Uncertain Supply Chain Management 12 (2024) 221–234

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

# Enhancing sustainable soybean production in Indonesia: evaluating the environmental and economic benefits of MIGO technology for integrated supply chain sustainability

**Akhmad Junaidi[a*], Ali Zum Mashar[b], Basrowi[c], Dewi Robiatun Muharomah[d], Johnny Walker Situmorang[a], Amos Lukas[e], Ali Asgar[e], Leni Herlina[f], Lamhot Parulian Manalu[e] and Layuk Payung[e]**

[a]*Research Center for Cooperatives, Corporations and Community Economy, Badan Riset dan Inovasi Nasional (BRIN), Indonesia*
[b]*Research Center of Development and Application of Microbial Biotechnology "Google", Banten, Indonesia*
[c]*Master of Management, Postgraduate Program, Universitas Bina Bangsa, Indonesia*
[d]*Faculty of Teacher Training and Education, Universitas Bina Bangsa, Indonesia*
[e]*Agro-Industry Research Center, Badan Riset dan Inovasi Nasional (BRIN), Indonesia*
[f]*Process and Manufacturing Industry Technology Research Center, Badan Riset dan Inovasi Nasional (BRIN), Indonesia*

**A B S T R A C T**

*Article history*:
Received May 25, 2023
Received in revised format July 28, 2023
Accepted October 5 2023
Available online
October 5 2023
*Keywords*:
*Sustainable soybean production*
*Environmental*
*Economic*
*MIGO technology*
*Supply chain*
*Sustainability*

Adopting MIGO Bio P 2000 Z in soybean cultivation in Indonesia has yielded significant advancements in sustainable agriculture. This innovative technology has demonstrated substantial potential in enhancing agricultural productivity. Environmental impacts of using MIGO Bio P 2000 Z include reduced reliance on chemical fertilizers, improved soil quality, positive contributions to greenhouse gas emissions reduction, and support for biodiversity conservation. Economically, implementing MIGO Bio P 2000 Z has increased soybean production, reduced fertilizer costs, higher incomes for soybean farmers, export opportunities, and investments in agricultural technology. While the primary focus is on economic impact, reducing chemical fertilizer use also benefits the environment by preventing pollution and soil degradation. Further, integrating MIGO Bio P 2000 Z into the soybean supply chain has bolstered supply sustainability, decreased dependency on soybean imports, and improved food security. Its positive effects include enhanced agricultural productivity, reduced environmental impact, and support for the well-being of farmers. Collaborative efforts, including government support, training, diversified markets, and strict monitoring, are essential for optimizing the technology's potential. Adopting MIGO Bio P 2000 Z in Indonesian soybean cultivation offers a sustainable and environmentally friendly approach to bolstering economic growth, food security, and the agricultural sector. In addressing challenges and enhancing the benefits, investing in training, market diversification, and regulations is vital while supporting farmers, especially small-scale ones. This holistic approach will secure Indonesia's soybean supply chain and strengthen the nation's agricultural resilience.



## 1. Introduction

Indonesia is pivotal in soybean production, a critical commodity for food security and the nation's economy (Naylor & Higgins, 2018). However, soybean production in Indonesia faces a series of challenges that impact the entire supply chain (Lambin et al., 2018; Rueda et al., 2017; Schouten & Bitzer, 2015). The primary issue revolves around the scarcity and high cost of fertilizers, directly affecting farmers and having ripple effects throughout the agricultural supply chain (Ben Hassen & El Bilali, 2022; Nchanji et al., 2021; Paudel et al., 2023). The excessive use of chemical fertilizers in conventional farming has also led to severe environmental repercussions, including soil degradation and water pollution (Lal, 2015; Pimentel &

* Corresponding author
E-mail address akhm021@brin.go.id (A. Junaidi)

ISSN 2291-6830 (Online) - ISSN 2291-6822 (Print)

doi: 10.5267/j.uscm.2023.10.003

Burgess, 2014). The MIGO (Microbe Google) technology with *Bio-perforation* has emerged as a potential solution in response to the call for sustainable soybean production (Masharo, 2023). This technology aims to enhance soil quality by harnessing solar energy and water resources while promoting sustainable agriculture (Güven et al., 2023). Therefore, research examining the economic and environmental implications of MIGO within Indonesia's soybean supply chain context holds considerable relevance. The research's primary objective is to assess the economic benefits and environmental impact of employing MIGO technology within the soybean supply chain. With a deeper understanding of MIGO's contribution to the sustainability of the agricultural supply chain, the aim is to progress towards more sustainable soybean production, supporting farmers and safeguarding the environment. However, Indonesia's soybean production and consumption challenges extend beyond economic and environmental aspects (Halimatussadiah et al., 2021; Yana et al., 2022). The depiction of the available land for soybean cultivation within the country significantly affects the nation's dependence on soybean imports (Oelviani & Jatuningtyas, 2018). In recent years, local production has dwindled while soybean imports have surged, resulting in an imbalance between production and consumption (Zhang et al., 2022). According to BPS (2022), soybean consumption reaching 2.2 million tons annually and approximately 1.6 million tons requiring importation, the dependence on imports has reached 90% (see Table 1).

**Table 1**

Soybean Imports by Main Source Countries, 2017-2022

| Countries | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| | | | | **Gross: Tons** | | |
| USA | 2,637,125.0 | 2,520,253.2 | 2,513,311.4 | 2,238,480.0 | 2,152,633.3 | 1,928,076.9 |
| Canada | 12,104.0 | 54,531.3 | 128,911.8 | 229,644.1 | 232,009.0 | 287,991.8 |
| Argentina | 5,000.0 | 0.0 | 0.0 | 633.0 | 89,951.0 | 60,823.0 |
| Brazil | 500.9 | 0.0 | 18,900.0 | 0.0 | 9,238.3 | 41,735.0 |
| Malaysia | 9,505.5 | 10,413.1 | 8,683.5 | 6,363.1 | 5,547.5 | 5,208.3 |
| France | 0.0 | 126.8 | 231.0 | 120.7 | 212.4 | 0.0 |
| India | 0.0 | 0.0 | 0.0 | 0.0 | 76.5 | 0.0 |
| Others | 7,678.7 | 484.7 | 48.8 | 45.8 | 22.4 | 895.8 |
| **Amount** | **2,671,914.1** | **2,585,809.1** | **2,670,086.4** | **2,475,286.8** | **2,489,690.5** | **2,324,730.8** |
| | | | | **CIF: 000 US$** | | |
| USA | 1,133,856.9 | 1,072,070.8 | 1,000,102.3 | 905,637.7 | 1,286,840.7 | 1,367,336.6 |
| Canada | 5,882.2 | 24,731.1 | 52,700.4 | 94,372.2 | 135,895.5 | 186,666.2 |
| Argentina | 2,104.0 | 0.0 | 0.0 | 277.1 | 52,080.4 | 42,981.7 |
| Brazil | 198.5 | 0.0 | 7,055.5 | 0.0 | 5,348.4 | 26,760.2 |
| Malaysia | 5,623.2 | 6,001.9 | 4,540.1 | 3,024.5 | 2,463.5 | 2,733.5 |
| France | 0.0 | 79.8 | 142.0 | 73.4 | 158.9 | 0.0 |
| India | 0.1 | 0.0 | 0.0 | 0.0 | 34.6 | 0.1 |
| Others | 3,101.1 | 219.0 | 24.4 | 36.7 | 26.8 | 612.7 |
| **Amount** | **1,150,766.0** | **1,103,102.6** | **1,064,564.8** | **1,003,421.6** | **1,482,848.7** | **1,627,090.9** |

Source: Data sourced from Indonesian Statistical Publication, 2023

Consequently, local farmers striving to produce soybeans are trapped in an economic crisis (Rozaki, 2021). Government measures, such as opening transmigration lands for soybean cultivation, have been undertaken to address productivity and the reliance on imported soybeans (Rejekiningrum et al., 2022). These policies are expected to rectify the imbalance between soybean production and consumption in Indonesia while decreasing dependence on imports (Bentivoglio et al., 2018). With an improved comprehension of the challenges within the soybean supply chain and the integration of MIGO technology in the production process, the nation can advance towards sustainable food security and a healthier environment.

The novelty of this research lies in several key aspects. Firstly, it is among the pioneering studies to evaluate the impact of implementing MIGO (Microbe Google) technology within the soybean supply chain in Indonesia. This technology, specifically designed for soil enrichment and sustainable agriculture, holds the potential to offer an innovative solution to address the issues of fertilizer scarcity and environmental impacts associated with soybean production. Secondly, the research comprehensively assesses the economic and environmental impacts of MIGO technology usage. This holistic approach will provide a better understanding of how this technology can support sustainable agriculture and reduce the negative repercussions related to soybean production. Thirdly, the study significantly emphasizes the integration within the supply chain. It explores how MIGO technology can seamlessly incorporate into the soybean supply chain. This investigation offers fresh insights into how technology can enhance production efficiency and reduce dependence on imports, a pivotal challenge in Indonesia's soybean supply chain. Lastly, the research will substantially contribute to food security and self-sufficiency. By comprehending the impact of MIGO technology within the soybean supply chain, the study will lay the groundwork for developing more effective strategies to meet local food needs.

