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Application of Soil Amendment to Improve Farmer's Income in Corn, Beans, Cotton, Soybeans, Kales and Mustard Production in the United States of America

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ABSTRACT

This study evaluates the impact of soil amendment applications on improving farmers' income in the production of corn, beans, cotton, soybeans, kale, and mustard greens in the United States. By examining various soil amendment practices, this research aims to identify the most effective methods for enhancing soil fertility, crop yields, and overall profitability for farmers. This study used a descriptive research design and secondary data sources. The dataset was retrieved from the archives of the USDA National Agricultural Statistics Service (NASS), USDA Economic Research Service (ERS), and relevant scientific studies. The dataset period ranges from 2000 to 2022. As part of the findings, this study found that the application of compost and biochar significantly improved corn yields. On average, corn fields treated with compost saw a 15% increase in yields, while biochar treatments resulted in a 20% yield improvement. The study further reveals that the increased yields from soil amendments led to higher incomes for corn farmers, whereby on average, corn farmers experienced a $150 per acre increase in profit due to the yield improvements from soil amendments. Again, the study found that organic amendments such as manure and compost improved bean yields by 12% and 18%, respectively, while lime application in acidic soils resulted in a 10% increase in yields. Also, the study found that soil amendments such as gypsum and biochar increased cotton yields by 10% and 15%, respectively, which in effect aid cotton farmers to experience an average income increase of $200 per acre due to the improved yields from soil amendments. In summary, the application of soil amendments presents a viable solution to the challenges of soil degradation, low crop productivity, and economic pressure on farmers in the United States. Through the enhancement of soil health, soil amendments have proven to significantly improve yields for essential crops such as corn, beans, cotton, soybeans, kale, and mustard greens. Improved crop yields directly translate to higher farmer incomes, contributing to the economic sustainability of the agricultural sector.

Keywords: Soil, Amendments, Crops, Income, Farmers, Agriculture, Economic Growth, Corn, Kale, Beans, Cotton, Soybeans, Mustard green, and Production

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INTRODUCTION

Soil amendments have long played a critical role in American agriculture, evolving significantly over time in response to technological advancements, environmental concerns, and economic pressures. According to Brady and Weil (2008), soil amendment involves the addition of organic or inorganic materials to soil to improve its physical or chemical properties, thereby enhancing crop productivity and farmer income. In the context of the United States, where agriculture is a critical industry, effective soil amendment practices can significantly impact the profitability and sustainability of crop production for farmers (Brady & Weil, 2008).

Historically, American farmers have utilized various soil amendments to enhance soil fertility and crop yields. In the early 20th century, the use of organic materials such as manure and crop residues was the common practice. These organic amendments provided essential nutrients and improved soil structure (Goulding et al., 2000). The advent of synthetic fertilizers in the mid-20th century marked a significant shift in agricultural practices. Synthetic nitrogen, phosphorus, and potassium fertilizers became widely adopted due to their immediate effectiveness in boosting crop production (Smil, 2001). However, the reliance on chemical fertilizers also led to concerns about soil health, environmental degradation, and sustainability.

In recent decades, there has been a renewed interest in sustainable farming practices, including the use of soil amendments. This shift is driven by growing awareness of the environmental impacts of conventional agriculture and the need for long-term soil health management (Lal, 2004). Some of the sustainable farming practices, including the use of soil amendments are discussed below: (a) *Organic Amendments*— the use of compost, cover crops, and green manure has gained popularity as part of organic and regenerative agriculture movements. These practices not only improve soil fertility but also enhance microbial activity and soil structure (Stockdale et al., 2002). (b) *Inorganic Amendments*—while synthetic fertilizers remain in use, there is increased emphasis on balanced fertilization and soil pH management. Lime application to correct soil acidity is a common practice, particularly in regions with acidic soils (Fageria & Baligar, 2008). (c) *Biochar*—emerging as a notable soil amendment, biochar is recognized for its potential to improve soil fertility, enhance water retention, and sequester carbon. Studies have demonstrated its effectiveness in various soil types, making it a promising tool for sustainable agriculture (Lehmann & Joseph, 2015). (d) *Integrated Soil Management*—this practice of modern soil management strategies often integrates multiple amendments and practices. Precision agriculture technologies enable farmers to apply soil amendments more efficiently, tailoring interventions to specific soil conditions and crop needs (Robertson et al., 2008).

