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Agricultural Sources of Biofuels: Selection and Optimization of Energy Crops

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Abstract The increasing demand for sustainable and renewable energy sources has led to significant research into biofuels derived from agricultural sources. This study explores the selection and optimization of energy crops for biofuel production, focusing on their environmental impact, economic viability, and potential for large-scale implementation. Various energy crops, including first-generation food crops like corn and sugarcane, second-generation lignocellulosic biomass, and third-generation microalgae, are evaluated for their efficiency in biofuel production. The review highlights the advantages of using non-food crops such as Miscanthus, switchgrass, and sweet sorghum, which can grow on marginal lands and have high biomass yields. Additionally, the environmental benefits of using perennial grasses and short-rotation woody crops for soil improvement and carbon sequestration are discussed. The study also addresses the challenges associated with biofuel production, such as land use changes, carbon debt, and the need for advanced technologies to enhance yield and sustainability. Overall, this study provides a comprehensive analysis of the current state and future prospects of agricultural biofuels, emphasizing the importance of selecting appropriate energy crops and optimizing their cultivation to meet global energy demands sustainably.

Keywords Biofuels; Energy crops; Biomass; Sustainability; Carbon sequestration

1 Introduction

The increasing demand for energy, coupled with the environmental impacts of fossil fuel consumption, has driven the search for sustainable and renewable energy sources. Biofuels, derived from biological materials, have emerged as a promising alternative to fossil fuels. They offer the potential to reduce greenhouse gas emissions, mitigate climate change, and provide a renewable source of energy. Biofuels can be produced from various feedstocks, including agricultural residues, energy crops, and microalgae, each presenting unique advantages and challenges (Demirbaş, 2009; Rodionova et al., 2017; Ambaye et al., 2021).

Biofuels are categorized into different generations based on their feedstock sources and production processes. First-generation biofuels are derived from food crops, such as corn and sugarcane, which has raised concerns about food security and land use (Femeena et al., 2018; Callegari et al., 2020). Second-generation biofuels utilize non-food biomass, including agricultural residues and dedicated energy crops like Miscanthus and switchgrass, which offer higher biomass yields and lower environmental impacts (Heaton et al., 2008; Kiran et al., 2014). Third-generation biofuels, produced from microalgae, present a high potential for sustainable energy production due to their rapid growth rates and high oil content (Rodionova et al., 2017; Callegari et al., 2020).

The primary objective of this study is to evaluate the selection and optimization of agricultural sources for biofuel production. This study aims to assess the potential of various energy crops and agricultural residues for biofuel production, analyze the environmental and economic impacts of using different feedstocks. Identify the technological advancements and challenges in biofuel production from agricultural sources. And provide recommendations for optimizing the use of energy crops to enhance biofuel yield and sustainability.

This study encompasses a comprehensive analysis of recent research on biofuel production from agricultural sources. The scope includes first-, second-, and third-generation biofuels, with a focus on energy crops and agricultural residues. The methodology involves a systematic examination of peer-reviewed articles. Evaluation of various energy crops and agricultural residues, including their biomass yield, growth conditions, and suitability for biofuel production (Heaton et al., 2008; Demirbaş, 2009; Femeena et al., 2018). Analysis of biochemical, thermochemical, and genetic engineering techniques used in biofuel production (Ambaye et al., 2021; Rodionova et al., 2017). Assessment of the carbon footprint, land use, and sustainability of different biofuel feedstocks (Fargione et al., 2008; Demirbaş, 2009). Examination of the cost-effectiveness and market potential of biofuels derived from agricultural sources (Kiran et al., 2014; Rodionova et al., 2017). By synthesizing the findings from multiple studies, this study aims to provide a holistic understanding of the current status and future prospects of biofuels from agricultural sources, guiding future research and policy decisions in the field of sustainable energy.