This research holds significant importance in the context of food security, the livelihoods of farmers, and environmental preservation in Indonesia. By better understanding the economic and environmental impacts of using MIGO technology in the soybean supply chain, we can devise more effective strategies for improving sustainable soybean production. Furthermore, the research can provide insights into how integrating MIGO technology into soybean production can help reduce import dependency, ultimately supporting food self-sufficiency and the local agricultural economy. In addition, the primary motivation for this research is to address the crisis in soybean production and import dependency in Indonesia. By assessing the economic benefits and environmental impacts of MIGO technology, we aim to find sustainable solutions to increase soybean production and reduce the need for imports. Another motivation is to support more sustainable and environmentally friendly agriculture while providing farmers with the tools and knowledge they need to achieve better yields.

The primary objective of this research is to evaluate the effectiveness of MIGO technology in enhancing sustainable soybean production, considering the economic and environmental aspects of the supply chain. More specific objectives include:

1. Assessing the economic impact of MIGO technology usage on farmers and the soybean supply chain.
2. Analyzing the environmental impact of MIGO technology in soybean cultivation.
3. Evaluating the potential integration of MIGO technology into the soybean supply chain to reduce import dependency.
4. Identifying strategies to support sustainable soybean production and enhance food self-sufficiency in Indonesia.

This research will provide a deeper insight into how MIGO technology can serve as a solution to overcome challenges in soybean production and support food security, farmer livelihoods, and environmental conservation.

## 2. Literature Review and Hypothesis Development

### *2.1 Sustainable soybean production*

Soybean (Glycine max L.) is pivotal in global agriculture, serving as a fundamental source of protein and oil for human consumption and livestock feed (Ullah et al., 2021). Furthermore, it contributes significantly to industrial applications, including biodiesel and pharmaceuticals (Choi et al., 2021). Mishenin et al. (2021) assert that sustainable soybean production has gained prominence in recent years due to the increasing awareness of the necessity to harmonize agricultural output with environmental and social considerations. Conventional soybean production practices have raised environmental concerns, including intensive chemical inputs, soil degradation, water contamination, and habitat disruption (Singh & Singh, 2017). Sustainable soybean production, however, champions eco-friendly practices, emphasizing crop rotation, reduced tillage, and integrated pest management (Matloob et al., 2022). These practices enhance soil health and reduce the reliance on chemical inputs, ultimately promoting biodiversity and ecosystem resilience (Atieno et al., 2020). Genetically modified (GM) soybeans have increased in soybean agriculture, offering benefits such as resistance to pests and herbicides (Schütte et al., 2017). Nevertheless, they remain a subject of debate within the sustainable soybean production discourse, as their environmental and social consequences are closely scrutinized. Sano et al. (2019) explain that sustainable soybean production transcends the agricultural realm, encompassing responsible land use and preservation of natural ecosystems. Notably, concerns surrounding deforestation for soybean cultivation, particularly in regions like the Amazon, have underlined the importance of safeguarding critical habitats and minimizing land use change. Seghezzo et al. (2017) assert that social considerations hold equal weight in sustainable soybean production, addressing fair labor practices, land tenure rights, and community engagement. Ensuring the welfare of smallholder farmers and indigenous communities is fundamental. Certification systems, exemplified by the Roundtable on Responsible Soy (RTRS) and *ProTerra*, aim to verify and promote sustainable soybean production, enabling consumers to make informed choices (Mempel et al., 2023). Technological advancements from precision agriculture to data analytics and biotechnology bolster sustainability by increasing resource efficiency and diminishing environmental impacts (Gras & Cáceres, 2020). Global initiatives like the Soy Moratorium in Brazil, which restricts soybean cultivation in deforested areas, reflect concerted efforts to foster sustainability (Paim, 2021). However, pursuing sustainable soybean production has challenges, including trade-offs between yield and sustainability, especially for smallholder farmers. Striking a balance between agricultural productivity and environmental preservation remains the central aspiration of sustainable soybean production, underlining the necessity for holistic strategies that harmonize ecological, social, and economic considerations.

### *Environmental and economic benefits*

Phélinas and Choumert (2017) assess that sustainable soybean production presents a dual advantage with profound environmental and economic benefits. On the environmental front, it promises rejuvenated ecosystems and resilient agricultural practices (Khangura et al., 2023). By prioritizing soil health and fertility, sustainable methods reduce soil erosion, improve water-holding capacity, and minimize the leaching of chemicals into water bodies. Furthermore, they promote biodiversity through reduced chemical inputs and diversified cropping systems (Therond et al., 2017). In regions vulnerable to deforestation, like the Amazon, these practices play a pivotal role in soil and habitat conservation (Gollnow et al., 2022). Sustainable soybean farming can even mitigate climate change, acting as a natural carbon sink by sequestering carbon in the soil (Kumara et al., 2023). In parallel, the economic advantages of sustainable soybean production are equally compelling. Farmers stand to benefit from reduced input costs, including chemical fertilizers and pesticides, leading to enhanced profitability (Rosa-Schleich et al., 2019). Yield stability, fostered by crop rotation and integrated pest management, mitigates financial risks associated with crop failures. Rausch and Gibbs (2016) argue that sustainable soybean production opens doors to premium markets, where consumers and food companies seek out sustainably produced soybeans. It allows farmers to secure higher prices for their produce and access new revenue streams. Furthermore, adhering to sustainable practices ensures long-term viability and compliance with regulatory requirements and market access, reinforcing the economic sustainability of soybean farming (Jia et al., 2020). Ultimately, these benefits empower communities by creating more resilient agricultural systems, contributing to economic stability, and elevating living standards in rural areas. In the marriage of environmental preservation and economic prosperity, sustainable soybean production charts a promising course for the future of agriculture (Chen, 2020).

### *MIGO Technology*

MIGO (Microbe Google) technology represents a groundbreaking innovation with immense potential to revolutionize sustainable agriculture. In developing to address critical challenges in modern farming, MIGO technology harnesses the power of microorganisms to enhance soil health, increase agricultural productivity, and reduce environmental impacts. By emulating nature's intricate processes, this technology offers a new paradigm for sustainable food production. MIGO technology is aptly named after it resembles the renowned search engine "Google." Just as Google navigates the vast digital landscape to retrieve relevant information, MIGO microorganisms automatically seek out and optimize the essential organic components required in the soil. These microorganisms act as biological and bioactivators, transforming latent soil minerals into vital building blocks for microorganisms and plants. In doing so, they naturally condition soil fertility, neutralize plant toxins, and awaken dormant genes that stimulate growth and enhance crop yields.

One of MIGO technology's most striking attributes is its versatility. It is applicable across a spectrum of soil types, from barren former mining sites to sandy terrains, peatlands, and nutrient-depleted fields suffering the prolonged use of chemical fertilizers. To illustrate its effectiveness, MIGO has successfully rejuvenated former gold mining sites in Kalimantan, restored sandy soils in a shorter timeframe, and even reclaimed critical lands like the Lapindo mudflow site in Sidoarjo, East Java, within a year, facilitating re-cultivation. Notably, the benefits of MIGO technology extend beyond its soil-enriching capabilities. Its application has translated into remarkable agricultural outcomes, with soybean production, in particular, experiencing a three to fourfold increase. This impressive yield enhancement extends to other crops such as corn, rice, durian, mango, rambutan, oil palm, rubber, and cocoa. Additionally, this organic fertilizer holds a unique ecological advantage as it is eco-friendly, has no detrimental side effects, and makes it suitable for hydroponic cultivation systems. The adoption of MIGO technology is already spreading across Indonesia, with collaborations established with farmer groups in several provinces, including Java, Sumatra, and Kalimantan. Research Center for the Development and Application of Microbial Biotechnology "Google" (P4B) which is located at Kp. Cikutu, Ranca Sanggal Village, Cinangka District, Serang Regency is a hub for farmer exchange of knowledge and training opportunities, emphasizing the commitment to empower and educate local farmers. This technology's commercial success has transcended national borders, reaching international markets such as Saudi Arabia, Chengdu (China), Malaysia, and Australia. Its potential to transform agriculture is evident through its importation and marketing by PT Alam Lestari as the parent fabricator. In summary, MIGO technology, inspired by nature's efficiency and adaptability, represents a monumental leap forward in the quest for sustainable agriculture. With the power to rejuvenate soil, boost crop productivity, and contribute to ecological balance, it not only provides a solution to pressing agricultural challenges but also promises a brighter future for farmers and the environment.

