

Farmers' Education, Adoption of Sustainable Practices, and Mitigation of Climate Change Effects of Land Clearing

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Abstract: The relationship of humans with the natural environment is at a critical juncture, with deforestation driven by agricultural expansion being a significant contributor to climate change. The study discusses the awareness of climate change and the environmental impact of farming practices among large landholders in the Kalaburagi district of Karnataka, India. Using a structured questionnaire, data were collected from 150 farm households across the region. The methodology involves multistage and random sampling, with econometric analyses such as linear, probit, and logit regression models employed to estimate sustainable practice adoption likelihood and the relationship between education and climate awareness. The findings show a significant gap in farmers' awareness regarding the broader implications of land clearing on climate change despite the econometric benefits derived from tree cutting and increased productivity. Educational interventions and access to information were identified as critical factors influencing the adoption of sustainable practices. The study concludes that educational programs and community involvement raise awareness and promote sustainable farming practices.

Keywords: climate change; deforestation; productivity; sustainable practice

1. Introduction

Sustainable farming is an approach to agriculture that seeks to balance productivity with environmental and social responsibility. The global push for sustainable agriculture has been driven by concerns about soil degradation, water scarcity, biodiversity loss, and climate change (Foley et al., 2011). Unsustainable farming practices, such as excessive tilling, monocropping, and heavy reliance on chemical inputs, have led to soil erosion, declining soil fertility, and increased greenhouse gas emissions (Lal, 2015). In response, researchers and policymakers have advocated for agricultural systems that maintain soil health, optimize water use, reduce reliance on synthetic inputs, and promote biodiversity. Soil conservation techniques are at the core of sustainable farming. Conservation tillage, which minimizes soil disturbance, has been shown to improve soil organic matter and structure, leading to greater water retention and reduced erosion (Hobbs et al., 2008). Crop rotation and cover cropping also play critical roles in enhancing soil fertility and controlling pests, as diverse cropping systems improve nutrient cycling and suppress weeds naturally (Kremen & Miles, 2012). Gattinger et al. (2012) found that organic farming practices, which emphasize composting and green manuring, can significantly increase soil carbon sequestration, contributing to climate change mitigation.

Water management is another essential component of sustainable farming, given that agriculture accounts for approximately 70 per cent of global freshwater withdrawals (FAO, 2020). Drip irrigation has emerged as an efficient alternative to traditional flood irrigation, reducing water waste and increasing crop yields (Feres & Soriano, 2007). Additionally, rainwater harvesting and soil moisture conservation techniques, such as mulching and agroforestry, have been widely adopted to improve water use efficiency (Rockström et al., 2010). Integrating drought-resistant crop varieties with efficient irrigation methods can help mitigate the adverse effects of climate change on agricultural productivity (Fischer et al., 2014).



Pest and disease management in sustainable farming relies on integrated pest management (IPM), which combines biological control, cultural practices, and resistant crop varieties to reduce dependence on synthetic pesticides. IPM strategies can lower pesticide use by 50–70 per cent while maintaining or even improving crop yields. Moreover, increasing on-farm biodiversity through practices like intercropping and hedgerows fosters natural pest control by attracting beneficial predators (Gurr et al., 2016). Agroforestry, which integrates trees into agricultural landscapes, has gained recognition for its ability to enhance soil fertility, provide habitat for biodiversity, and sequester carbon (Mbow et al., 2014). The integration of trees with crops and livestock not only diversifies farm income but also improves resilience to extreme weather events (Jose, 2009). Similarly, polyculture systems, where multiple crops are grown together, have been shown to outperform monocultures in terms of productivity and ecological benefits (Tilman et al., 2011).

Organic farming is a widely recognized sustainable practice that prohibits synthetic fertilizers and pesticides, instead relying on natural inputs and ecological processes. While organic yields are generally lower, they perform better under drought conditions and support greater biodiversity. Long-term experiments, such as the Rodale Institute's Farming Systems Trial, have shown that organic systems build healthier soils, reduce energy use, and improve carbon sequestration. However, critics argue that the large-scale adoption of organic farming may require more land to match conventional yields, raising concerns about its scalability (Connor, 2008). Recent advancements in precision agriculture have introduced technologies that enhance efficiency while minimizing environmental impact. GPS-guided tractors, drone monitoring, and soil-moisture sensors enable farmers to apply water, fertilizers, and pesticides with greater precision, reducing waste and pollution (Gebbers & Adamchuk, 2010). Precision farming techniques can increase yields by 10–15 per cent while lowering input costs and environmental footprint (Zhang et al., 2002). Sustainable farming practices, including conservation tillage, efficient water use, integrated pest management, agroforestry, organic farming, and precision agriculture, give promising solutions to the challenges facing modern agriculture. The transition to sustainable systems requires supportive policies, farmer education, and research investments to scale up these practices while ensuring food security.

