attentive focus on the process equal to the product (McKim et al., 2017). These priorities are executed through Kolb's method of learning, which begins with experiencing something concrete, followed by reflective observation, abstract conceptualization, and finally, active experimentation (McKim et al., 2017). Students will emerge with adaptable skills and a deeper understanding of real-world agricultural challenges, earned through experiential learning.

However, problems posed by experiential learning include three barriers that must be overcome for proper execution to occur. Firstly, experiential learning is not widely incorporated across all universities and colleges. Therefore, postsecondary educators, specifically those within agricultural colleges, need to receive further training to effectively implement experiential learning techniques in their classrooms. Next, student engagement requires outside guidance beyond concrete experiences, which includes reflections, conversations, conceptualizations, and applications, often facilitated by teachers. Lastly, teacher engagement is necessary to self-identify individualized opportunities for their students (McKim et al., 2017). Ultimately, the potential barriers one must overcome to effectively execute experiential learning are fewer in comparison to the benefits that promoting sustainable agricultural practices can result in. The promotion of sustainable agricultural practices through education and experiential learning programs enables individuals to acquire the knowledge necessary to help preserve our environment, ensure access to nutritious food, and promote overall health.

Figure 2:

David Kolb's Method of Learning



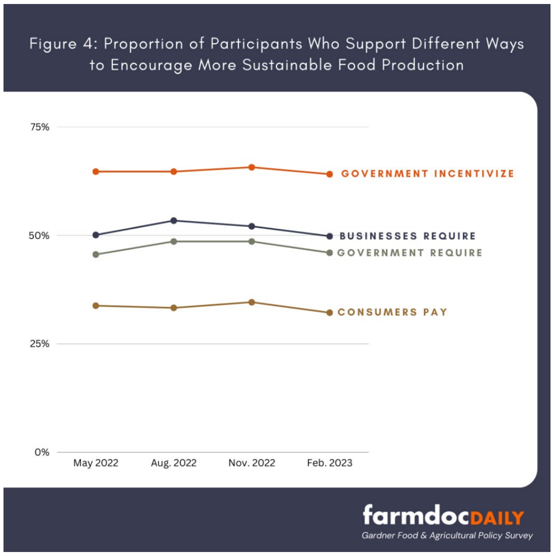
Note: David Kolb's Method of Learning emphasizes learning through the experience of a four-stage cycle (McLeod, 2025).

Economics

Acquiring the tools, resources, and equipment necessary for engaging in sustainable agricultural practices can often be difficult for small-scale farmers. Financial constraints and a lack of education about sustainable practices lead some farmers to perceive investing in eco-friendly agricultural practices as insufficient, resulting in a perceived lower return on investment. A study conducted in Thailand used logistic regression to identify the key factors influencing small-scale farmers' adoption of Good Agricultural Practices (GAP). It was found that demographic characteristics such as age, gender, race, income, education, and more were key factors in the adoption rate of GAP (Laosutsan et al., 2019). This suggests that one's income and education play a vital role in the adoption of sustainable agricultural practices. Even if small scale farmers adopt sustainable agricultural methods, they often cannot compete with large farmers who dominate the supply and demand chain. This makes it harder for them to benefit financially without additional support. They are already at a disadvantage; therefore, small farmers are hesitant and stick with conventional agricultural practices due to the lack of a transition safety net (Wartenberg et al., 2018). These barriers lead them to focus more on short-term outcomes than on the long-term benefits of adopting sustainable agricultural practices. This is why economic incentives are important. When individuals are offered financial security against loss, they are more likely to make that transition. Incentives can take many forms, including government subsidies, tax incentives, low-interest loans/grants, access to premium markets, and more.

Figure 3:

Proportion Of Participants Supporting Various Strategies To Promote Sustainable Food Production



Note: Government incentives received the highest level of support among participants. This suggests that financial assistance is widely viewed as a key solution for encouraging farmers to adopt sustainable agricultural practices (Kalaitzandonakes et al., 2023).

The poultry industry provides a clear example of how economic factors influence farmers' ability to adopt sustainable practices. A study conducted by Bist on sustainable poultry agricultural practices discussed the rising demand for poultry and sustainability. Organic poultry farming and certification were introduced as a solution to meet this demand, offering access to premium markets where consumers are willing to pay higher prices because of the guaranteed product quality. Organic poultry farming uses no antibiotics or genetically modified organisms in feed. Organic methods have lots of environmental benefits, including reduced pesticide use and improved animal welfare. However, the high cost of organic certification and implementation remains a barrier for many farmers (Bist et al., 2023). This highlights why farmers need economic incentives such as premium market access and subsidies to afford sustainable transitions. This ties back to SDG 2, Zero Hunger, as the objective of globalizing organic methods is to ensure long-term food security for low-income and small-scale farmers. Improved nutrition and food security will ensure improved health for all.

In the United States, over 20 billion dollars is spent on subsidies for farmers each year. In 2011, a study showed that 3% of farmers owned 30% of crop insurance subsidies (Mosquera, 2018). Subsidies for farmers are intended to manage risk. However, these subsidies mainly benefit large-scale farmers. Due to the insurance against losses, some large farmers are more likely to engage in risky and environmentally harmful practices. This occurs because insurance reduces the financial consequences of failure, so farmers prioritize higher yields and profits even if they damage the environment. This suggests that the crop insurance subsidy should be restructured to address harmful practices and ensure fairness. Instead of rewarding harmful and unjust practices, subsidies should be given to individuals who actively practice or plan to practice eco-friendly agricultural methods. Millions of dollars would be saved with the restructuring of the crop insurance subsidy program, which could then be used towards government-led economic incentives that encourage farmers to adopt eco-friendly methods (United Nations, 2025).