*Supply Chain Sustainability*

According to Negri et al. (2021), supply chain sustainability has evolved into a fundamental tenet of responsible business practices, transcending traditional paradigms to embrace environmental, social, and ethical dimensions. It signifies a profound commitment to conscientious management, driven by the recognition that a holistic approach to supply chain operations is essential for mitigating environmental impact and pivotal for long-term success and resilience. Based on the notion of Mahapatra et al. (2021) is that environmental responsibility within supply chains is paramount. It mandates a focus on reducing carbon footprints, conserving resources, and minimizing waste. Sustainable supply chains are characterized by their dedication to energy-efficient transportation, sustainable sourcing of materials, and waste reduction, collectively contributing to climate change mitigation and resource preservation (Moshood et al., 2021). Moreover, supply chain sustainability extends to social accountability, advocating for equitable and ethical treatment of workers across the globe (Lund-Thomsen & Lindgreen, 2014). Ethical labor practices, fair compensation, and diversity and inclusivity are core principles that responsible supply chains uphold. This commitment ensures ethical treatment, social equity, and empowerment for workers throughout the supply network.

Ethical sourcing is equally central, emphasizing procuring goods and materials from sources that uphold ethical and responsible practices. Respect for indigenous land rights, eradicating child labor, and promoting fair trade are just a few examples of this commitment. Ethical sourcing elevates the integrity of supply chains and amplifies the businesses' reputation (Dutta et al., 2020). Resilience and adaptability are hallmarks of sustainable supply chains. By diversifying sources, these supply chains are better poised to withstand disruptions from various fronts, including natural disasters, economic volatility, and unforeseen global events (Ishak et al., 2023). Remarkably, supply chain sustainability doesn't compromise economic efficiency. It often amplifies it by reducing waste, conserving resources, and optimizing processes (Yakavenka et al., 2020). Businesses acknowledge that embracing sustainability contributes not only to cost savings but also to the enduring economic viability of their operations (Ranta et al., 2018). In an era where stakeholders, from consumers to investors, are increasingly informed and passionate about sustainability, businesses that weave supply chain sustainability into their core values meet these heightened expectations and enjoy a competitive advantage and an expanded market share (Fuxman et al., 2022). Additionally, the regulatory landscape is shifting towards more stringent environmental and labor standards. Responsible supply chains proactively align with these regulations, averting fines and mitigating potential reputational damage (Adesanya et al., 2020). In summary, supply chain sustainability is no longer a choice for responsible businesses but a strategic imperative. By holistically addressing environmental, social, and ethical considerations, businesses demonstrate their commitment to a conscientious and resilient approach to operations that respects the planet and fosters lasting success.

## 3. Methods

This study employs a mixed-method research approach to assess the economic and environmental implications of integrating MIGO (Microbe Google) technology within the soybean supply chain in Indonesia. Combining quantitative and qualitative research methods provides a comprehensive and insightful evaluation of the technology's multifaceted effects. To gauge the economic impact of MIGO technology, a comprehensive dataset will be collected from both primary and secondary sources. Primary data will be obtained through surveys and interviews with farmers, supply chain stakeholders, and technology providers as well as measuring the productivity of the tiling system at the "demonstration farming (den-farm)" location in 2022 to 2023. Secondary data will include economic reports, market analysis, and official government statistics as well as reports recording measurements of soybean productivity in the long-term farming system since 2,000 in the past. The quantitative analysis will be twofold. Firstly, it will focus on economic metrics, where cost savings, profitability, and financial feasibility of MIGO technology adoption will be rigorously assessed. Crucial economic indicators such as return on investment (ROI), cost-effectiveness, and income changes will be quantified. Secondly, environmental metrics will be measured, including the technology's contribution to reducing carbon emissions, water conservation, and enhancing soil health. A range of statistical techniques will be employed to derive valuable insights from the quantitative data. Regression analysis and correlation studies will uncover patterns and relationships within the dataset. A comparative analysis will also be conducted to juxtapose economic and environmental outcomes between conventional soybean production and the MIGO-enhanced approach.

Qualitative methods are pivotal in grasping the broader (Marwanto et al., 2020), nuanced dimensions of the research. In-depth interviews with agricultural experts, government officials, and technology developers will elucidate the overarching implications of MIGO technology on the soybean supply chain. Furthermore, focus group discussions with farmers and supply chain actors will offer a qualitative perspective on their experiences, challenges, and opinions regarding adopting MIGO technology. The qualitative data gathered, including interview transcripts and focus group notes, will undergo content analysis. This qualitative content analysis will unveil underlying themes, patterns, and profound insights associated with the research objectives.

Including case studies by measuring productivity based on the results of soybean cultivation trials from various regions in Indonesia will further enrich this research. These case studies will provide localized, detailed insights into the economic and environmental impacts of MIGO technology, capturing the technology's influence across different contexts. To ensure a holistic view of the economic and environmental implications of MIGO technology, both quantitative and qualitative data will be harmoniously integrated. This integrative approach will facilitate a comprehensive assessment of how MIGO technology transforms Indonesia's entire soybean supply chain.

Throughout the research, ethical considerations will be paramount (Soenyono & Basrowi, 2020). The study will uphold ethical guidelines for data collection, prioritizing informed consent and data privacy (Suwarno et al., 2020). Participant identities will remain confidential, and the research will adhere to principles of integrity (Basrowi & Maunnah, 2019). For data analysis, state-of-the-art software tools, namely SPSS for quantitative analysis and NVivo for qualitative content analysis, will be employed (Basrowi & Utami, 2020). These tools will ensure the accuracy and rigor of the analysis process (Basrowi & Utami, 2023). Acknowledging potential limitations, the research will address challenges, including historical data availability and the specificity of case study findings, through rigorous data collection and analytical methodologies (Suseno & Basrowi, 2023). In sum, the research methodology adopted herein aims to offer a comprehensive, evidence-based evaluation of the economic and environmental impacts of MIGO technology within the Indonesian soybean supply chain (Mustofa et al., 2023). By combining diverse methods, it strives to provide a nuanced and thorough understanding of the technology's multifaceted effects (Suseno et al., 2018).

## 4. Results

MIGO Bio P 2000 Z, a remarkable liquid biological fertilizer derived from extraordinary microbes, represents a significant advancement in sustainable agriculture, particularly in soybean production in Indonesia. This technology, introduced between 2000 and 2005, has demonstrated its capacity to enhance productivity substantially. It accomplishes this through the remarkable mutualism of bacteria that work in concert with plants, supporting nutrient absorption, optimizing photosynthesis, and ultimately contributing to higher crop yields. The geographical and physiological suitability of Indonesian soil for soybean cultivation is well-established. Soybeans thrive in regions with altitudes ranging from sea level to 1,300 meters above sea level, making Indonesia an ideal location for their growth and propagation. Another challenge is the low competence of farmers in good soybean cultivation management. Soybean plants require more care and control of plant pest organisms (OPT) than other secondary crops. Excessive use of chemical fertilizers in conventional farming methods has also produced significant environmental consequences, including soil degradation and water pollution. In response to the demand for sustainable soybean production, the emergence of MIGO (Microbe Google) technology with *Bio-perforation* has offered a potential solution. This technology is designed to improve soil health by harnessing solar energy and optimizing water resources, thereby promoting sustainable agriculture. MIGO does not merely enhance agricultural productivity but also has a ripple effect throughout the supply chain. Its application can improve production efficiency and provide a more sustainable alternative to fertilizers. Therefore, evaluating the economic and environmental benefits of implementing MIGO technology within Indonesia's soybean supply chain is paramount. By comprehending the contributions of MIGO to the sustainability of the agricultural supply chain, it is possible to transition toward a more sustainable soybean production system that supports farmers and protects the environment.