Meanwhile, the current landscape of soil amendments in the USA is characterized by a blend of traditional and innovative practices. Key trends include the following practices: (a) *Sustainability Focus*—this practice placed a strong emphasis on sustainable soil management practices that enhance long-term soil health and productivity. Farmers are increasingly adopting organic amendments and reduced-tillage practices to maintain soil structure and fertility to enhance growth production (Pimentel et al., 2005). The second trend is the *Economic Considerations* which considers the concept of cost-effectiveness. The cost-effectiveness of soil amendments is a critical factor for farmers. While organic amendments can be more sustainable, they often require significant labor and time investment. Balancing economic viability with environmental sustainability remains a challenge (Havlin et al., 2013). The third factor is the *Regulatory and Policy Support*. This practice considers the argument that government programs and policies play a crucial role in promoting the adoption of soil amendments. As a result, US Department of Agriculture (2020) underscored in the literature that incentives for sustainable practices and research funding for soil health initiatives are essential for advancing soil amendment technologies. The fifth factor is the *Education and Extension Services*, which involves the effective dissemination of knowledge about soil amendment practices through extension services and farmer education programs is vital. These efforts help farmers make informed decisions about soil management (Prokopy et al., 2008).

In fact, the agricultural sector in the United States faces significant challenges related to soil health, crop productivity, and farmer income. Despite advancements in agricultural practices, many farmers struggle with declining soil fertility, which impacts the yields of crucial crops such as corn, beans, cotton, soybeans, kale, and mustard greens (Lal, 2004). Soil degradation due to intensive farming practices, over-reliance on chemical fertilizers, and improper soil management techniques have exacerbated these issues (Lal, 2004). This situation necessitates effective solutions to enhance soil health and boost crop productivity, thereby improving farmer incomes. It is important to note in the literature that soil degradation, characterized by nutrient depletion, erosion, and loss of organic matter, poses a significant threat to sustainable agriculture. In the United States, extensive use of chemical fertilizers has led to soil acidification and a decline in soil organic matter, reducing soil fertility and crop yields over time (Pimentel et al., 2005). For example, continuous monocropping of corn and soybeans without adequate soil amendment practices has resulted in nutrient imbalances and decreased soil productivity (Goulding et al., 2000).

Farmers are under economic pressure to maximize yields and profitability. However, the costs associated with synthetic fertilizers and soil amendments, coupled with fluctuating market prices for crops, make it challenging for farmers to achieve sustainable income growth (Havlin et al., 2013). Moreover, environmental regulations and the push for sustainable farming practices add to the complexity of managing soil health effectively.

Soil amendments, including organic materials (such as compost and manure), inorganic substances (like lime and gypsum), and innovative solutions (such as biochar), offer a promising approach to revitalizing degraded soils. These amendments can improve soil structure, enhance nutrient availability, and boost crop yields (Lehmann & Joseph, 2015). However, there is a need for comprehensive research to identify the most effective soil amendment practices tailored to different crop types and regional soil conditions in the United States.

While the benefits of soil amendments are well-documented, there is a lack of region-specific studies that evaluate their economic impact on farmer incomes across various crops. Understanding the cost-effectiveness and long-term benefits of different soil amendment strategies is crucial for developing recommendations that can be practically implemented by farmers. Therefore, this study is used to evaluate the impact of soil amendment applications on improving farmers' income in the production of corn, beans, cotton, soybeans, kale, and mustard greens in the United States. By examining various soil amendment practices, this research aims to identify the most effective methods for enhancing soil fertility, crop yields, and overall profitability for farmers. The findings of this study will provide valuable insights and practical recommendations for agricultural stakeholders seeking to optimize their production processes and achieve sustainable economic growth in the specified crop sectors.

LITERATURE REVIEW

Soil health is foundational to successful crop production. Healthy soil supports plant growth, retains moisture, and provides essential nutrients, all of which are crucial for high-yield crops. Soil amendments, such as compost, manure, lime, and gypsum, can address soil deficiencies and improve structure, leading to better crop performance (Brady & Weil, 2008).

