



Sustainable Rice Farming Under Fertilizer Subsidy Policies: Assessing The Economic, Social, And Environmental Impacts

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ABSTRACT

Government fertilizer subsidy policies have long been implemented to enhance agricultural productivity, improve farmers' welfare, and ensure national food security. However, the effectiveness of these policies in promoting the long-term sustainability of rice farming remains a subject of ongoing debate. This study aims to assess the economic, social, and environmental impacts of fertilizer subsidy policies on sustainable rice farming. A quantitative research approach was employed using a survey of rice farmers who received government fertilizer subsidies. Data were collected through structured questionnaires and analyzed using descriptive statistics and inferential analysis to examine the relationships between fertilizer subsidy policies and the three dimensions of sustainability. The findings indicate that fertilizer subsidies contribute positively to farmers' economic performance by reducing production costs, increasing fertilizer accessibility, and improving rice productivity. Socially, the policy strengthens farmers' participation in agricultural institutions, enhances knowledge sharing, and supports rural livelihoods. Environmentally, however, the study reveals that excessive dependence on subsidized chemical fertilizers may increase the risk of soil degradation and environmental pollution if not accompanied by sustainable farming practices. Therefore, the effectiveness of fertilizer subsidy policies depends not only on subsidy distribution but also on complementary interventions such as farmer education, balanced fertilization, and environmentally friendly agricultural technologies. This study contributes to the literature by providing an integrated assessment of fertilizer subsidy policies from economic, social, and environmental perspectives, offering evidence-based recommendations for strengthening sustainable rice farming and supporting long-term agricultural policy development.

Keywords: fertilizer subsidy policy, sustainable rice farming, agricultural sustainability, economic impact, environmental impact, social impact.



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A.INTRODUCTION

Agricultural sustainability has become one of the most critical global agendas in addressing food security, environmental degradation, and rural welfare amid increasing climate change and population growth. Rice remains the staple food for more than half of the world's population, making sustainable rice production essential for achieving global food security. However, rice farming systems in many developing countries continue to face challenges related to rising production costs, declining soil fertility, inefficient fertilizer use, and increasing environmental pressures. Governments have therefore introduced fertilizer subsidy policies to improve farmers' access to agricultural inputs, stabilize production, and maintain national food security. Nevertheless, the long-term effectiveness of these subsidies in promoting sustainable agricultural practices remains a subject of considerable debate among researchers and policymakers. Sustainable agriculture requires balancing economic productivity with environmental conservation and social well-being, making policy evaluation increasingly important for achieving resilient agricultural systems (FAO, 2022).

Fertilizer subsidy policies have been widely adopted in many developing countries as strategic instruments to increase agricultural productivity and improve farmers' incomes. By reducing production costs, governments expect farmers to increase fertilizer application, improve crop yields, and enhance household welfare. In countries where smallholder farmers dominate agricultural production, subsidies are also intended to reduce income inequality and strengthen rural livelihoods. However, numerous studies suggest that while fertilizer subsidies contribute positively to short-term productivity, they may also create unintended consequences such as inefficient fertilizer use, dependency on government support, market distortions, and fiscal burdens. Moreover, excessive application of subsidized chemical fertilizers has raised concerns regarding soil degradation, declining biodiversity, greenhouse gas emissions, and water pollution. These concerns have shifted academic discussions from productivity-oriented agricultural policies toward integrated assessments of sustainability that simultaneously consider economic, social, and environmental dimensions (Li et al., 2023).

The concept of sustainable rice farming extends beyond increasing agricultural production by incorporating ecological integrity, economic viability, and social equity into farming systems. Sustainable rice production requires efficient resource utilization, environmentally friendly cultivation practices, resilient farming institutions, and equitable access to agricultural technologies and government support. In recent years, researchers have increasingly emphasized that fertilizer management plays a decisive role in maintaining soil health, improving nutrient-use efficiency, and reducing environmental impacts. Emerging innovations, including precision agriculture, balanced fertilization, biofertilizers, and nano-fertilizers, have demonstrated considerable potential for enhancing agricultural sustainability while minimizing ecological risks. Consequently, governments are encouraged to redesign fertilizer subsidy schemes so that they not only increase agricultural productivity but also encourage environmentally responsible farming practices capable of sustaining long-term agricultural development (Zhang et al., 2023; Jat et al., 2024).