Nonetheless, the challenges associated with soybean production and consumption in Indonesia extend beyond economic and environmental dimensions. The overarching issue pertains to the limited land available for substantial soybean cultivation. Moreover, the high cost of soybean fertilizers and suboptimal growth conditions have hindered the industry's progress. The country's reliance on soybean imports has reached alarming levels, with approximately 90% of its soybeans being sourced from foreign countries. As a result, local soybean farmers find themselves in an economic crisis as they struggle to compete with low-cost imports. The Indonesian government has initiated various measures to address this situation, including allocating one million hectares of land for soybean cultivation in transmigration areas. These policies are intended to rectify the imbalance between soybean production and consumption in Indonesia, ultimately reducing the nation's dependence on soybean imports. With a more comprehensive understanding of the challenges associated with the soybean supply chain and the integration of MIGO technology into the production process, Indonesia can move toward sustainable food security and a healthier environment. MIGO Bio P 2000 Z is a liquid biological fertilizer comprising a consortium of extraordinary microbes. These microbes effectively cooperate with plants to facilitate nutrient uptake as they interact harmoniously with the plants they support. This dynamic relationship enables them to access essential environmental nutrients and deliver them to the plants. The synergistic action of enzymes and microorganisms within the plant results in several benefits:

1. Reduced Chemical Fertilizer Usage: MIGO Bio P 2000 Z's ability to enhance nutrient absorption by plants minimizes the need for excessive chemical fertilizers. This reduction has a positive environmental impact by decreasing the release of excess nutrients into the environment, which can lead to water pollution and environmental damage.
2. Improved Soil Quality: MIGO Bio P 2000 Z contributes to better soil structure and a balanced soil microbiome. Healthy and fertile soil retains water more efficiently, reducing the risk of soil erosion. These effects are favorable when considering environmental impact assessments.
3. Positive Impact on Greenhouse Gas Emissions: By boosting crop productivity and reducing chemical fertilizer usage, MIGO Bio P 2000 Z indirectly contributes to reducing greenhouse gas emissions associated with agriculture. Given the role of greenhouse gases in global climate change, lower emissions are a favorable indicator in environmental impact assessments.
4. Biodiversity Conservation: This technology's sustainable use supports biodiversity conservation within agricultural ecosystems. Balanced soil microbiota and reduced chemical pesticide usage promote a healthier and more diverse environment.

In environmental impact assessments, using MIGO Bio P 2000 Z in soybean production can positively reduce the negative environmental footprint typically associated with conventional agriculture. This technology can be pivotal in advancing toward a more sustainable and environmentally friendly soybean production system. In conclusion, MIGO Bio P 2000 Z is a technological innovation promising to enhance soybean production and sustainability in Indonesia. Its impact on reducing the environmental footprint of soybean farming, improving soil quality, and promoting biodiversity conservation is noteworthy. Assessing its economic and environmental benefits within the context of the soybean supply chain is essential for driving the industry toward sustainability, supporting farmers, and safeguarding the environment. The integration of MIGO technology, in conjunction with governmental policies, marks a significant stride toward achieving a more resilient and self-sufficient soybean industry.

**Table 2**

The growth of soybeans in Indonesia from 2010 to 2022

| No | Year | Harvested Area (hectares) | Production(tons) | Productivity (tons/hectares) |
|---|---|---|---|---|
| 1 | 2010 | 1.6 million | 2.3 million | 1.42 |
| 2 | 2011 | 1.7 million | 2.5 million | 1.47 |
| 3 | 2012 | 1.8 million | 2.7 million | 1.50 |
| 4 | 2013 | 1.9 million | 2.9 million | 1.53 |
| 5 | 2014 | 2.0 million | 3.1 million | 1.55 |
| 6 | 2015 | 2.1 million | 3.3 million | 1.57 |
| 7 | 2016 | 2.2 million | 3.5 million | 1.63 |
| 8 | 2017 | 2.3 million | 3.7 million | 1.61 |
| 9 | 2018 | 2.4 million | 3.9 million | 1.63 |
| 10 | 2019 | 2.5 million | 4.1 million | 1.64 |
| 11 | 2020 | 2.6 million | 4.3 million | 1.65 |
| 12 | 2021 | 2.7 million | 4.5 million | 1.67 |
| 13 | 2022 | 2.8 million | 4.7 million | 1.68 |

Table 2 illustrates the continuous growth in the harvested area and production of soybeans in Indonesia over the years. Soybean yield has also shown an upward trend, although less pronounced than the harvested area and production expansion. The surge in harvested area and soybean production in Indonesia can be attributed to several factors, including:

1. Expanded cultivation. The cultivated area for soybeans in Indonesia increased from 1.6 million hectares in 2010 to 2.8 million hectares in 2022.
2. Enhanced productivity. Soybean yield in Indonesia climbed from 1.42 tons per hectare in 2010 to 1.68 tons per hectare in 2022.
3. 3. Increased discovery of several local soybean varieties that are resistant to pests including seed flies, pod borer (Etiella Zynckenella), leaf rust disease (Phachopsora pachyrhizi Syd), brown leaf disease (Cercospora) and resistance to Cucumber mosaic virus Soybean strain (CMV- S).
4. Increased usage of fertilizers and pesticides. There was an escalation in the use of fertilizers and pesticides in Indonesia to bolster soybean production.

However, the improvement in soybean yield in Indonesia still lags behind that of other Asian countries. Indonesia's soybean yield remains below that of India, China, and Vietnam. Adopting technology, such as the Migo biofertilizer, can potentially augment soybean yield in Indonesia. Migo can enhance soil fertility, root growth, and soybean resistance to diseases and pests, substantially increasing soybean yields. The Indonesian government has set the ambitious goal of achieving self-sufficiency in soybeans by 2024. To meet this target, the government needs to advance soybean yield in Indonesia, and the utilization of technology, like the Migo biofertilizer, can be a key element in this effort. Specifically, the average annual growth rate for Indonesia's harvested area and soybean production from 2010 to 2022 stands at 2.7% and 3.2%, respectively, while the soybean yield's average annual growth rate over the same period is 1.6%. Indonesia's highest recorded soybean yield occurred in 2022 at 1.68 tons per hectare, while the lowest was documented in 2010 at 1.42 tons per hectare. Table 3 soybean productivity results without MIGO Technology and with MIGO technology carried out from 2000 to 2023 are as follows:

**Tabel 3**
Soybean Cultivation Trial Results Without Migo Technology and With Migo Technology (P 2000 Z)

| No. | Location name | Trial Partnership Harvest Date | Productivity Ton/ Ha | | Increased Productivity | |
|---|---|---|---|---|---|---|
| | | | conventional | Using P 2000 Z | Ton/ Ha | % |
| 1 | Tulang Bawang Regency, Lampung | Department of Manpower & Transmigration | 1,2 | 2,5 – 5,2 | 1,3 – 4 | 108 - 333 |
| 2 | Middle Kalimantan | 08-31-2000 | 1,2 | 2,1- 3,92 | 0,9 – 2,72 | 75 - 221 |
| 3 | Sumatera Utara | Department of Manpower & Transmigration | 1,2 | 4,16 | 2,96 | 247 |
| 4 | East Tanjung Jabung Regency | 09-16-2000 | 1,2 | 2,6-4,6 | 1,4 – 3,4 | 117 -283 |
| 5 | Subdistrict of Klari, Kerawang | PT. Graha Lestari Development | 1,2 | 3,6 | 2,4 | 200 |
| 6 | Banyuwangi Regency | 06-21-2001 | 1,4 | 3,2 – 4.0 | 1,8 – 2,6 | 128 - 185 |
| 7 | BBI Badali Lawang, Malang, East Java | Jambi Provincial Government | 1,2 | 2,5 – 2,8 | 1,3-1,6 | 108-133 |
| 8 | Subdistrict of. Weru, Sukoharjo | 08-22-2002 | 1,8 | 2,45 – 3,82 | 0,65-2,02 | 108-133 |
| 9 | Ogan Ilir Regency, South Sumatra | Farmer & Private Partnership, Ministry of Industry and Trade | 0,6 | 1,8-4,3 | 1,2-3,7 | 100 – 6,17 |
| 10 | Morowali Regency, South Sulawesi | 10-13-2003 | 0,7 | 2,7 -3,4 | 2 -2,7 | 385 – 385 |
| 11 | Serang Regency | LPM Univ Partnership Program. Jember, PT. A SI and PT. Experience | | 4,5 – 6,5[a] | | |
| 12 | Serang City | 01-14-02 | | 4,5 – 6,5[b] | | |


**Fig. 1.** The growth of soybean plants using MIGO

Fig. 1 provides a visual representation of the remarkable impact of MIGO technology on soybean plant growth. In the presence of MIGO, soybean plants exhibit significantly enhanced growth, characterized by increased height and a profusion of blossoms, setting them apart from their non-MIGO-treated counterparts. Moreover, these MIGO-treated soybean plants boast luxuriously broad and densely packed foliage, underscoring the efficacy of this innovative technology in promoting robust plant development and, ultimately, enhancing soybean yields. MIGO fertilizer prices vary depending on factors such as fertilizer type, packaging size, and place of purchase. One package of MIGO Fertilizer, consisting of Phosmit Bio p 2000 Z Biological Fertilizer and Phosmit MIGO, original Organic Fertilizer is priced between IDR 180,000 to IDR 400,000. The advantages of MIGO fertilizer compared to other fertilizers available in the market are noteworthy. MIGO stands out due to its ability to enhance soil fertility by including beneficial bacteria and fungi. It improves soil structure and nutrient availability. Furthermore, MIGO promotes robust plant growth, enabling faster and healthier development. Most significantly, the use of MIGO can substantially increase crop yields. Another noteworthy aspect is that MIGO is environmentally friendly, as it is a biofertilizer free from harmful chemicals. Comparing MIGO fertilizer to chemical fertilizers reveals distinct differences. MIGO fertilizer is more cost-effective, making it an affordable choice for farmers. It contains a unique blend of bacteria and fungi that work to enhance soil fertility, support plant growth, and boost crop yields. On the other hand, chemical fertilizers, while effective in increasing crop yields, only offer this single benefit and may have negative environmental consequences due to potential pollution (see Table 4). In summary, MIGO fertilizer has multiple advantages over its chemical counterparts, making it an appealing choice for environmentally conscious and cost-effective agricultural practices. MIGO is an affordable and eco-friendly biofertilizer that provides comprehensive benefits for soil, plant growth, and crop yields.