2 Overview of Biofuels

2.1 Types of biofuels

Biofuels are renewable energy sources derived from biological materials, offering a sustainable alternative to fossil fuels. They are categorized into three generations based on the source and production technology. Understanding these types and their respective advantages and disadvantages, as well as the current global status and trends in biofuel production, is crucial for optimizing the selection and use of energy crops. First-generation biofuels are produced from food crops such as corn, sugarcane, and vegetable oils through conventional processes like fermentation and transesterification. While these biofuels are relatively easy to produce and have established markets, their reliance on food crops raises concerns about food security and land use (Jegannathan and Ravindra, 2009).

Second-generation biofuels are derived from non-food biomass, including agricultural residues, wood chips, and dedicated energy crops like switchgrass. These biofuels utilize advanced technologies such as gasification and enzymatic hydrolysis. They offer an improvement over first-generation biofuels by minimizing competition with food resources and utilizing waste materials, although their production processes are more complex and costly (Cheng and Timilsina, 2011).

Third-generation biofuels are produced from algae and other microorganisms. These biofuels have the potential for high yields and can be cultivated on non-arable land, reducing the impact on food production and land use. Additionally, algae can absorb CO_2 during growth, contributing to greenhouse gas mitigation. However, third-generation biofuels are still in the experimental stage and face significant technical and economic challenges before they can be scaled up for widespread use (Gharabaghi et al., 2015).

2.2 Advantages and disadvantages of biofuels

Biofuels offer several advantages over fossil fuels. They are renewable and can be produced locally, reducing dependence on imported oil and enhancing energy security. Biofuels can also help mitigate climate change by reducing greenhouse gas emissions, especially when derived from waste materials or cultivated with sustainable practices. Additionally, biofuels can stimulate rural development and create jobs in agriculture and bioenergy sectors (Hafizan and Zainura, 2013).

However, there are also disadvantages to consider. First-generation biofuels can compete with food production, leading to higher food prices and potential food shortages. The land use changes associated with biofuel crop cultivation can result in deforestation, habitat loss, and biodiversity decline. Second and third-generation biofuels, while more sustainable, require advanced technologies and significant investments, making them less economically viable at present. Moreover, the environmental benefits of biofuels can be offset by unsustainable agricultural practices and the energy-intensive nature of some production processes (Elfasakhany, 2019).

2.3 Current global status and trends in biofuel production

The global production and use of biofuels have been steadily increasing, driven by policies aimed at reducing greenhouse gas emissions and promoting renewable energy. The United States and Brazil are the leading producers of bioethanol, primarily from corn and sugarcane, respectively. The European Union, on the other hand, dominates the biodiesel market, with production based on rapeseed oil and other vegetable oils (Araújo and Silva, 2017).

There is a growing interest in second-generation biofuels, supported by research and development efforts and government incentives. Countries like the United States, Canada, and members of the European Union are investing in advanced biofuel technologies to overcome the limitations of first-generation biofuels. Additionally, there is a significant focus on developing third-generation biofuels, with numerous pilot projects and research initiatives aimed at scaling up algae-based biofuel production (Gendy and El-Temtamy, 2013).

Despite these advancements, biofuels still represent a small fraction of the global energy mix. The future growth of biofuel production will depend on technological innovations, economic viability, and the development of sustainable agricultural practices. Policies that promote research, provide financial incentives, and ensure sustainability standards will be crucial in shaping the biofuel industry and maximizing its benefits.

3 Selection Criteria for Energy Crops

3.1 Agronomic factors

The selection of energy crops for biofuel production involves a comprehensive evaluation of various factors to ensure sustainability, economic viability, and minimal environmental impact. This section outlines the key criteria for selecting energy crops, categorized into agronomic, environmental, economic, and socio-economic factors. Agronomic factors are critical in determining the suitability of a crop for biofuel production. High yield, appropriate growth cycle, and adaptability to different environmental conditions are essential characteristics. High biomass yield is a primary criterion. For instance, Miscanthus × giganteus has shown promising results with an average annual yield of 30 t/ha and a maximum of 61 t/ha in trials conducted in Illinois (Heaton et al., 2008). Similarly, maize classes 600 and 700 have demonstrated high biomass yields in Northern Italy (González-García et al., 2013). The growth cycle of the crop should align with the local agricultural calendar to optimize land use. Perennial crops like switchgrass and Miscanthus are advantageous due to their long growth cycles and minimal replanting requirements (Heaton et al., 2008; Zegada-Lizarazu et al., 2013). Crops must be adaptable to local soil and climatic conditions. For example, switchgrass and Miscanthus have been successfully cultivated in both the USA and Europe, indicating their adaptability to diverse environments (Zegada-Lizarazu et al., 2013).