Policy

As the world globalizes, so does agriculture; and policy improves the adoption of sustainable agricultural practices. Agriculture has become more and more focused on commercialization and making a profit with low costs. Policy often fuels this with reduction and tax credits focused on creating the best margins possible. Instead, policy implementation should be focused on policy margins in relation to keeping agriculture sustainable and clean energy wise. However, policy implementation can be challenging, often due to the challenges associated with rural areas, including land fragmentation, income disparities, and product testing (NCSL, 2025). Nonetheless, including policy when starting a shift towards sustainable agriculture greatly outweighs the challenges associated with the problem.

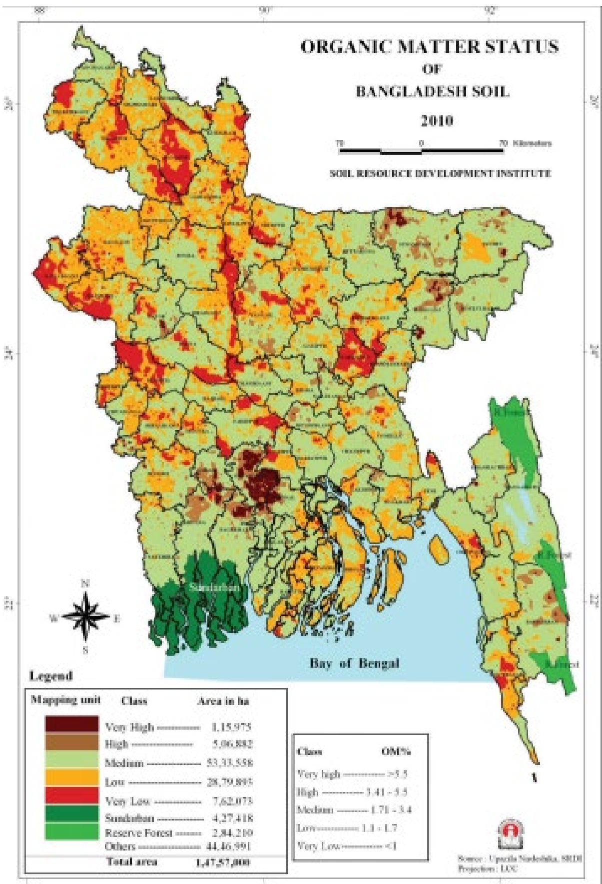
In Southeast Asia, large sections of soil and water are critically impacted by decades of unsustainable agricultural practices focused on profit and efficiency (Pereira et al., 2023). Specifically in Bangladesh and Nepal, soil degradation is critically impacted with 56% and 60% of soil missing critical organic materials, respectively (Cook et. al., 2016).

As Figure 4 shows, organic matter is largely depleted from the soil. This is due to the large usage of unnatural fertilizers that often bleach the soil, and the usage of various unsustainable agricultural practices like tilling. The usage of organic fertilizer is challenging due to various barriers, including up to two years for any fertilizer to be licensed, which leads to less use overall and fewer people applying for licenses (Government of the People’s Republic of Bangladesh’s Ministry of Agriculture, 2006). In those areas, the usage of policy is crucial to streamline the adaptation process for organic fertilizers and to open up the process to more individuals. By reducing the fees and lab requirements, the Bangladesh and Nepalese governments could set a model for an organic fertilizer testing global standard.

In addition, policy provides a foundation for greater change in the future. In China, the large population has relied on resource-intensive and commercialized agriculture to provide food for the country. This has led to rapid industrialization, negatively impacting the soil quality and decreasing organic nutrients. Industrialization creates a large income disparity between rural and urban areas, furthering agricultural fragmentation through the urbanization of land. The government aims to address these issues through the introduction of a policy designed to protect farmland by preventing it from being used for non-agricultural purposes (Wilkes et al., 2016). This solution, along with the introduction of circular farming, a circular agricultural system designed to reduce waste through nutrient recycling, will have a positive impact on the ecological footprint related to agriculture, aligning with UN SDG 12, which focuses on Responsible Production. By producing the food we eat sustainably, we can have a positive impact on the planet.

Figure 4:

Bangladesh Soil Quality



Note: This is a diagram of the organic matter in Bangeledhi soil. Large parts of the country have a very low status (Cook et. al., 2016).Around the world, efforts are being made to promote the adoption of sustainable agriculture. This is done by using policy to provide a stable base and streamline the process of implementing sustainable agriculture. By utilizing policy, the world can reduce its ecological footprint and take one step closer to achieving the UN's SDGs.

Future Direction

Despite our wide range of research, our review does not dwell heavily on local impacts or an abundance of specific examples. Further research includes exploring how to implement experiential learning and applying policies, economic incentives, and technology on a local scale.

Conclusion

Current agricultural practices are creating a large ecological footprint through environmental pollution. However, modern sustainable agricultural practices have the potential to minimize the ecological footprint by reducing greenhouse gas emissions and agricultural runoff. The practices themselves are important, but without the promotion of said practices, they would not be able to make a difference. Sustainable agricultural practices are promoted through the use of modern technologies, education, economic incentives, and effective policies. The pollution and runoff from agricultural practices are leading to issues such as biodiversity loss. The UN encourages the promotion of sustainable agriculture through its SDGs of Climate Action, No Hunger, and Responsible Consumption and Production.

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