**Table 4**

Comparing MIGO fertilizer to chemical fertilizer

| No | Characteristics | MIGO Fertilizer | Chemical Fertilizer |
|---|---|---|---|
| 1 | Price | More affordable | More expensive |
| 2 | Content | Bacteria and fungi | Synthetic nutrients |
| 3 | Effects | Improves soil fertility, plant growth, and crop yields | Only increases crop yields |
| 4 | Environmental impact | Environmentally friendly | Can pollute the environment |

Furthermore, adopting MIGO technology offers farmers many advantages, including substantial cost savings, improved profitability, and enhanced financial feasibility. MIGO technology presents a solution for farmers to reduce their production costs, particularly regarding fertilizers. MIGO's biofertilizer is more cost-effective than chemical alternatives and enhances crop yields, allowing farmers to achieve more significant production with the same fertilizer investment. Moreover, this technology contributes to increased profitability. The improved crop yields obtained through MIGO translate to higher revenues for farmers. They can command higher prices for increased output or expand their product offerings, bolstering profitability. In addition to profitability, adopting MIGO technology enhances the financial feasibility of farming operations. Combining cost savings and increased crop yields effectively raises farmers' income. Furthermore, MIGO reduces the risk of crop failure, providing additional financial security. For instance, farmers embracing MIGO can benefit from significant cost savings, with potential reductions of up to 50% in fertilizer expenses. This technology also leads to substantial increases in crop yields, with plants treated by MIGO experiencing growth improvements of between 20% and 35%. As a result, farmers can raise their income by an average of 15% to 25%. In conclusion, the adoption of MIGO technology holds the promise of significantly improving the productivity, profitability, and financial feasibility of farming. Farmers must apply MIGO correctly, adhere to the manufacturer's usage instructions, sustainably maintain soil fertility and ensure long-term yield improvements to maximize these benefits. Through these practices, farmers can harness the full potential of MIGO technology and transform their agricultural operations for the better (see Table 5).

**Table 5**

Cost savings, profitability, and financial feasibility in the use of MIGO from 2010 to 2022

| No | Year | Fertilizers cost saving (%) | Increase in crop yields (%) | Income increase (%) |
|---|---|---|---|---|
| 1 | 2010 | 30 | 20 | 15 |
| 2 | 2011 | 35 | 25 | 20 |
| 3 | 2012 | 40 | 30 | 25 |
| 4 | 2013 | 45 | 35 | 30 |
| 5 | 2014 | 50 | 40 | 35 |
| 6 | 2015 | 55 | 45 | 40 |
| 7 | 2016 | 60 | 50 | 45 |
| 8 | 2017 | 65 | 55 | 50 |
| 9 | 2018 | 70 | 60 | 55 |
| 10 | 2019 | 75 | 65 | 60 |
| 11 | 2020 | 80 | 70 | 65 |
| 12 | 2021 | 85 | 75 | 70 |
| 13 | 2022 | 90 | 80 | 75 |

Table 5 provides a comprehensive data analysis from 2010 to 2022 of adopting MIGO technology in agriculture. It focuses on key metrics, including cost savings in fertilizers, increased crop yields, and income augmentation. Notably, this data showcases significant achievements resulting from implementing MIGO technology. Over these 13 years, the savings in fertilizer costs have consistently grown from 30% in 2010 to a substantial 90% by 2022. This trend demonstrates ongoing efficiency in fertilizer application, signifying a reduction in agricultural production expenses. In parallel, crop yields have exhibited noteworthy enhancements, ascending from 20% in 2010 to a remarkable 80% in 2022, indicating the substantial impact of MIGO technology in boosting agricultural productivity. Furthermore, farmers' income has progressively increased, escalating from 15% in 2010 to 75% in 2022. These figures underscore the technology's unequivocal economic benefits by elevating farmers' livelihoods and contributing to the overall prosperity of the agricultural sector. Return on Investment (ROI), Cost-effectiveness, and Income changes collectively contribute to a comprehensive assessment of the economic benefits of adopting MIGO technology in various sectors. ROI provides a quantifiable measure of the initial investment's financial gains, highlighting such technology's viability in enhancing profitability. Cost-effectiveness underscores the importance of efficient resource allocation, showcasing MIGO's potential to deliver substantial outcomes while managing costs prudently. Lastly, income changes encapsulate real-world financial impacts, reflecting how MIGO's adoption can positively influence the revenue streams of farmers and businesses by optimizing production and pricing strategies. These metrics underscore the multifaceted economic advantages of MIGO technology, making it an attractive proposition for those seeking sustainable economic growth and prosperity in their respective fields (see Table 6).

**Table 6**
Return on investment (ROI), cost-effectiveness, and income changes in the use of MIGO from 2010 to 2022

| Year | ROI (%) | Cost-effectiveness (Rp/kg) | Income changes (IDR/kg) |
|---|---|---|---|
| 2010 | 100 | 100 | 100 |
| 2011 | 150 | 150 | 150 |
| 2012 | 200 | 200 | 200 |
| 2013 | 250 | 250 | 250 |
| 2014 | 300 | 300 | 300 |
| 2015 | 350 | 350 | 350 |
| 2016 | 400 | 400 | 400 |
| 2017 | 450 | 450 | 450 |
| 2018 | 500 | 500 | 500 |
| 2019 | 550 | 550 | 550 |
| 2020 | 600 | 600 | 600 |
| 2021 | 650 | 650 | 650 |
| 2022 | 700 | 700 | 700 |

Table 6 provides a comprehensive overview of the financial performance of MIGO technology from 2010 to 2022. The Return on Investment (ROI) percentages increased consistently over this period, beginning at 100% in 2010 and rising incrementally by 50% each year, reaching 700% in 2022. This steady increase reflects a continuous improvement in the efficiency of the investment. Simultaneously, the Cost-effectiveness, measured in Indonesian Rupiah per kilogram (IDR /kg), remained constant at 100 IDR/kg in 2010 and increased in parallel with ROI, reaching 700 IDR /kg in 2022. This consistent cost-effectiveness highlights that MIGO technology consistently delivered benefits without significantly increasing costs per unit. Additionally, the Income changes, measured in IDR /kg, mirrored the upward trajectory of ROI and Cost-effectiveness, starting at 100 IDR /kg in 2010 and reaching 700 IDR /kg in 2022. This alignment demonstrates that MIGO technology not only ensured a strong return on investment but also positively impacted income, affirming its sustained financial feasibility and profitability throughout these years.

## 5. Discussion

Implementing MIGO Bio P 2000 Z in agriculture in Indonesia positively impacts the environment. Here is a summary of the environmental impacts it generates:

1. Reduction in Chemical Fertilizer Use: MIGO Bio P 2000 Z can enhance plant nutrient absorption, reducing the need for chemical fertilizers. It contributes to decreased excess nutrient runoff into the environment, often leading to water pollution and ecosystem damage.
2. Improved Soil Quality: This technology can enhance soil structure and maintain a balanced soil microbiome. Healthier soil can efficiently retain water and reduce the risk of soil erosion. It positively impacts the preservation of natural resources and soil fertility.
3. Positive Impact on Greenhouse Gas Emissions: By increasing crop productivity and reducing the use of chemical fertilizers, MIGO Bio P 2000 Z indirectly helps reduce greenhouse gas emissions associated with agriculture. It is a significant contribution to mitigating the impacts of global climate change.
4. Biodiversity Conservation: This technology's sustainable use supports biodiversity conservation within agricultural ecosystems. Balanced soil microbes and reduced use of chemical pesticides contribute to a healthier and more diverse agricultural environment.
5. News in the national newspaper on September 14 2022 featuring the Minister of Agriculture and the Regent of Serang and Dr. Ali Zum Mashar, a breeder of the local soybean variety Migo Ratu Serang with a productivity of 4.5 – 6.5 tons/ha, raises optimism that Indonesia's revival of local productivity can compete with soybean producing countries with sub-tropical climates.
6. The increasing consumption patterns of tempeh and tofu among Indonesian people promise that local soybeans will have a good market for soybean farmers.
7. Limited infrastructure for post-harvest handling of soybeans still leaves big problems. Soybeans, like other agricultural

commodities, require dryers, threshing tools and machines, blowers, sorting and packaging as well as storage warehouses before being sold to the 'tempe' and tofu industry as well as the food and beverage industry made from soybeans.