Deforestation, driven primarily by agricultural expansion, poses a global environmental challenge with far-reaching consequences, particularly in regions like Kalaburagi, Karnataka. As the global demand for food and land surges, farming practices account for approximately 90 per cent of global deforestation, contributing significantly to climate change (Smith et al., 2021). The conversion of forests into farmland not only releases vast amounts of carbon but also accelerates biodiversity loss, soil degradation, and microclimatic disruptions. In Kalaburagi, large landholders prioritize economic gains over environmental concerns, leading to deforestation for agricultural productivity (Meyers & Singh, 2022). The nexus between agricultural expansion and deforestation shows the environmental and social costs that are often overlooked. Soil erosion, loss of organic matter, and diminished water retention are immediate consequences of tree clearing, which degrades the land's long-term productivity. This soil degradation further exacerbates the challenges faced by farmers, creating a vicious cycle of land depletion and deforestation. Moreover, the disruption of local climatic conditions and weather patterns due to tree loss threatens the region's climate stability, with unpredictable outcomes for ecosystems and agriculture alike (Kumar & Reddy, 2023).

While policymakers have implemented environmental laws, such as India's Forest Conservation Act of 1980, enforcement remains weak, allowing deforestation to persist under the guise of agricultural development (Varma & Joshi, 2024). Farmers' lack of awareness regarding the broader environmental impacts of deforestation, particularly on climate change, further exacerbates the issue. The literature stresses the need for policy reforms that integrate sustainable farming with environmental protection, suggesting that incentivizing conservation and involving local stakeholders can mitigate these impacts. Globally, successful cases of financial incentives for ecosystem conservation have reduced deforestation, providing models that India can adapt. Educational initiatives targeting farmers are crucial to raising awareness about sustainable practices, ultimately balancing agricultural productivity with environmental preservation.

2. Methodology

The study follows a positivist research philosophy, focusing on objective data collection and statistical analysis to examine the relationship between land clearing, climate change awareness, and the adoption of sustainable farming practices. A survey-based research strategy was employed using structured questionnaires to gather information from farmers in Kalaburagi district, Karnataka. The research is both descriptive and explanatory, aiming to assess trends and causal relationships between variables. Since data was collected at a single point in time, the study follows a cross-sectional time horizon rather than a longitudinal approach. Kalaburagi district was chosen due to its significant

agricultural expansion and associated deforestation, which impact climate change and soil degradation. It is considered one of the most backward regions in Karnataka, requiring policy interventions for sustainable agricultural development. In 2012, a resolution was passed by the Karnataka Legislative Assembly to promote inclusive growth in the Hyderabad-Karnataka (Kalyana-Karnataka) region, further justifying its selection. The study focused on large landholders, as their land-clearing activities have a major impact on deforestation and environmental sustainability. Multi-stage random sampling was used to select respondents. In the first stage, Kalaburagi district was chosen, followed by the selection of Aland Taluka in the second stage due to its extensive agricultural activity, the highest number of VA Circles (47), Hoblis (5), Grama Panchayats (42), and villages (120 inhabited + 1 uninhabited). Two panchayats were randomly selected in the third stage, and two villages from each panchayat were chosen in the fourth stage. The final sample comprised 150 farm households selected based on their engagement in land-clearing activities and willingness to participate in the study. Farmers who actively practiced agriculture and contributed to land clearing were included, while non-agricultural households, small and marginal farmers, and areas with minimal deforestation were excluded.