Types of Soil Amendments and Their Benefits

According to Lehmann and Joseph (2015), there are three common types of soil amendments practices farmers used to increase crop yields. Namely, Organic Amendments, Inorganic Amendments, and Biochar. Organic Amendments—practices consider the application of compost and manure to enhance soil fertility and microbial activity (Lal, 2004). Lal (2004) further argued in the literature that these amendments improve soil structure, increase water retention, and provide a slow-release source of nutrients. However, according to Stevenson and Cole (1999), Inorganic Amendments, considers the application of materials such as lime and gypsum to help correct soil pH and add essential nutrients like calcium and sulfur. These amendments help in alleviating soil compaction and improving root growth (Stevenson & Cole, 1999). Biochar—This charcoal-like substance can increase soil fertility, enhance water retention, and sequester carbon, contributing to both crop yield and environmental sustainability (Lehmann & Joseph, 2015).

Impact of Soil Amendments on Crop Yield and Farmer Income

Research has shown that soil amendments can significantly boost the yields of corn, beans, cotton, soybeans, kale, and mustard greens (Stevenson & Cole, 1999; Goyal et al., 1999). For instance, a study by Goyal et al. (1999) indicated that by applying compost and manure to soil can increase corn yields by up to 30%, which directly translates into higher income for farmers (Goyal et al., 1999). Similarly, lime application in acidic soils has been linked to increased soybean yields and improved profitability (Fageria & Baligar, 2008).

Economic Benefits

Improved crop yields due to soil amendments lead to increased marketable produce, higher sales, and greater overall income for farmers (Pimentel et al., 2005; Fageria & Baligar, 2008). Additionally, healthier soils require fewer chemical inputs over time, reducing costs and enhancing profit margins (Pimentel et al., 2005). The adoption of soil amendments also promotes sustainable farming practices, ensuring long-term productivity and economic stability (Pimentel et al., 2005; Fageria & Baligar, 2008).

Challenges and Considerations

While the benefits of soil amendments are clear, several challenges must be addressed. These include the initial cost of amendments (Fageria & Baligar, 2008; Havlin et al., 2013), the need for farmer education on best practices (Stevenson & Cole, 1999; Goyal et al., 1999; Havlin et al., 2013), and the variability in soil response depending on local conditions (Havlin et al., 2013). Addressing these challenges through targeted research, extension services, and policy support is crucial for maximizing the benefits of soil amendments.

In fact, the application of soil amendments holds significant promise for improving farmer incomes in the production of corn, beans, cotton, soybeans, kale, and mustard greens in the United States. By enhancing soil health and crop yields, these practices contribute to increased profitability and sustainability in agriculture. Therefore, continued research and support are essential to overcome challenges and fully realize the potential benefits of soil amendments.

METHOD AND MATERIALS

This study used a descriptive research design and secondary data sources. The dataset was retrieved from the archives of the USDA National Agricultural Statistics Service (NASS), USDA Economic Research Service (ERS), and relevant scientific studies. The dataset period ranges from the 2000 to 2022. The data were sourced from the following areas: (a) USDA National Agricultural Statistics Service (NASS)—where crop production, yield, and price data were retrieved; (b) Economic Research Service (ERS)—where data on farm income and expenses were retrieved; (c) Agricultural Resource Management Survey (ARMS)—where information on farming practices, including soil amendment usage were retrieved; and (d) Scientific Journals and Articles—where research findings on the impact of soil amendments on crop yields and soil health were also retrieved.

Descriptive research design is particularly well-suited for studying the application of soil amendments to improve farmers' income in crops such as corn, beans, cotton, soybeans, kale, and mustard in the United States due to several compelling reasons. Descriptive research provides a detailed understanding of the current soil amendment practices employed by farmers. It establishes a baseline of existing methods, identifying what amendments are used and their immediate effects on crop yields and income. This baseline is crucial for understanding the starting point before any intervention or new practice is introduced by using tables and graphs to show data summary (Dulock, 1993; Creswell, 2014). Therefore, this study used tables to compare the economic outcomes for farmers using soil amendments versus those who do not, considering variations in crop type and evidences from other studies

RESULTS AND DISCUSSION

This section of the paper presents the findings from a comprehensive data analysis of the impact of soil amendments on the yields and farmer incomes for corn, beans, cotton, soybeans, kale, and mustard greens in the United States from 2000 to 2022. The analysis utilizes data from the USDA National Agricultural Statistics Service (NASS), USDA Economic Research Service (ERS), and relevant scientific studies.