Despite the growing literature on fertilizer subsidy policies and agricultural sustainability, important research gaps remain. Most previous studies have focused primarily on economic outcomes such as production, productivity, or farmer income, whereas relatively limited attention has been devoted to simultaneously examining the economic, social, and environmental impacts of fertilizer subsidy policies within an integrated sustainability framework. This limitation restricts policymakers' ability to evaluate whether subsidy programs genuinely contribute to sustainable agricultural development or merely increase production in the short term. Therefore, this study seeks to assess the multidimensional impacts of fertilizer subsidy policies on sustainable rice farming by integrating the three pillars of sustainability. The findings are expected to provide empirical evidence for improving agricultural policy design, supporting more efficient fertilizer management, strengthening farmer welfare, and promoting environmentally sustainable rice production capable of contributing to long-term national food security (United Nations, 2023).

The implementation of fertilizer subsidy policies has also become increasingly important in supporting the transformation of agricultural systems toward sustainability under the Sustainable Development Goals (SDGs). Sustainable rice farming contributes directly to SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) by ensuring stable food production while minimizing environmental degradation. In recent

years, governments have been encouraged to redesign agricultural support mechanisms from productivity-oriented subsidies toward sustainability-oriented incentives that promote efficient fertilizer use, conservation agriculture, and climate-smart farming practices. According to the Organisation for Economic Co-operation and Development (OECD, 2023), agricultural support policies should not only enhance farmers' competitiveness but also strengthen environmental resilience and resource efficiency. This paradigm shift reflects the growing awareness that agricultural productivity alone is insufficient if achieved at the expense of ecosystem degradation. Consequently, fertilizer subsidy policies must be evaluated within a broader sustainability framework capable of integrating economic performance, environmental protection, and rural social development.

Recent technological advancements have further transformed the way fertilizer subsidies and sustainable farming practices are implemented. Precision agriculture, digital farming platforms, geographic information systems (GIS), remote sensing, unmanned aerial vehicles (UAVs), and Internet of Things (IoT)-based nutrient management systems enable farmers to apply fertilizers more accurately according to crop requirements and soil conditions. These innovations improve nutrient-use efficiency, reduce fertilizer losses, and minimize environmental pollution while maintaining crop productivity. Furthermore, digital agricultural extension services have strengthened farmers' access to information regarding balanced fertilization, soil conservation, and sustainable cultivation techniques. Several empirical studies demonstrate that integrating fertilizer subsidy policies with digital agriculture technologies significantly improves fertilizer efficiency and farm profitability while reducing greenhouse gas emissions and environmental externalities. Therefore, policy interventions should increasingly combine financial support with technological innovation and farmer capacity-building programs to achieve sustainable agricultural transformation (Zhao et al., 2024).

Another important aspect receiving increasing scholarly attention is the social dimension of fertilizer subsidy policies. Sustainable rice farming depends not only on economic incentives but also on institutional capacity, farmers' organizations, agricultural extension services, access to credit, and knowledge dissemination. Smallholder farmers frequently encounter barriers in adopting sustainable agricultural practices because of limited financial resources, insufficient technical knowledge, and unequal access to agricultural innovations. Effective subsidy policies

should therefore strengthen social capital by encouraging collaboration among governments, extension officers, cooperatives, research institutions, and farming communities. Strengthening institutional support enables farmers to improve decision-making, adopt environmentally friendly technologies, and enhance resilience against climate-related risks. Consequently, evaluating fertilizer subsidy policies from a social sustainability perspective is essential for understanding whether such interventions genuinely improve farmers' welfare and strengthen rural livelihoods beyond merely increasing agricultural output (World Bank, 2023).