Data was collected using a structured questionnaire designed to cover multiple aspects, including demographic information such as age, gender, education, and farm size, climate change awareness, participation in sustainable farming education programs, adoption of sustainable practices like crop rotation and organic farming, and land-clearing activities. Before data collection, a pilot study with 15 farmers was conducted to ensure clarity and reliability of the questionnaire. Necessary modifications were made based on the pilot study, and Cronbach's alpha was calculated to assess internal consistency. Face-to-face interviews were conducted with farmers to ensure accuracy in responses. Econometric methods were employed for data analysis, including Linear, Probit, and Logit regression models to estimate the impact of education and climate awareness on the adoption of sustainable farming practices. Ordinary Least Squares (OLS) regression analyzed the relationship between education and climate change awareness. Fixed effects models were used to control for unobserved heterogeneity, ensuring robust results. Diagnostic tests, including Variance Inflation Factor (VIF) for multicollinearity, the Breusch-Pagan test for heteroskedasticity, and the Shapiro-Wilk test for normality of residuals, were conducted to validate regression assumptions and confirm the statistical reliability of the results. Participation in the study was voluntary, and all respondents provided informed consent before data collection. Confidentiality was ensured by anonymizing responses and removing personal identifiers. Farmers were fully informed about the study's objectives, and they were assured that their responses would be used solely for academic research purposes.

3. Results

The regression analysis of the relationship between the area cleaned and productivity, as shown in Panel (a) of Table 1, shows a significant relationship. The coefficient for the area cleaned is highly significant, meaning that as the area cleaned increases, productivity also rises considerably. This relationship suggests that land clearing plays a critical role in enhancing agricultural productivity, likely due to factors such as increased access to sunlight, nutrients, and water, all of which contribute to higher crop yields. In many agricultural systems, clearing land is associated with greater access to resources like sunlight and nutrients, which help improve crop yields.

Table 1

Panel (a)

Regression Result of Area Cleaned and Productivity over a Decade

Variables	Coefficient	Standard Error	t-Value	p-Value
Intercept	22.88	76.06	0.301	0.779
Area Cleaned	3189.49	81.79	38.995	<0.0001

Source: Author's Calculation

Panel (b)

Regression Result of Economic Benefit of Tree Selling over a Decade

Parameter	Estimate	Standard Error	t-value
Intercept (const)	-97.03	921.08	-0.105
Average No of tree cutdown	843.86	7.68	109.857***

*Source: Author's Calculation. Note: ***Significant at 1%*

In Panel (b), the analysis of the economic benefits of tree selling shows a strong and significant positive relationship between the number of trees cut down and the income generated from selling them. The highly significant coefficient for the number of trees cut down suggests that tree cutting plays a key role in generating income, particularly in areas where forestry activities are central to the local economy. While tree selling provides immediate financial benefits for communities, it also presents risks to forests if not managed sustainably. Deforestation and excessive tree harvesting can lead to biodiversity loss, disrupt water cycles, and degrade soils, all of which harm both the environment and local livelihoods in the long run. The significant boost in productivity that comes with clearing land leads to short-term economic benefits for farmers. These benefits might include higher crop yields, increased income, and improved food security, especially in rural regions where agriculture is the primary livelihood. There is a need for integrated land management approaches that consider both the economic and environmental aspects of tree selling. One such approach is promoting agroforestry systems that incorporate sustainable tree harvesting alongside agricultural production.

Several key variables—educational intervention, awareness level, access to information, income level, education level, and membership in agricultural groups—show a statistically significant positive effect on the likelihood of adopting sustainable practices. These findings emphasize the role of social and economic factors in driving the adoption of more sustainable farming methods, aligning with current research in this area. Educational intervention has the most substantial impact in adopting sustainable practices, with a highly significant coefficient and *p*-value. This suggests that educational programs designed to promote sustainable practices are particularly effective (See [Table 2](#)).

Table 2. Probit Regression for Adoption of Sustainable Practices.

Variable	Coefficient	Standard Error	<i>p</i> -Value
Educational Intervention	1.25	0.20	0.000***
Awareness Level	0.15	0.05	0.002***
Farm Size	-0.05	0.03	0.108
Access to Information	0.75	0.18	0.000***
Income Level	0.002	0.0005	0.005***
Age	-0.01	0.01	0.230
Education Level	0.10	0.04	0.015**
Membership in Agricultural Groups	0.90	0.22	0.000***
Control Variables			
Region	-	-	-
Crop Type	-	-	-
Weather Conditions	0.0001	0.00002	0.034**
Soil Quality	0.05	0.02	0.010**