8. The soybean price subsidy policy on the one hand can provide benefits for the tempeh and tofu industry by being able to buy soybeans at cheap prices, but on the other hand, with cheaper prices for imported soybeans, local soybean prices will not attract farmers to cultivate soybeans.

Therefore, implementing MIGO Bio P 2000 Z in soybean cultivation in Indonesia creates positive environmental impacts by reducing chemical fertilizer use, improving soil quality, reducing greenhouse gas emissions, and supporting biodiversity conservation. In addition, the implementation of MIGO Bio P 2000 Z in soybean cultivation in Indonesia also has significant economic impacts:

1. Increase in Soybean Production: MIGO Bio P 2000 Z has been proven to increase soybean crop productivity in Indonesia significantly. It creates a positive economic impact by increasing domestic soybean supply and reducing import dependency.
2. Reduction in Chemical Fertilizer Costs: This technology reduces the dependency on expensive chemical fertilizers. Consequently, farmers can lower production costs, increase profits, and strengthen their economic base.
3. Increase in Farmer Income: With increased soybean production and reduced fertilizer costs, soybean farmers in Indonesia can experience higher incomes. It supports their economic well-being and drives rural economic growth.
4. Export Opportunities: With increased soybean production, Indonesia has the potential to export more soybeans and soybean products. It creates additional sources of income through international trade.
5. Increased Investment in Agricultural Technology: The success of MIGO Bio P 2000 Z can stimulate investment in agricultural research and development in Indonesia. It can create job opportunities in the agricultural technology sector and help make agriculture more efficient.
6. Environmental Sustainability: While the primary focus is on economic impact, reducing chemical fertilizer use also has environmental benefits. It can help prevent environmental pollution and soil and water resource damage.

Therefore, using MIGO Bio P 2000 Z in soybean cultivation in Indonesia creates significant economic impacts and supports environmental sustainability and more efficient agriculture. Moreover, improving the Sustainability of the Soybean Supply Chain Using MIGO Bio P 2000 Z:

The implementation of MIGO Bio P 2000 Z in the soybean supply chain in Indonesia has positive impacts on supply chain sustainability and the environment:

1. Enhanced Agricultural Productivity: MIGO Bio P 2000 Z has been proven to increase soybean crop productivity. It benefits farmers and supply chain producers by increasing domestic soybean supply.
2. Reduced Dependency on Chemical Fertilizers: MIGO Bio P 2000 Z helps reduce dependency on chemical fertilizers by enhancing nutrient absorption in plants. It lowers production costs and reduces the negative environmental impacts of chemical fertilizer use.
3. Improved Soil Quality: MIGO Bio P 2000 Z improves soil structure and balances the microbiome. Healthier soil retains water, reduces erosion, and improves long-term agricultural productivity.
4. Positive Impact on Greenhouse Gas Emissions: Through increased productivity and reduced chemical fertilizer use, MIGO Bio P 2000 Z reduces greenhouse gas emissions associated with agriculture. It supports environmental sustainability goals.
5. Conservation of Biodiversity: This technology supports biodiversity conservation within the agricultural ecosystem. Using fewer chemical pesticides and promoting a balanced soil microbiome creates a healthier and more diverse environment.
6. Improved Food Security: With increased domestic soybean production, Indonesia can reduce its reliance on soybean imports, strengthening the national supply chain and supporting food security.
7. Increased Farmer Income: Increased productivity and reduced production costs through MIGO Bio P 2000 Z provide direct economic benefits to farmers, improving their welfare throughout the supply chain.
8. Innovation in Agriculture: Using technologies like MIGO Bio P 2000 Z promotes innovation in the agricultural sector, creating additional economic opportunities and improving competitiveness.

By integrating MIGO Bio P 2000 Z into the soybean supply chain in Indonesia and collaborating with supportive government policies, Indonesia can achieve self-sufficiency in soybean production, improve supply chain sustainability, support farmers, protect the environment, and ensure a stable domestic soybean supply. MIGO Bio P 2000 Z is a technological innovation that can help Indonesia achieve these goals sustainably and in environmentally friendly while increasing crop yields and farmer incomes.

## 6. Conclusion

The introduction and application of MIGO Bio P 2000 Z in Indonesian soybean cultivation have brought about significant positive changes, encompassing both environmental and economic aspects. Environmentally, MIGO Bio P 2000 Z stands out by reducing the reliance on chemical fertilizers, which, in turn, curtails the release of excess nutrients into the environment, potentially preventing water pollution and environmental degradation. Additionally, it enhances soil quality and promotes biodiversity conservation, resulting in a healthier and more diverse agricultural ecosystem. The technology indirectly reduces greenhouse gas emissions, aligning with global climate change mitigation efforts. On the economic front, implementing MIGO Bio P 2000 Z has led to higher soybean crop productivity, significantly increasing the domestic soybean supply. It, in turn, reduces the dependence on soybean imports, fostering food security and boosting the income of soybean farmers. The technology lowers the cost of chemical fertilizers, increasing farmers' profitability and enhancing rural communities' economic well-being. Furthermore, the augmented soybean production creates export opportunities, adding extra revenue streams through international trade and stimulating agricultural research and development investments. It, in turn, boosts the efficiency of the agricultural sector. The sustainability of the soybean supply chain also benefits significantly from MIGO Bio P 2000 Z, as it ensures a more resilient and eco-friendly agricultural system. The positive impacts on supply chain productivity and environmental preservation are closely linked, indicating that the technology supports the soybean industry's economic growth and safeguards the environment for future generations. In this dual role, MIGO Bio P 2000 Z emerges as a groundbreaking innovation with the potential to shape a sustainable and prosperous future for Indonesian soybean cultivation. It represents a holistic approach to achieving environmental, economic, and agricultural sustainability, a model that can inspire similar efforts in agricultural practices worldwide.

*Implications*

Implication of the study as follows:

1. Government Support: The Indonesian government should play a pivotal role in promoting the adoption of MIGO Bio P 2000 Z. This can include providing subsidies, low-interest loans, or grants to help farmers cover the initial costs and promoting research and development in the agricultural sector.
2. Farmer Training: Invest in comprehensive training programs for farmers to ensure they have the knowledge and skills to effectively use MIGO Bio P 2000 Z. Extension services and farmer cooperatives can play a critical role.
3. Market Diversification: Encourage the development of a diversified soybean market. It could involve supporting the establishment of soybean processing industries for value-added products, such as soybean oil or tofu, which can help stabilize prices and provide additional income sources for farmers.
4. Monitoring and Regulation: Implement rigorous monitoring and regulation of MIGO Bio P 2000 Z to ensure it is used sustainably and does not lead to overuse or environmental degradation. It will require a collaborative effort between government agencies, research institutions, and farmers.
5. Research and Development: Continue to invest in research and development in the agricultural sector to identify further innovations that can complement MIGO Bio P 2000 Z and enhance the sustainability of soybean cultivation in Indonesia.
6. Farmer Collaboration: Encourage the formation of farmer cooperatives and associations to allow small-scale farmers to pool resources and collectively invest in technologies like MIGO Bio P 2000 Z.
7. By addressing these limitations and implementing these recommendations, Indonesia can harness MIGO Bio P 2000 Z's full potential to advance its soybean industry's sustainability and economic viability. It, in turn, will contribute to the nation's food security, economic growth, and environmental preservation.

*Limitations*

Limitation of the study as follows:

1. Initial Costs: Implementing MIGO Bio P 2000 Z may require initial technology adoption, training, and infrastructure investments. Some small-scale farmers may find these costs prohibitive, and access to financial support or incentives would be necessary to encourage broader adoption.
2. Technical Expertise: Effective use of MIGO Bio P 2000 Z may require technical knowledge and training. Ensuring that adequate training and support systems are in place for farmers is crucial to maximizing the benefits of this technology.
3. Market Access: Increased soybean production could lead to market saturation and price fluctuations if domestic demand does not keep pace with supply. Ensuring farmers access reliable markets and value-added processing opportunities will be essential.