3.2 Environmental factors

Environmental sustainability is a crucial consideration in the selection of energy crops. Factors such as water usage, soil requirements, and climate resilience play significant roles. Efficient water use is vital, especially in regions with limited water resources. Microalgae, for instance, require relatively small amounts of water compared to conventional land crops (Peng et al., 2019). The ability to grow in marginal soils without significant soil degradation is important. Warm-season grasses (WSGs) and short-rotation woody crops (SRWCs) can improve soil properties and sequester soil organic carbon (SOC), making them suitable for marginal lands (Blanco-Canqui, 2010). Crops must be resilient to climatic variations. C4 crops like Miscanthus and switchgrass are known for their high photosynthetic efficiency and resilience to arid conditions, making them suitable for energy farming.

3.3 Economic factors

Economic viability is essential for the large-scale adoption of energy crops. Factors such as the cost of cultivation, market value, and availability of subsidies influence the economic feasibility. The cost of growing, harvesting, and processing energy crops should be competitive. For example, the cost of growing willow, including transportation and shredding, is about $510 per hectare, with a payback period of 3.8 to 11 years depending on the use of biomass (Nosko et al., 2019). The market value of the biofuel produced from the crops should justify the investment. Crops like sugarcane, which is highly efficient in bioethanol production, have a significant market value. Government subsidies and incentives can enhance the economic attractiveness of energy crops. Policies such as the Renewable Energy Development Plan for Europe have historically supported the growth of energy crops (Nosko et al., 2019).

3.4 Socio-economic factors

Socio-economic factors are also important in the selection of energy crops, particularly their impact on food security and rural development. The use of food crops for biofuel production can compete with food supply, raising concerns about food security. Therefore, non-food crops or crops that can grow on marginal lands are preferred to avoid this competition (González-García et al., 2013; Kocar and Civaş, 2013). Energy crops can contribute to rural development by providing alternative income sources for farmers and creating job opportunities. The cultivation of energy crops like switchgrass and Miscanthus can stimulate economic activity in rural areas (González-García et al., 2013; Zegada-Lizarazu et al., 2013). The selection of energy crops for biofuel production requires a balanced consideration of agronomic, environmental, economic, and socio-economic factors to ensure sustainability and economic viability.

4 Major Energy Crops for Biofuel Production

4.1 First generation crops

First-generation biofuels are derived from food crops such as maize, sugarcane, wheat, and soybeans. These crops are primarily used for producing bioethanol and biodiesel. For instance, maize and sugarcane are extensively used for ethanol production, while soybeans and palm oil are common sources for biodiesel (Lemus and Parrish, 2009; Callegari et al., 2020). However, the use of these crops for biofuel production has been controversial due to their competition with food and feed, leading to concerns about food security and environmental sustainability (Lalman et al., 2016; Callegari et al., 2020).

4.2 Second generation crops

Second-generation biofuels are produced from non-food crops and lignocellulosic biomass, which include agricultural residues, perennial grasses, and woody crops. Examples of second-generation energy crops are Miscanthus, switchgrass, reed canarygrass, and short-rotation woody crops like black locust (Lemus and Parrish, 2009; Blanco-Canqui, 2010; Vries et al., 2014; Lalman et al., 2016; Callegari et al., 2020). These crops are advantageous as they can be grown on marginal lands, reducing competition with food crops and improving soil properties by sequestering soil organic carbon (SOC) and reducing soil erosion (Blanco-Canqui, 2010; Vries et al., 2014). Additionally, second-generation biofuels have a better environmental profile, contributing more significantly to greenhouse gas (GHG) emission reductions and resource use efficiencies compared to first-generation biofuels (Scranton et al., 2015).