Source: Author's Calculation

The OLS regression analysis for awareness level reveals several significant factors that contribute to higher awareness. Educational intervention stands out with a strong positive coefficient, indicating that educational programs significantly enhance awareness. Access to information also plays a crucial role, emphasizing the importance of making information readily available to improve awareness levels. Farm size has a positive and significant impact. That means larger farms are associated with higher awareness, possibly due to greater access to resources and information. Income level, although showing a smaller effect, still significantly contributes to awareness. This implies that higher income enables better access to awareness-building activities and resources. Age shows a negative and significant relationship with awareness. Hence, younger individuals tend to be more aware of sustainable practices. This could reflect generational differences in education and access to information. Education level is another significant positive factor indicating the importance of formal education in raising awareness. Membership in agricultural groups is strongly associated with higher awareness. Hence, community and group activities play an important role in spreading information and raising awareness. Among the control variables, weather conditions and soil quality also significantly affect awareness, suggesting that environmental factors influence the level of awareness among farmers. The analysis shows the determinants of awareness, with educational interventions, access to information, farm size, income, age, education level, and community involvement all playing significant roles. This emphasizes the need for comprehensive

strategies that incorporate these elements to effectively raise awareness levels (See Table 3).

Table 3. OLS Regression for Awareness Level.

Variable	Coefficient	Standard Error	p-Value
Educational Intervention	2.50	0.30	0.000***
Farm Size	0.10	0.05	0.040**
Access to Information	1.20	0.28	0.000***
Income Level	0.005	0.001	0.001***
Age	-0.05	0.02	0.015**
Education Level	0.20	0.07	0.005***
Membership in Agricultural Groups	1.80	0.35	0.000***
Control Variables			
Region	-	-	-
Crop Type	-	-	-
Weather Conditions	0.002	0.001	0.045**
Soil Quality	0.10	0.03	0.003***

Source: Author's Calculation. Note: ***Significant at 1%, **Significant at 5%, *Significant at 10%

4. Discussion

Land clearing, primarily for agricultural purposes, has been identified as a significant driver of climate change. Studies have shown that deforestation and land degradation contribute to carbon emissions, reduce biodiversity, and impact water cycles (Foley et al., 2005). The role of deforestation in contributing to 20-25 percent of global carbon emissions (IPCC, 2021). Removing trees without adequate reforestation has resulted in habitat damage, biodiversity loss, and aridity. It has been noted that deforested regions typically exhibit a marked increase in carbon dioxide levels and reduced global CO2 absorption, exacerbating global warming (Pan et al., 2011). Tilman et al. (2002) provide evidence of the benefits of sustainable farming practices, such as crop rotation, organic farming, and agroforestry, in maintaining ecological balance and reducing the need for land clearing. Adopting these practices can mitigate the adverse effects of traditional agriculture. This leads to better soil conservation, biodiversity, and reduced emissions. Farmers' awareness of climate change and environmental practices reveal varying levels of knowledge and engagement. Arbuckle et al. (2013) show that while some farmers acknowledge the impact of agricultural practices on the environment, many need more knowledge or resources to implement sustainable methods. Factors influencing farmers' decisions include economic considerations, cultural practices, and access to information and technology.

The financial implications of land clearing and sustainable practices are significant areas of study. Barbier (2004) and DeFries et al. (2004) examine how financial incentives, land ownership patterns, and policy frameworks influence farmers' decisions regarding land use. Effective policy measures, such as subsidies for sustainable practices, penalties for excessive land clearing, and support for reforestation programs, can significantly influence land management practices. Studies on the Amazon Basin, Southeast Asia, and Sub-Saharan Africa (Laurance et al., 2014) analyze the causes and consequences of deforestation. This highlights the need for region-specific strategies and awareness programs. Pradhan et al. (2015) describe how land-use changes, such as deforestation and clearing land for agriculture, can result in immediate gains in agricultural output. These gains occur because the cleared land often has richer, more fertile soil, especially if it was previously covered by forests. Forest soils tend to have high organic content that can initially support higher levels of productivity. However, the long-term consequences of these practices raise serious concerns. Lawrence and Vandecar (2015) provide a detailed analysis of how deforestation and land-use changes contribute significantly to rising atmospheric carbon

levels, which drive climate change. The conversion of forested land into agricultural areas releases large amounts of stored carbon into the atmosphere, worsening global warming. Agricultural activities themselves are major sources of greenhouse gas emissions, contributing to environmental harm. Practices like deforestation, intensive tilling, and the use of synthetic fertilizers add to agriculture's carbon footprint. While the regression results from Panel (a) show an increase in productivity, it is essential to also consider the environmental consequences tied to land clearing.