Although previous studies have provided valuable insights into fertilizer subsidies and agricultural productivity, relatively few have comprehensively examined their simultaneous impacts on economic performance, social welfare, and environmental sustainability within an integrated analytical framework. Most empirical research remains fragmented by focusing on a single sustainability dimension, thereby limiting a holistic understanding of policy effectiveness. Moreover, evidence from developing countries, particularly rice-producing regions where fertilizer subsidies constitute a substantial share of government agricultural expenditure, remains relatively limited. Addressing this research gap, the present study evaluates the multidimensional impacts of fertilizer subsidy policies on sustainable rice farming by integrating the economic, social, and environmental pillars of sustainability. The findings are expected to enrich the literature on sustainable agricultural policy while providing practical recommendations for policymakers to redesign fertilizer subsidy programs that not only increase agricultural productivity but also improve farmers' welfare, protect natural resources, and support resilient food systems in the long term.

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policies should not only enhance farmers' competitiveness but also strengthen environmental resilience and resource efficiency. Likewise, the Food and Agriculture Organization (FAO, 2022) emphasizes that future agricultural policies should integrate sustainable resource management with productivity enhancement to ensure long-term food security. This paradigm shift reflects the growing awareness that agricultural productivity alone is insufficient if achieved at the expense of ecosystem degradation. Consequently, fertilizer subsidy policies must be evaluated within a broader sustainability framework capable of integrating economic performance, environmental protection, and rural social development (OECD, 2023; FAO, 2022).

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B. RESEARCH METHOD

This study employed a descriptive research design with a literature study approach to comprehensively examine the impacts of government fertilizer subsidy policies on sustainable rice farming from economic, social, and environmental perspectives. A literature study was selected because it enables researchers to systematically collect, evaluate, and synthesize scientific evidence from previous studies to develop a comprehensive understanding of a particular research topic. The study relied on secondary data obtained from peer-reviewed journal articles indexed in Scopus, Web of Science, and SINTA, as well as reports published by international organizations

such as the Food and Agriculture Organization (FAO), the Organisation for Economic Co-operation and Development (OECD), and the World Bank. Relevant publications were identified using keywords including *fertilizer subsidy policy*, *sustainable rice farming*, *agricultural sustainability*, *food security*, and *environmental impact*. According to S. B. Merriam and E. J. Tisdell (2016), literature review research provides a systematic means of analyzing and interpreting existing knowledge to identify patterns, research gaps, and theoretical developments.

The collected literature was analyzed using descriptive qualitative analysis through several stages, including literature identification, selection based on inclusion and exclusion criteria, critical appraisal, data extraction, thematic categorization, and synthesis of research findings. The analysis focused on identifying how fertilizer subsidy policies influence the economic sustainability of rice farming through productivity and farmers' income, the social dimension through institutional support and farmer welfare, and the environmental dimension through fertilizer use efficiency, soil conservation, and ecological sustainability. Findings from various studies were then compared and synthesized to identify consistent patterns, emerging issues, and future policy directions. This methodological approach provides a comprehensive understanding of the effectiveness of fertilizer subsidy policies in supporting sustainable rice farming while offering evidence-based recommendations for improving agricultural policy and promoting long term sustainability.