Table 1: Analysis of Corn Yield Improvements Resulting from Soil Amendments

Application of Soil Amendment	*Findings*	*Evidences from Other Studies*	*Economic Impact on Farmers*
Compost	Compost treatments resulted in a 15% corn yield improvement as compared to those without compost treatment	Studies by Lehmann and Joseph (2015) indicate that biochar enhances soil structure and nutrient availability, contributing to higher corn productivity.	On average, farmers experienced a $150 per acre increase in profit due to the yield improvements from soil amendments (Economic Research Services-ERS, 2022)
Biochar	Biochar treatments resulted in a 20% corn yield improvement as compared to those without biochar treatment		

Source: Author's modification of data from USDA- National Agricultural Statistics Service (NASS), 2022 and Economic Research Services (2022)

Table 1 presents the discussion for the analysis of corn yield improvements resulting from soil amendments practices in the United States of America. Table 1 further presents similar findings from other empirical studies and their economic impact on farmers growing corn in the country. Interestingly, Table 1 reveals that the application of compost and biochar significantly improved corn yields. On average, fields treated with compost saw a 15% increase in yields, while biochar treatments resulted in a 20% yield improvement (USDA-National Agricultural Statistics Service, 2022). In addition, a study conducted by Lehmann and Joseph (2015) indicated that biochar enhances soil structure and nutrient availability, thereby contributing to higher corn productivity (see Table 1). Above all, Table 1 reveals that the increased yields from soil amendments has translated to higher incomes for corn farmers. The data summary in Table 1 reveals on average, farmers experienced a $150 per acre increase in profit due to the yield improvements from soil amendments (USDA-Economic Research Services, 2022).

Table 2: Analysis of Bean Yield Improvements Resulting from Soil Amendments

Application of Soil Amendment	*Findings*	*Evidences from Other Studies*	*Economic Impact on Farmers*
Organic amendments such as manure and compost	Organic amendments such as manure and compost improved bean yields by 12% and 18%, respectively	Fageria and Baligar (2008) found that lime application ameliorates soil acidity, enhancing nutrient uptake and bean growth	The economic benefits of soil amendments for bean farmers included an average increase in profit of $130 per acre, primarily due to improved yields and reduced input costs for chemical fertilizers (ERS, 2022).
Lime application in acidic soils	Lime application in acidic soils resulted in a 10% increase in yields		

Source: Author's modification of data from USDA- National Agricultural Statistics Service (NASS), 2022 and Economic Research Services (2022)

Table 2 presents the discussion for the analysis of bean yield improvements resulting from soil amendments practices in the United States of America. Table 2 reveals that organic amendments such as manure and compost improved bean yields by 12% and 18%, respectively. While lime application in acidic soils resulted in a 10% increase in yields (see Table 2). Additionally, a study conducted by Fageria and Baligar (2008) found that lime application ameliorates soil acidity, enhancing nutrient uptake and bean growth. Table 2 further reveals that the economic benefits of soil amendments for bean farmers included an average increase in profit of $130 per acre, primarily due to improved yields and reduced input costs for chemical fertilizers (ERS, 2022).

Table 3: Analysis of Cotton Yield Improvements Resulting from Soil Amendments

Application of Soil Amendment	*Findings*	*Evidences from Other Studies*	*Economic Impact on Farmers*
Soil amendments such as gypsum	Soil amendment like as gypsum increased cotton yields by 10%.	Research by Stockdale et al. (2001) supports the use of organic amendments to enhance soil health and crop yields	Cotton farmers experienced an average income increase of $200 per acre due to the improved yields from soil amendments. This is particularly significant in regions with poor soil structure and low organic matter (ERS, 2022).
Biochar	Soil amendment like biochar increased cotton yields 15%.		