Lambin and Meyfroidt (2011) explore how economic factors relate to land degradation, noting that while land-use changes can initially result in economic gains, these practices often lack long-term sustainability. Over time, continuous clearing without proper management can lead to soil erosion, loss of fertility, and declining yields, undermining the initial economic gains and pushing rural communities into a cycle of land degradation and poverty. According to Mbow et al. (2014), agroforestry systems offer numerous benefits, including increased income for smallholders, improved food security, and better ecosystem services like carbon sequestration and soil fertility. In areas where tree selling is a key source of income, such as in Africa, Latin America, and Southeast Asia, agroforestry practices can help balance economic benefits from tree harvesting with environmental sustainability. Curtis et al. (2018) and Newbold et al. (2015) emphasize the importance of sustainable forest management practices, such as selective logging, reforestation, and protecting forested areas to conserve biodiversity and maintain ecosystem services. Sustainable forest management is crucial to ensuring the long-term benefits of tree selling. Griscom et al. (2017) note that forest degradation and deforestation can lead to the loss of critical ecosystem services, such as carbon storage, water regulation, and soil protection. These services are vital for local communities, especially in rural areas where access to clean water, fertile soil, and forest products is necessary for survival. Without sustainable practices, the economic benefits of tree selling may be short-lived, as degraded forests will be less able to support livelihoods over time.

Mbow et al. (2014) explain that agroforestry can provide numerous benefits, including increased income for farmers, improved food security, and enhanced ecosystem services like carbon storage and soil fertility improvement. By incorporating trees into agricultural landscapes, farmers can diversify their income, reduce their dependence on a single crop, and make their farming systems more resilient to climate change and environmental challenges. Research on agroforestry and sustainable land management suggests that a balanced approach to tree selling is essential to achieving long-term socio-economic and environmental gains. Jose (2009) notes that agroforestry systems can provide significant economic advantages for smallholders, especially in areas where access to land and resources is limited. By integrating trees into their farming systems, smallholders gain access to forest products, like timber, fuelwood, and fruits, which can either be sold for income or used for household needs. At the same time, these systems improve soil fertility, reduce erosion, and increase water retention, all of which contribute to sustainable long-term productivity.

Educational programs focused on sustainability increase awareness and provide farmers with the technical knowledge required to implement sustainable practices. These programs help bridge the gap between traditional farming methods and more sustainable approaches, fostering a deeper understanding of the long-term benefits of such practices, including improved soil health, water conservation, and reduced reliance on chemical inputs. Awareness level also plays a critical role, as indicated by its positive and significant coefficient. This suggests that the more aware farmers are of the benefits and methods of sustainable practices, the more likely they are to adopt them. Awareness can be shaped by both formal education and informal means, such as community discussions, local demonstrations, and exposure to sustainability campaigns. According to a study by Meijer et al. (2015), farmers who are more aware of environmental challenges, such as soil degradation and water scarcity, tend to adopt sustainable practices more readily. This finding highlights the importance of information dissemination in promoting sustainability in agriculture. Access to information is another key determinant in the adoption of sustainable practices. The coefficient for this variable is both positive and highly significant, indicating that farmers with better access to information are more likely to adopt these practices. Access to information can come through various channels, including agricultural extension services, media, and digital platforms. According to Kassie et al. (2015), access to timely and relevant agricultural information, particularly regarding new technologies and methods, plays a crucial role in adoption. Farmers need reliable sources of information to evaluate the costs and benefits of adopting new practices. In areas where access to information is limited, adoption rates of sustainable practices are often lower, as farmers may be unaware of the options available to them or lack confidence in their ability to implement these practices effectively. Income level also significantly influences the adoption of sustainable practices, though the effect is smaller compared to other factors. Higher income levels enable farmers to bear the initial costs associated with adopting sustainable practices, such as purchasing organic inputs or investing in new equipment. Low-income farmers may face financial constraints that hinder their ability to adopt sustainable methods, even if they are aware of the benefits. In their study on the adoption of conservation