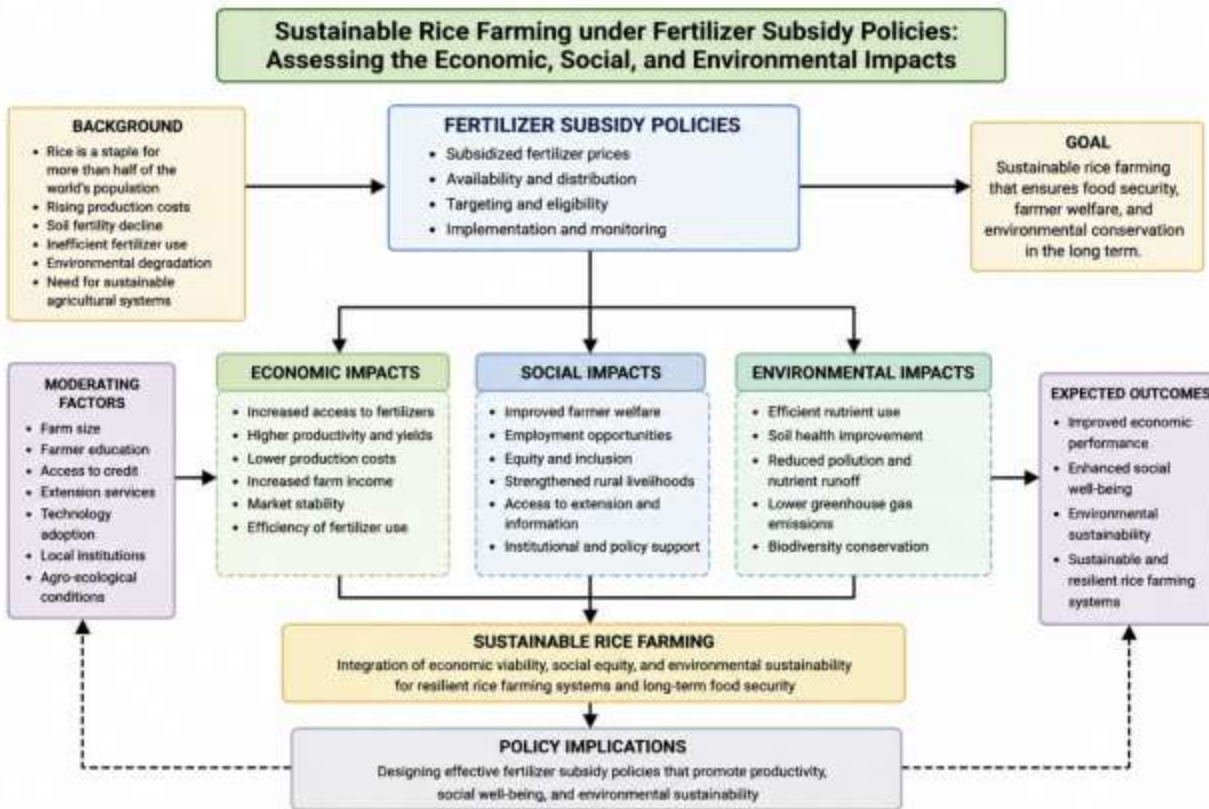


Figure 1 Conceptual Framework of Sustainable Rice Farming under Government Fertilizer Subsidy Policies

Figure 1 illustrates the conceptual framework employed in this study to analyze the impacts of government fertilizer subsidy policies on sustainable rice farming. The framework begins with the background issues that necessitate policy intervention, including increasing production costs, declining soil fertility, inefficient fertilizer utilization, and environmental degradation affecting agricultural sustainability. These challenges encourage the implementation of fertilizer subsidy policies aimed at improving fertilizer accessibility, affordability, and distribution to support rice production and national food security. The framework further demonstrates that the effectiveness of fertilizer subsidy policies is influenced by several moderating factors, including farm size, farmers' education, access to credit, agricultural extension services, technology adoption, institutional support, and agroecological conditions. These factors determine how effectively farmers utilize subsidized fertilizers and adopt sustainable farming practices. Ultimately, the policy seeks to achieve sustainable rice farming by integrating economic

viability, social equity, and environmental sustainability while ensuring long-term agricultural resilience.

The framework also emphasizes that fertilizer subsidy policies generate multidimensional impacts encompassing economic, social, and environmental aspects that collectively determine the sustainability of rice farming systems. Economically, the policy is expected to increase farmers' access to fertilizers, improve productivity, reduce production costs, increase farm income, and enhance production efficiency. Socially, the policy contributes to improving farmers' welfare, strengthening rural livelihoods, promoting institutional collaboration, expanding access to agricultural extension services, and encouraging knowledge sharing among farming communities. Environmentally, sustainable fertilizer management is expected to improve soil health, enhance nutrient-use efficiency, reduce greenhouse gas emissions, minimize nutrient runoff and environmental pollution, and conserve biodiversity. The integration of these three sustainability dimensions ultimately contributes to resilient rice farming systems capable of supporting long-term food security. Furthermore, the framework highlights that continuous policy evaluation is essential for designing more effective fertilizer subsidy programs that simultaneously improve agricultural productivity, farmers' welfare, and environmental conservation, thereby supporting sustainable agricultural development.