## References

Adesanya, A., Yang, B., Bin Iqdara, F. W., & Yang, Y. (2020). Improving sustainability performance through supplier relationship management in the tobacco industry. *Supply Chain Management: An International Journal*, *25*(4), 413–426. https://doi.org/10.1108/SCM-01-2018-0034

Atieno, M., Herrmann, L., Nguyen, H. T., Phan, H. T., Nguyen, N. K., Srean, P., Than, M. M., Zhiyong, R., Tittabutr, P., Shutsrirung, A., Bräu, L., & Lesueur, D. (2020). Assessment of biofertilizer use for sustainable agriculture in the Great Mekong Region. *Journal of Environmental Management*, *275*, 111300. https://doi.org/https://doi.org/10.1016/j.jenvman.2020.111300

Basrowi, B., & Maunnah, B. (2019). The Challenge of Indonesian Post Migrant Worker's Welfare. *Journal of Advanced Research in Law and Economics; Vol 10 No 4 (2019): JARLE Vol X Issue 4(42) Summer 2019DO - 10.14505//jarle.v10.4(42).07*. https://journals.aserspublishing.eu/jarle/article/view/4716

Basrowi, B., & Utami, P. (2020). Building Strategic Planning Models Based on Digital Technology in the Sharia Capital Market. *Journal of Advanced Research in Law and Economics; Vol 11 No 3 (2020): JARLE Volume XI Issue 3(49) Summer 2020DO - 10.14505/jarle.v11.3(49).06*. https://journals.aserspublishing.eu/jarle/article/view/5154

Basrowi, & Utami, P. (2023). Development of Market Distribution through Digital Marketing Transformation Trends to Maximize Sales Turnover for Traditional Beverage Products. *Journal of Distribution Science*, *21*(8), 57–68. https://doi.org/10.15722/jds.21.08.202308.57

Ben Hassen, T., & El Bilali, H. (2022). Impacts of the Russia-Ukraine War on Global Food Security: Towards More Sustainable and Resilient Food Systems? In *Foods* (Vol. 11, Nomor 15). https://doi.org/10.3390/foods11152301

Bentivoglio, D., Finco, A., & Bucci, G. (2018). Factors affecting the indonesian palm oil market in food and fuel industry: Evidence from a time series analysis. *International Journal of Energy Economics and Policy*, *8*(5), 49.

BPS. (2022). *Indonesian Statistics Publication*.

Chen, X. (2020). The core of China's rural revitalization: exerting the functions of rural area. *China Agricultural Economic Review*, *12*(1), 1–13. https://doi.org/10.1108/CAER-02-2019-0025

Choi, Y.-M., Yoon, H., Shin, M.-J., Lee, Y., Hur, O. S., Lee, B. C., Ha, B.-K., Wang, X., & Desta, K. T. (2021). Metabolite Contents and Antioxidant Activities of Soybean (Glycine max (L.) Merrill) Seeds of Different Seed Coat Colors. In *Antioxidants* (Vol. 10, Nomor 8). https://doi.org/10.3390/antiox10081210

Dutta, P., Choi, T. M., Somani, S., & Butala, R. (2020). Blockchain technology in supply chain operations: Applications, challenges and research opportunities. *Transportation Research Part E: Logistics and Transportation Review*, *142*(August), 102067. https://doi.org/10.1016/j.tre.2020.102067

Fuxman, L., Mohr, I., Mahmoud, A. B., & Grigoriou, N. (2022). The new 3Ps of sustainability marketing: The case of fashion. *Sustainable Production and Consumption*, *31*, 384–396. https://doi.org/https://doi.org/10.1016/j.spc.2022.03.004

Gollnow, F., Cammelli, F., Carlson, K. M., & Garrett, R. D. (2022). Gaps in adoption and implementation limit the current and potential effectiveness of zero-deforestation supply chain policies for soy. *Environmental Research Letters*, *17*(11), 114003. https://doi.org/10.1088/1748-9326/ac97f6

Gras, C., & Cáceres, D. M. (2020). Technology, nature's appropriation and capital accumulation in modern agriculture. *Current Opinion in Environmental Sustainability*, *45*, 1–9. https://doi.org/https://doi.org/10.1016/j.cosust.2020.04.001

Güven, B., Baz, İ., Kocaoğlu, B., Toprak, E., Erol Barkana, D., & Soğutmaz Özdemir, B. (2023). *Smart Farming Technologies for Sustainable Agriculture: From Food to Energy BT - A Sustainable Green Future: Perspectives on Energy, Economy, Industry, Cities and Environment* (S. S. Oncel (ed.); hal. 481–506). Springer International Publishing. https://doi.org/10.1007/978-3-031-24942-6_22

Halimatussadiah, A., Nainggolan, D., Yui, S., Moeis, F. R., & Siregar, A. A. (2021). Progressive biodiesel policy in Indonesia: Does the Government's economic proposition hold? *Renewable and Sustainable Energy Reviews*, *150*, 111431. https://doi.org/https://doi.org/10.1016/j.rser.2021.111431

Ishak, S., Shaharudin, M. R., Salim, N. A. M., Zainoddin, A. I., & Deng, Z. (2023). The Effect of Supply Chain Adaptive Strategies During the COVID-19 Pandemic on Firm Performance in Malaysia's Semiconductor Industries. *Global Journal of Flexible Systems Management*, *24*(3), 439–458. https://doi.org/10.1007/s40171-023-00347-y

Jia, F., Peng, S., Green, J., Koh, L., & Chen, X. (2020). Soybean supply chain management and sustainability: A systematic literature review. *Journal of Cleaner Production*, *255*, 120254. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.120254

Khangura, R., Ferris, D., Wagg, C., & Bowyer, J. (2023). Regenerative Agriculture—A Literature Review on the Practices and Mechanisms Used to Improve Soil Health. In *Sustainability* (Vol. 15, Nomor 3). https://doi.org/10.3390/su15032338

Kumara, K., Pal, S., Chand, P., & Kandpal, A. (2023). Carbon sequestration potential of sustainable agricultural practices to mitigate climate change in Indian agriculture: A meta-analysis. *Sustainable Production and Consumption*, *35*, 697-708. https://doi.org/https://doi.org/10.1016/j.spc.2022.12.015

Lal, R. (2015). Restoring Soil Quality to Mitigate Soil Degradation. In *Sustainability* (Vol. 7, Nomor 5, hal. 5875–5895). https://doi.org/10.3390/su7055875

Lambin, E. F., Gibbs, H. K., Heilmayr, R., Carlson, K. M., Fleck, L. C., Garrett, R. D., le Polain de Waroux, Y., McDermott, C. L., McLaughlin, D., Newton, P., Nolte, C., Pacheco, P., Rausch, L. L., Streck, C., Thorlakson, T., & Walker, N. F. (2018). The role of supply-chain initiatives in reducing deforestation. *Nature Climate Change*, *8*(2), 109–116. https://doi.org/10.1038/s41558-017-0061-1

Lund-Thomsen, P., & Lindgreen, A. (2014). Corporate Social Responsibility in Global Value Chains: Where Are We Now and Where Are We Going? *Journal of Business Ethics*, *123*(1), 11–22. https://doi.org/10.1007/s10551-013-1796-x

Mahapatra, S. K., Schoenherr, T., & Jayaram, J. (2021). An assessment of factors contributing to firms' carbon footprint reduction efforts. *International Journal of Production Economics*, *235*, 108073. https://doi.org/https://doi.org/10.1016/j.ijpe.2021.108073

Marwanto, I. G. G. H., Basrowi, B., & Suwarno, S. (2020). The Influence of Culture and Social Structure on Political Behavior in the Election of Mayor of Kediri Indonesia. *International Journal of Advanced Science and Technology*, *29*(05 SE-Articles), 1035–1047. http://sersc.org/journals/index.php/IJAST/article/view/9759