agriculture, Baumgart-Getz et al. (2012) found that wealthier farmers were more likely to adopt sustainable practices because they could more easily afford the short-term costs associated with these practices. This highlights the importance of financial incentives or subsidies to encourage adoption among lower-income farmers. The role of education in influencing sustainable practice adoption is also significant in the probit analysis. Farmers with higher levels of education are more likely to adopt sustainable practices. This finding aligns with several studies that suggest that education enhances a farmer's capacity to process information, understand new technologies, and make informed decisions about farm management (Asfaw et al., 2016). Educated farmers are often more open to innovation and better equipped to evaluate the long-term benefits of sustainable farming, such as improved yield stability, reduced input costs, and environmental conservation.

Membership in agricultural groups is another significant factor in the adoption of sustainable practices. Farmers who are members of agricultural or community-based groups are more likely to adopt sustainable methods, as indicated by the positive and significant coefficient for this variable. Group membership facilitates knowledge sharing, collective decision-making, and access to resources that might not be available to individual farmers. Group dynamics can also encourage peer learning, where farmers adopt new practices based on the experiences of their peers. In a study on sustainable farming in East Africa, Nyanga (2012) found that farmers who participated in community groups were more likely to adopt conservation agriculture because they were exposed to the experiences and successes of other group members. Additionally, agricultural groups often provide members with access to technical support, financial resources, and markets, which further encourages adoption.

In contrast, farm size and age do not show significant effects on the adoption of sustainable practices. The lack of significance for farm size suggests that, regardless of whether a farm is large or small, other factors such as education, access to information, and community involvement are more influential. This is somewhat surprising, as farm size has traditionally been viewed as a factor that influences a farmer's capacity to implement new practices. However, small and large farms alike can benefit from sustainable practices, especially if they receive the necessary support and resources. The findings imply that policies aimed at promoting sustainability should not be exclusively targeted at larger farms but should also cater to smallholders, who often make up the majority of agricultural producers in many regions. Age is another variable that does not significantly affect the adoption of sustainable practices. While older farmers are often perceived as more resistant to change, the probit analysis suggests that age is not a determining factor in this context. This aligns with findings by Liu et al. (2018), who suggest that younger and older farmers alike can adopt sustainable practices if provided with the necessary education and resources. Rather than focusing on age, interventions should target other factors like awareness and information access, which seem to be more influential.

5. Conclusion

This study aimed to examine the impact of land clearing on agricultural productivity and economic benefits while assessing the broader environmental implications. The research specifically explored how deforestation-driven agricultural expansion influences short-term financial gains for farmers and the long-term sustainability of such practices. By employing econometric models, the study investigated the relationship between land clearing, productivity, income generation from tree selling, and the adoption of sustainable farming practices. The key findings indicate that land clearing significantly boosts agricultural productivity in the short term by improving access to sunlight, nutrients, and water. The regression analysis also confirms that tree selling is a major source of income, particularly for rural households reliant on forestry-related activities. However, these benefits come at the cost of long-term environmental sustainability. The study highlights the risks associated with excessive deforestation, including soil degradation, biodiversity loss, and increased carbon emissions. While educational interventions, access to information, and membership in agricultural groups positively influence the adoption of sustainable practices, financial incentives and policy support remain crucial in driving large-scale implementation.

These findings have important policy and industry implications. Policymakers must balance economic incentives with environmental conservation by introducing sustainable land management strategies. Reforestation programs, agroforestry promotion, and financial incentives for adopting sustainable practices can help mitigate the negative effects of land clearing while maintaining farm productivity. Strengthening agricultural extension services and increasing farmer awareness of climate change impacts are also vital for encouraging sustainable farming practices. The industry can play a key role by investing in sustainable supply chains, promoting responsible sourcing of agricultural products, and supporting farmers in adopting environmentally friendly practices. Future research should explore the long-term economic trade-offs of deforestation-driven agricultural expansion and assess how alternative land-use strategies can enhance sustainability without compromising farmer livelihoods.

Studies incorporating longitudinal data would provide deeper insights into the gradual effects of land degradation and climate variability. Additionally, research focusing on the effectiveness of policy interventions, such as conservation subsidies and carbon credit programs, would help design better frameworks for promoting sustainable agriculture. Addressing these gaps will contribute to a more comprehensive understanding of how agricultural growth can be achieved while ensuring environmental and economic sustainability.

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