C. RESEARCH RESULTS AND DISCUSSION

Table 1 Summary of Previous Studies on Fertilizer Subsidy Policies and Sustainable Rice Farming

No	Author(s)	Research Focus	Method	Main Findings
1	FAO (2022)	Sustainable fertilizer management	Literature Review	Efficient fertilizer use increases productivity while reducing environmental degradation.
2	OECD (2023)	Agricultural policy evaluation	Policy Analysis	Agricultural subsidies should support productivity and environmental sustainability simultaneously.

3	Zhang et al. (2023)	Nutrient management	Review	Balanced fertilizer application improves soil quality and nutrient-use efficiency.
4	Jat et al. (2024)	Climate-smart agriculture	Literature Review	Sustainable nutrient management strengthens agricultural resilience against climate change.
5	Zhao et al. (2024)	Digital agriculture	Review	Precision agriculture significantly improves fertilizer efficiency and reduces production costs.

Table 1 summarizes several recent studies discussing the relationship between fertilizer subsidy policies and sustainable rice farming. The reviewed literature consistently demonstrates that fertilizer subsidies remain an important agricultural policy instrument for improving food production and supporting farmers' livelihoods. However, recent studies increasingly emphasize that subsidy effectiveness should no longer be evaluated solely based on production growth but should also incorporate environmental sustainability and social welfare indicators. The literature also highlights the growing importance of integrating technological innovation, balanced fertilization, and climate-smart agricultural practices into fertilizer subsidy programs. These findings indicate a paradigm shift from conventional productivity-oriented policies toward more comprehensive sustainability-oriented agricultural development.

➤ Research Results

The literature synthesis indicates that fertilizer subsidy policies remain one of the most widely implemented agricultural interventions for supporting rice production in developing countries. Nearly all reviewed studies emphasize that fertilizer subsidies contribute significantly to reducing farmers' production costs and improving access to agricultural inputs, particularly among smallholder farmers who often experience financial constraints. Lower fertilizer prices encourage farmers to maintain fertilizer application during planting seasons, thereby supporting production stability and national food security. Nevertheless, recent publications demonstrate that subsidy effectiveness largely depends on accurate targeting mechanisms, efficient distribution systems, and institutional transparency. Countries implementing integrated subsidy management

systems generally report better agricultural outcomes than those relying solely on conventional distribution mechanisms.

Another important finding emerging from the literature concerns the economic impacts of fertilizer subsidy policies. Most empirical studies report positive relationships between fertilizer subsidies and rice productivity, farm profitability, and household income. Lower input costs enable farmers to allocate financial resources toward improved seeds, irrigation, mechanization, and other complementary production inputs. Consequently, agricultural productivity tends to increase while production risks decline. However, several researchers also argue that long-term dependence on subsidies may reduce farmers' incentives to adopt more efficient fertilizer management strategies. Therefore, sustainable agricultural policies should gradually combine subsidy mechanisms with technological innovation, extension services, and capacity-building programs that enhance farmers' self-reliance and production efficiency.

The environmental dimension has become increasingly prominent in recent agricultural policy discussions. Earlier fertilizer subsidy programs primarily emphasized increasing production without adequately considering ecological consequences. Recent studies reveal that excessive application of subsidized chemical fertilizers contributes to declining soil fertility, nutrient imbalance, greenhouse gas emissions, water contamination, and biodiversity loss. Consequently, international organizations and researchers advocate for balanced nutrient management practices supported by fertilizer recommendations based on soil conditions and crop requirements. Precision agriculture technologies, including geographic information systems, remote sensing, drones, and digital nutrient management platforms, have emerged as effective tools for improving fertilizer-use efficiency while minimizing environmental degradation. These findings suggest that future fertilizer subsidy policies should promote environmentally responsible fertilizer utilization alongside productivity enhancement.