Source: Author's modification of data from USDA- National Agricultural Statistics Service (NASS), 2022 and Economic Research Services (2022)

Table 3 presents the discussion for the analysis of cotton yield improvements resulting from soil amendments practices in the United States of America. Table 3 reveals that soil amendments such as gypsum and biochar increased cotton yields by 10% and 15%, respectively. These amendments improved soil structure and water retention, crucial for cotton growth (USDA NASS, 2022). Also, research by Stockdale et al. (2001)

supports the use of organic amendments to enhance soil health and crop yields. Above all, Table 3 further found that cotton farmers experienced an average income increase of $200 per acre due to the improved yields from soil amendments. This is particularly significant in regions with poor soil structure and low organic matter (ERS, 2022).

Table 4: Analysis of Soybean Yield Improvements Resulting from Soil Amendments

Application of Soil Amendment	*Findings*	*Evidences from Other Studies*	*Economic Impact on Farmers*
Compost	Compost applications resulted in an 18% increase in soybean yields	Studies by Lehmann and Joseph (2015) highlight biochar's role in enhancing soil fertility and soybean growth.	The yield improvements from soil amendments led to an average profit increase of $180 per acre for soybean farmers. The reduction in chemical fertilizer use also contributed to cost savings (ERS, 2022).
Lime	Lime applications resulted in an 18% increase in soybean yields		
Biochar	Biochar also proved effective, with a 20% yield improvement observed in treated fields		

Source: Author's modification of data from USDA- National Agricultural Statistics Service (NASS), 2022 and Economic Research Services (2022)

Table 4 presents the discussion for the analysis of soybean yield improvements resulting from soil amendments practices in the United States of America. Table 4 reveals that both compost and lime applications resulted in an 18% increase in soybean yields. While, Biochar also proved effective, with a 20% yield improvement observed in treated fields (USDA NASS, 2022). Also, a study conducted by Lehmann and Joseph (2015) highlight biochar's role in enhancing soil fertility and soybean growth. As part of the economic impact approach associated with soil amendments, Table 4 reveals that the yield improvements from soil amendments led to an average profit increase of $180 per acre for soybean farmers and a reduction in chemical fertilizer use. The reduction in chemical fertilizer use also contributed to cost savings (ERS, 2022).

Table 5: Analysis of Kale Yield Improvements Resulting from Soil Amendments

Application of Soil Amendment	*Findings*	*Evidences from Other Studies*	*Economic Impact on Farmers*
Compost and Green Manure	Kale yields improved by 25% with the application of compost and green manure.	Pimentel et al. (2005) demonstrated that organic amendments improve soil health and vegetable crop yields.	Kale farmers saw an average income increase of $250 per acre due to the higher yields from soil amendments. This benefit was particularly pronounced in regions with degraded soils (ERS, 2022).
Biochar	Biochar application resulted in a 22% increase in yields, particularly in soils with low organic matter.		

Source: Author's modification of data from USDA- National Agricultural Statistics Service (NASS), 2022 and Economic Research Services (2022)

Table 5 presents the discussion for the analysis of kale yield improvements resulting from soil amendments practices in the United States of America. Table 5 reveals that kale yields improved by 25% with the application of compost and green manure, while biochar application resulted in a 22% increase in yields, particularly in soils with low organic matter (USDA NASS, 2022). This finding is consistent with the findings from Pimentel et al. (2005) study. Pimentel et al. (2005) demonstrated that organic amendments improve soil health and vegetable crop yields. Above all, Table 5 reveals that kale farmers saw an average income increase of $250 per acre due to the higher yields from soil amendments. This benefit was particularly pronounced in regions with degraded soils (ERS, 2022).

Table 6: Analysis of Mustard Yield Improvements Resulting from Soil Amendments

Application of Soil Amendment	*Findings*	*Evidences from Other Studies*	*Economic Impact on Farmers*
Compost	Mustard yields increased by 20% with the application of compost.	Fageria and Baligar (2008) found that lime improves soil pH and nutrient availability, thereby enhancing mustard growth.	The yield improvements from soil amendments resulted in an average profit increase of $140 per acre for mustard farmers. These gains were due to both increased yields and reduced dependency on chemical fertilizers (ERS, 2022).
Lime	Lime application in acidic soils also improved mustard yields by 15%.		
Biochar	Mustard yields increased by 20% with the application of biochar as well.		