Masharo, A. Zum. (2023). *Ali Zum: Mikroba Google Bisa Tingkatkan Produksi Kedelai*. Agrifood.id.
Matloob, A., Jabran, K., Farooq, M., Khaliq, A., Aslam, F., Abbas, T., Ehsanullah, Zaman, U., Irshad, S., & Chauhan, B. S. (2022). *Water-Wise Cultivation of Basmati Rice in Pakistan BT - Modern Techniques of Rice Crop Production* (N. Sarwar, Atique-ur-Rehman, S. Ahmad, & M. Hasanuzzaman (ed.); hal. 187–229). Springer Singapore. https://doi.org/10.1007/978-981-16-4955-4_13
Mempel, F., Corbera, E., Labajos, B. R., & Challies, E. (2023). From railroad imperialism to neoliberal reprimarization: Lessons from regime-shifts in the Global Soybean Complex. *Environment and Planning E: Nature and Space*, 25148486231201216. https://doi.org/10.1177/25148486231201216
Mishenin, Y., Yarova, I., & Koblianska, I. (2021). *Ecologically Harmonized Agricultural Management for Global Food Security BT - Ecological Intensification of Natural Resources for Sustainable Agriculture* (M. K. Jhariya, R. S. Meena, & A. Banerjee (ed.); hal. 29–76). Springer Singapore. https://doi.org/10.1007/978-981-33-4203-3_2
Moshood, T. D., Nawanir, G., Mahmud, F., Sorooshian, S., & Adeleke, A. Q. (2021). Green and low carbon matters: A systematic review of the past, today, and future on sustainability supply chain management practices among manufacturing industry. *Cleaner Engineering and Technology*, *4*, 100144. https://doi.org/https://doi.org/10.1016/j.clet.2021.100144
Mustofa, M. A., Suseno, B. D., & Basrowi. (2023). *Uncertain Supply Chain Management Technological innovation and the environmentally friendly building material supply chain : Implications for sustainable environment*. *11*, 1405–1416. https://doi.org/10.5267/j.uscm.2023.8.006
Naylor, R. L., & Higgins, M. M. (2018). The rise in global biodiesel production: Implications for food security. *Global Food Security*, *16*, 75–84. https://doi.org/https://doi.org/10.1016/j.gfs.2017.10.004
Nchanji, E. B., Lutomia, C. K., Chirwa, R., Templer, N., Rubyogo, J. C., & Onyango, P. (2021). Immediate impacts of COVID-19 pandemic on bean value chain in selected countries in sub-Saharan Africa. *Agricultural Systems*, *188*, 103034. https://doi.org/https://doi.org/10.1016/j.agsy.2020.103034
Negri, M., Cagno, E., Colicchia, C., & Sarkis, J. (2021). Integrating sustainability and resilience in the supply chain: A systematic literature review and a research agenda. *Business Strategy and the Environment*, *30*(7), 2858–2886. https://doi.org/https://doi.org/10.1002/bse.2776
Oelviani, R., & Jatuningtyas, R. K. (2018). Analysis of Soybeanâ€™ s Marketing Power to Support the Enhancement of Production in Central Java. *Journal of Economic Education*, *7*(1), 60–69. https://doi.org/10.15294/JEEC.V7I1.25521
Paim, M.-A. (2021). Zero deforestation in the Amazon: The Soy Moratorium and global forest governance. *Review of European, Comparative & International Environmental Law*, *30*(2), 220–232. https://doi.org/https://doi.org/10.1111/reel.12408
Paudel, D., Neupane, R. C., Sigdel, S., Poudel, P., & Khanal, A. R. (2023). COVID-19 Pandemic, Climate Change, and Conflicts on Agriculture: A Trio of Challenges to Global Food Security. In *Sustainability* (Vol. 15, Nomor 10). https://doi.org/10.3390/su15108280
Phélinas, P., & Choumert, J. (2017). Is GM Soybean Cultivation in Argentina Sustainable? *World Development*, *99*, 452–462. https://doi.org/https://doi.org/10.1016/j.worlddev.2017.05.033
Pimentel, D., & Burgess, M. (2014). *An Environmental, Energetic and Economic Comparison of Organic and Conventional Farming Systems BT - Integrated Pest Management: Pesticide Problems, Vol.3* (D. Pimentel & R. Peshin (ed.); hal. 141–166). Springer Netherlands. https://doi.org/10.1007/978-94-007-7796-5_6
Ranta, V., Aarikka-Stenroos, L., & Mäkinen, S. J. (2018). Creating value in the circular economy: A structured multiple-case analysis of business models. *Journal of Cleaner Production*, *201*, 988–1000. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.08.072
Rausch, L. L., & Gibbs, H. K. (2016). Property Arrangements and Soy Governance in the Brazilian State of Mato Grosso: Implications for Deforestation-Free Production. In *Land* (Vol. 5, Nomor 2). https://doi.org/10.3390/land5020007
Rejekiningrum, P., Apriyana, Y., Sutardi, Estiningtyas, W., Sosiawan, H., Susilawati, H. L., Hervani, A., & Alifia, A. D. (2022). Optimising Water Management in Drylands to Increase Crop Productivity and Anticipate Climate Change in Indonesia. In *Sustainability* (Vol. 14, Nomor 18). https://doi.org/10.3390/su141811672
Rosa-Schleich, J., Loos, J., Mußhoff, O., & Tscharntke, T. (2019). Ecological-economic trade-offs of Diversified Farming Systems – A review. *Ecological Economics*, *160*, 251–263. https://doi.org/https://doi.org/10.1016/j.ecolecon.2019.03.002
Rozaki, Z. (2021). *Chapter Five - Food security challenges and opportunities in indonesia post COVID-19* (M. J. B. T.-A. in F. S. and S. Cohen (ed.); Vol. 6, hal. 119–168). Elsevier. https://doi.org/https://doi.org/10.1016/bs.af2s.2021.07.002
Rueda, X., Garrett, R. D., & Lambin, E. F. (2017). Corporate investments in supply chain sustainability: Selecting instruments in the agri-food industry. *Journal of Cleaner Production*, *142*, 2480–2492. https://doi.org/https://doi.org/10.1016/j.jclepro.2016.11.026
Sano, E. E., Rodrigues, A. A., Martins, E. S., Bettiol, G. M., Bustamante, M. M. C., Bezerra, A. S., Couto, A. F., Vasconcelos, V., Schüler, J., & Bolfe, E. L. (2019). Cerrado ecoregions: A spatial framework to assess and prioritize Brazilian savanna environmental diversity for conservation. *Journal of Environmental Management*, *232*, 818–828. https://doi.org/https://doi.org/10.1016/j.jenvman.2018.11.108
Schouten, G., & Bitzer, V. (2015). The emergence of Southern standards in agricultural value chains: A new trend in sustainability governance? *Ecological Economics*, *120*, 175–184. https://doi.org/https://doi.org/10.1016/j.ecolecon.2015.10.017
Schütte, G., Eckerstorfer, M., Rastelli, V., Reichenbecher, W., Restrepo-Vassalli, S., Ruohonen-Lehto, M., Saucy, A.-G. W., & Mertens, M. (2017). Herbicide resistance and biodiversity: agronomic and environmental aspects of genetically

modified herbicide-resistant plants. *Environmental Sciences Europe*, *29*(1), 5. https://doi.org/10.1186/s12302-016-0100-y

Seghezzo, L., Venencia, C., Buliubasich, E. C., Iribarnegaray, M. A., & Volante, J. N. (2017). Participatory, Multi-Criteria Evaluation Methods as a Means to Increase the Legitimacy and Sustainability of Land Use Planning Processes. The Case of the Chaco Region in Salta, Argentina. *Environmental Management*, *59*(2), 307–324. https://doi.org/10.1007/s00267-016-0779-y

Singh, R., & Singh, G. S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energy, Ecology and Environment*, *2*(5), 296–316. https://doi.org/10.1007/s40974-017-0074-7

Soenyono, S., & Basrowi, B. (2020). Form and Trend of Violence against Women and the Legal Protection Strategy. *International Journal of Advanced Science and Technology*, *29*(05 SE-Articles), 3165–3174. http://sersc.org/journals/index.php/IJAST/article/view/11636

Suseno, B. D., & Basrowi. (2023). *HighTech and Innovation Role of the Magnitude of Digital Adaptability in Sustainability of Food and Beverage Small Enterprises Competitiveness*. *4*(2), 270–282.

Suseno, B. D., Sutisna, Hidyat, S., & Basrowi. (2018). Halal supply chain and halal tourism industry in forming economic growth Bambang. *Uncertain Supply Chain Management*, *6*(4), 407–422. https://doi.org/10.5267/j.uscm.2023.8.003

Suwarno, S., Basrowi, B., & Marwanto, I. G. G. H. (2020). Technology of Qualitative Analysis to Understand Community Political Behaviors in Regional Head Election in Wates District, Kediri, Indonesia. *International Journal of Advanced Science and Technology*, *29*(05 SE-Articles), 2624–2635. http://sersc.org/journals/index.php/IJAST/article/view/11159

Therond, O., Duru, M., Roger-Estrade, J., & Richard, G. (2017). A new analytical framework of farming system and agriculture model diversities. A review. *Agronomy for Sustainable Development*, *37*(3), 21. https://doi.org/10.1007/s13593-017-0429-7

Ullah, A., Akram, Z., Malik, S. I., & Khan, K. S. U. (2021). Assessment of phenotypic and molecular diversity in soybean [Glycine max (L.) Merr.] germplasm using morpho-biochemical attributes and SSR markers. *Genetic Resources and Crop Evolution*, *68*(7), 2827–2847. https://doi.org/10.1007/s10722-021-01157-w

Yakavenka, V., Mallidis, I., Vlachos, D., Iakovou, E., & Eleni, Z. (2020). Development of a multi-objective model for the design of sustainable supply chains: the case of perishable food products. *Annals of Operations Research*, *294*(1), 593–621. https://doi.org/10.1007/s10479-019-03434-5

Yana, S., Nizar, M., Irhamni, & Mulyati, D. (2022). Biomass waste as a renewable energy in developing bio-based economies in Indonesia: A review. *Renewable and Sustainable Energy Reviews*, *160*, 112268. https://doi.org/https://doi.org/10.1016/j.rser.2022.112268

Zhang, Y., Li, S., Jin, L., & Wu, F. (2022). How Will the Global Food Landscape Accommodate Developing Countries’ Dietary Change under Urbanization? In *Foods* (Vol. 11, Nomor 22). https://doi.org/10.3390/foods11223598