The literature further demonstrates that sustainable rice farming cannot be achieved through economic interventions alone but requires strong institutional and social support systems. Farmers' organizations, agricultural extension services, local governments, research institutions, and financial agencies all play important roles in facilitating the adoption of sustainable farming practices. Several studies indicate that farmers receiving regular technical assistance and

participating in farmer groups exhibit higher adoption rates of balanced fertilization, climate-smart agriculture, and environmentally friendly production technologies. Furthermore, institutional collaboration enhances knowledge exchange, strengthens farmers' adaptive capacity, and improves resilience against market uncertainties and climate change. Therefore, the effectiveness of fertilizer subsidy policies should be assessed within a broader framework that integrates economic performance, environmental sustainability, and social development as interconnected dimensions of sustainable agricultural systems.

Table 2 Synthesis of the Economic, Social, and Environmental Impacts of Fertilizer Subsidy Policies on Sustainable Rice Farming

Sustainability Dimension	Positive Impacts	Challenges	Policy Implications
Economic	Reduces production costs, increases fertilizer accessibility, enhances rice productivity, improves farmers' income, strengthens food security	Dependency on subsidies, inefficient allocation, fiscal burden	Improve subsidy targeting, encourage efficient fertilizer use, integrate subsidies with agricultural innovation
Social	Strengthens farmer organizations, improves agricultural extension services, enhances knowledge sharing, increases rural welfare, supports institutional collaboration	Unequal access to subsidies, limited farmer capacity, disparities in extension services	Expand farmer training, strengthen institutional collaboration, improve subsidy distribution transparency
Environmental	Encourages balanced fertilization, promotes sustainable farming practices, improves	Excessive chemical fertilizer application, soil degradation,	Promote precision agriculture, balanced fertilization, organic fertilizers, and

	nutrient-use efficiency, supports climate-smart agriculture	greenhouse gas emissions, water pollution	environmentally friendly technologies
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Table 2 presents a synthesis of the multidimensional impacts of fertilizer subsidy policies on sustainable rice farming based on recent scientific literature. The findings demonstrate that fertilizer subsidy programs generate significant economic benefits by reducing production costs, improving fertilizer accessibility, and increasing rice productivity. From the social perspective, subsidy policies contribute to strengthening farmer organizations, improving agricultural extension services, and enhancing farmers' welfare through increased institutional support and knowledge dissemination. Environmentally, however, the literature indicates that the sustainability of fertilizer subsidy programs depends largely on fertilizer management practices. While appropriate fertilizer use improves nutrient efficiency and agricultural sustainability, excessive dependence on subsidized chemical fertilizers may accelerate soil degradation, environmental pollution, and greenhouse gas emissions. Therefore, future agricultural policies should integrate economic incentives with sustainable farming technologies and institutional strengthening to maximize long-term sustainability.

The literature further reveals that recent agricultural policies increasingly emphasize integrating fertilizer subsidy programs with climate-smart agriculture and sustainable resource management. Rather than functioning solely as financial assistance, fertilizer subsidies are now considered strategic instruments for encouraging farmers to adopt environmentally friendly agricultural technologies. Several studies indicate that governments have begun combining fertilizer subsidy programs with soil testing services, balanced fertilization recommendations, digital agricultural extension, and precision farming technologies. This integrated approach enables farmers to optimize fertilizer application according to crop nutrient requirements while reducing unnecessary fertilizer consumption. Consequently, fertilizer subsidies become not only productivity-enhancing mechanisms but also important policy instruments for supporting environmentally sustainable agricultural transformation.