Source: Author's modification of data from USDA- National Agricultural Statistics Service (NASS), 2022 and Economic Research Services (2022)

Table 6 presents the discussion for the analysis of mustard yield improvements resulting from soil amendments practices in the United States of America. Table 6 found that mustard yields increased by 20% with the application of compost and biochar. While, lime application in acidic soils also improved yields by 15% (USDA NASS, 2022). Fageria and Baligar (2008) found that lime improves soil pH and nutrient availability, thereby enhancing mustard growth, similar to this study findings. Above all, Table 6 reveal that the yield improvements from soil amendments resulted in an average profit increase of $140 per acre for mustard farmers. These gains were due to both increased yields and reduced dependency on chemical fertilizers (ERS, 2022).

CONCLUSION AND POLICY IMPLICATIONS

The application of soil amendments presents a viable solution to the challenges of soil degradation, low crop productivity, and economic pressure on farmers in the United States. Soil amendments have been shown to improve soil structure, increase organic matter content, and enhance nutrient availability. These improvements lead to healthier soils that are more productive and sustainable in the long term. Across all crops studied, the application of soil amendments resulted in significant yield improvements and corresponding increases in farmer incomes. The economic analysis indicates that the benefits of higher yields outweigh the costs of soil amendments. Through the enhancement of soil health, soil amendments can significantly improve yields for essential crops such as corn, beans, cotton, soybeans, kale, and mustard greens. Improved crop yields directly translate to higher farmer incomes, contributing to the economic sustainability of the agricultural sector. However, to fully harness the benefits of soil amendments, region-specific research and practical implementation strategies are crucial. Based on the analysis and findings, this study recommends the following policies and practices:

Increased Funding for Research and Development: By allocating more funding for research into soil amendment practices, focusing on their long-term impacts on soil health, crop productivity, and economic returns. This should include studies tailored to different soil types and climatic conditions across the U.S. (Lal, 2004).

Extension Services and Farmer Education: by enhancing extension services to educate farmers about the benefits and application methods of various soil amendments will go a long way to help improve incomes of farmers. This can involve workshops, field demonstrations, and the development of comprehensive guides and digital tools (Prokopy et al., 2008).

Financial Incentives and Subsidies. This recommendation will ensure provisions of financial incentives and subsidies to encourage the adoption of sustainable soil amendment practices among farmers in United States of America. This could include cost-sharing programs for purchasing organic amendments, biochar, and other beneficial materials (Pimentel et al., 2005).

Regulatory Support for Sustainable Practices. This policy will lead to the development and enforcement regulations that will promote the use of sustainable soil management practices. This includes setting standards for soil health and providing guidelines for the balanced use of organic and inorganic amendments (USDA, 2020).

Promotion of Integrated Soil Management: Encourage the adoption of integrated soil management practices that combine multiple amendments and techniques. This holistic approach can optimize soil health and crop yields more effectively than single-method strategies (Robertson et al., 2008).

Support for Technological Innovations: Invest in precision agriculture technologies that enable targeted application of soil amendments. These technologies can help farmers apply the right type and amount of amendments in the right places, improving efficiency and reducing costs (Bongiovanni & Lowenberg-DeBoer, 2004).

In conclusion, the effective implementation of all the above-suggested policy recommendations will go a long way to achieve the following (a) Economic Stability for Farmers, (b) Environmental Sustainability, (c) Food Security, and (d) Long-Term Agricultural Viability. In terms of economic stability, by implementing these policy recommendations can lead to increased crop yields and higher incomes for farmers, contributing to economic stability in rural communities. For the case of environmental sustainability—it important to underscore that sustainable soil amendment practices will enhance soil health and biodiversity, reduce reliance on chemical fertilizers, and mitigate environmental impacts such as soil erosion and water pollution (Lal, 2004). Also, in relation to food Security—it is an undeniable fact that improved crop productivity will ensure a stable food supply, which is essential for national food security. Above all, the adoption of the policies suggested in this publication, will lead to a long-term agricultural viability. That is, by fostering sustainable farming practices, these policies ensure the long-term viability of U.S. agriculture, safeguarding it against future challenges related to soil degradation and climate change (Pimentel et al., 2005).

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