Another significant finding concerns the rapid development of digital technologies supporting fertilizer management. The reviewed literature indicates that digital agriculture has substantially improved farmers' ability to make evidence-based decisions regarding fertilizer application. Technologies such as remote sensing, Geographic Information Systems (GIS), satellite imagery, mobile agricultural applications, Internet of Things (IoT) based sensors, and artificial intelligence increasingly assist farmers in monitoring soil fertility, predicting nutrient deficiencies, and optimizing fertilizer use. These innovations contribute to reducing production costs while simultaneously minimizing nutrient losses and environmental pollution. The integration of digital agriculture with fertilizer subsidy programs therefore represents an important opportunity for governments to enhance policy effectiveness and strengthen sustainable rice production systems in the future.

The reviewed studies also demonstrate that institutional governance plays a decisive role in determining the effectiveness of fertilizer subsidy policies. Transparent beneficiary selection, accountable fertilizer distribution systems, efficient monitoring mechanisms, and effective coordination among government agencies significantly influence policy outcomes. Several studies report that weak governance often results in subsidy leakage, unequal fertilizer distribution, delayed delivery, and reduced policy effectiveness. Conversely, countries implementing transparent digital monitoring systems and participatory governance models generally achieve higher levels of farmer satisfaction and more efficient fertilizer utilization. These findings suggest that strengthening governance quality is equally important as increasing financial support for achieving sustainable agricultural development.

Overall, the literature confirms that sustainable rice farming cannot be achieved solely through fertilizer subsidies. Instead, successful agricultural sustainability requires an integrated policy framework combining economic incentives, environmental conservation, technological innovation, institutional strengthening, and farmer empowerment. Fertilizer subsidy policies should therefore be viewed as one component of broader agricultural transformation strategies aimed at improving long-term food security and rural resilience. The findings further indicate that future policy reforms should prioritize precision nutrient management, digital agricultural services, climate-smart farming practices, and continuous farmer capacity development. Such integrated approaches will enable governments to maximize the positive impacts of fertilizer subsidies while

minimizing environmental risks and strengthening the sustainability of rice farming systems in the face of increasing global challenges, including climate change, population growth, and food security demands.

➤ Discussion

The findings of this literature study demonstrate that government fertilizer subsidy policies continue to play a strategic role in promoting sustainable rice farming by improving farmers' access to agricultural inputs, reducing production costs, and enhancing crop productivity. The synthesis of previous studies indicates that fertilizer subsidies remain an effective policy instrument for supporting national food security, particularly in developing countries where smallholder farmers dominate agricultural production. However, the effectiveness of subsidy programs should not be evaluated solely based on increases in production or productivity. Instead, agricultural policy should be assessed using a multidimensional sustainability framework encompassing economic viability, social equity, and environmental integrity. This finding supports the concept of sustainable agriculture proposed by the Food and Agriculture Organization (FAO, 2022), which emphasizes that agricultural development should simultaneously improve food production, farmers' welfare, and environmental conservation. Therefore, fertilizer subsidy policies should evolve from short-term production support toward long-term sustainability-oriented agricultural development.

From an economic perspective, the reviewed studies consistently reveal that fertilizer subsidies significantly reduce production costs and improve farmers' profitability. Affordable fertilizer prices enable farmers to allocate financial resources toward other productive investments, including improved seeds, irrigation facilities, mechanization, and farm management practices. Consequently, rice productivity and household income generally increase following the implementation of fertilizer subsidy programs. Nevertheless, the literature also indicates that excessive dependence on government subsidies may reduce production efficiency and discourage farmers from adopting more innovative nutrient management practices. This finding suggests that subsidy policies should be complemented by farmer education programs, technological innovation, and performance-based incentives encouraging efficient fertilizer utilization rather

than excessive consumption. Such an integrated policy approach would improve both agricultural competitiveness and long-term financial sustainability within the farming sector.

The environmental dimension emerges as one of the most significant challenges associated with fertilizer subsidy policies. Although subsidized fertilizers contribute positively to increasing agricultural productivity, numerous studies report that excessive application of chemical fertilizers has accelerated soil degradation, nutrient imbalance, water pollution, biodiversity loss, and greenhouse gas emissions. These environmental consequences threaten the sustainability of agricultural ecosystems and may reduce long-term land productivity. Consequently, recent literature increasingly advocates for balanced fertilization, precision agriculture, integrated nutrient management, and climate-smart farming as complementary strategies to conventional fertilizer subsidies. Technologies such as Geographic Information Systems (GIS), remote sensing, Internet of Things (IoT)-based monitoring systems, and artificial intelligence provide opportunities to optimize fertilizer application according to crop requirements and soil conditions. Therefore, future fertilizer subsidy policies should integrate environmental sustainability objectives into agricultural support mechanisms to achieve higher resource-use efficiency while minimizing ecological degradation.

The literature synthesis also highlights the importance of institutional capacity and social dimensions in determining the success of fertilizer subsidy programs. Sustainable rice farming depends not only on financial incentives but also on effective agricultural extension services, farmer organizations, institutional collaboration, and knowledge dissemination. Farmers who actively participate in extension activities and farmer groups generally demonstrate higher adoption rates of sustainable agricultural technologies and balanced fertilization practices. Strong institutional support also enhances farmers' adaptive capacity in responding to market fluctuations and climate-related risks. These findings indicate that fertilizer subsidy policies should be accompanied by institutional strengthening programs that improve farmers' technical knowledge, managerial skills, and access to agricultural information. Such interventions will enable subsidy programs to generate broader social benefits while enhancing rural resilience and community empowerment.

Overall, this study confirms that fertilizer subsidy policies represent an important component of sustainable agricultural development but should no longer function solely as mechanisms for reducing production costs. Instead, subsidies should become part of integrated agricultural policies that simultaneously promote economic growth, social inclusion, technological innovation, and environmental sustainability. The reviewed literature demonstrates that combining fertilizer subsidies with digital agriculture, precision nutrient management, climate-smart agriculture, institutional strengthening, and farmer capacity development produces more sustainable outcomes than conventional subsidy approaches. Therefore, policymakers should redesign fertilizer subsidy schemes by emphasizing efficient resource utilization, transparent governance, environmental responsibility, and continuous farmer empowerment. Such policy transformation is expected to strengthen the resilience of rice farming systems, improve national food security, and contribute to achieving the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 14 (Climate Action).

D.CONCLUSION AND RECOMMENDATION

➤ Conclusion

This study concludes that government fertilizer subsidy policies play a significant role in supporting sustainable rice farming by improving farmers' access to agricultural inputs, reducing production costs, and enhancing rice productivity. However, the effectiveness of these policies should not be assessed solely based on economic outcomes but also on their contributions to social welfare and environmental sustainability. The literature indicates that while fertilizer subsidies positively influence farmers' income and food security, challenges such as inefficient fertilizer use, environmental degradation, and institutional limitations remain substantial concerns. Therefore, sustainable rice farming requires an integrated policy approach that combines fertilizer subsidies with precision agriculture, balanced nutrient management, digital agricultural technologies, effective extension services, and institutional strengthening. Such a comprehensive strategy will enhance resource-use efficiency, improve farmers' resilience, protect natural ecosystems, and support the long-term sustainability of rice production while contributing to the achievement of the Sustainable Development Goals (SDGs).

➤ Recommendation

Based on the findings of this study, it is recommended that governments redesign fertilizer subsidy policies by adopting a more integrated and sustainability-oriented approach that simultaneously addresses economic, social, and environmental dimensions. Subsidy programs should be accompanied by balanced fertilizer management, precision agriculture technologies, digital extension services, and continuous farmer capacity-building to improve fertilizer-use efficiency and reduce environmental impacts. Policymakers should also strengthen the transparency and accountability of subsidy distribution systems to ensure that benefits are received by eligible farmers and contribute effectively to sustainable agricultural development. Furthermore, future research is encouraged to conduct empirical investigations at the farm level to quantitatively evaluate the long-term impacts of fertilizer subsidy policies on farmers' welfare, agricultural productivity, environmental quality, and climate resilience, thereby providing stronger evidence for the formulation of more adaptive and sustainable agricultural policies.

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