4.3 Third generation crops

Third-generation biofuels are derived from algae, which have shown great potential due to their high yield and lower GHG footprint compared to first and second-generation biofuels (Callegari et al., 2020). Algae can be cultivated in various environments, including wastewater, and do not compete with food crops for arable land. Species like Chlamydomonas reinhardtii have been extensively studied for their biofuel production capabilities and genetic engineering potential to maximize yields (Nanda et al., 2018). Despite their promise, the production of algal biofuels still faces challenges such as high water and nutrient requirements, which need to be addressed to make them economically viable on a large scale (Nanda et al., 2018). The selection and optimization of energy crops for biofuel production involve balancing the trade-offs between food security, environmental sustainability, and economic feasibility. First-generation crops are well-established but controversial, second-generation crops offer environmental benefits and reduced competition with food crops, and third-generation crops like algae hold significant promise for the future of sustainable biofuel production (Quevedo-Amador et al., 2024) (Figure 1).

5 Optimization Strategies for Energy Crop Cultivation

5.1. Genetic engineering and crop breeding

Genetic engineering and crop breeding are pivotal in enhancing the yield and resilience of energy crops. Recent advancements in genetic engineering have shown promise in increasing the biomass and lipid content of crops, which are essential for biofuel production. For instance, microalgae have been genetically modified to enhance lipid accumulation, making them a viable option for large-scale biofuel production (Rodionova et al., 2017). Additionally, the breeding of high-yielding varieties of Miscanthus and switchgrass has demonstrated significant potential in meeting biofuel demands with less land use (Femeena et al., 2018). These crops have been optimized to convert solar energy more efficiently into biomass, achieving higher yields with minimal agricultural inputs.

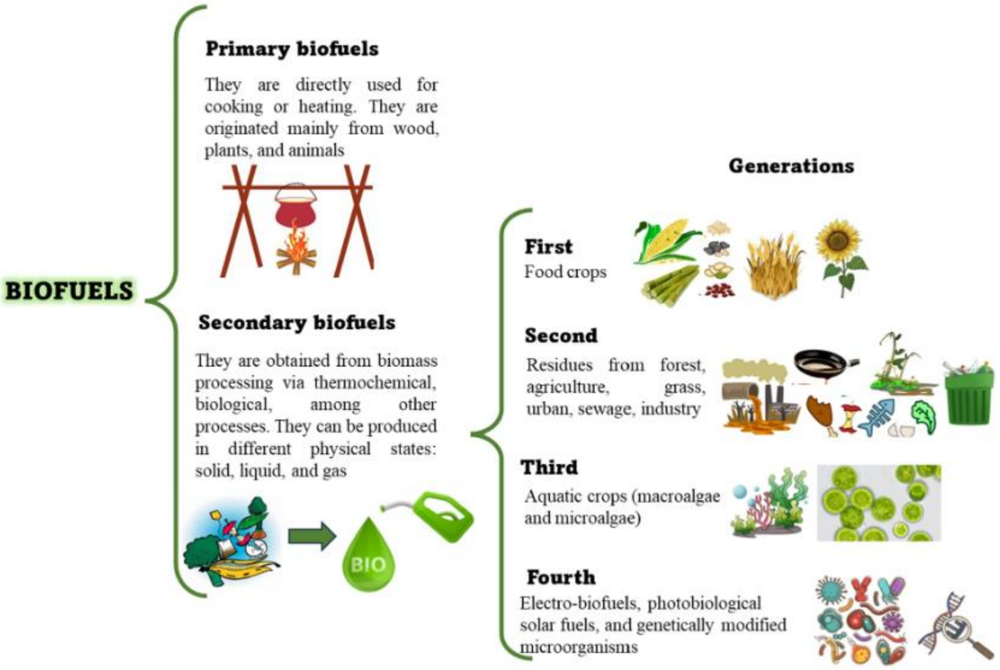

Figure 1 Classification of biofuels and their generations (Quevedo-Amador et al., 2024)
Image caption: his image is a diagram explaining biofuels, categorizing them into primary and secondary biofuels, and detailing the different generations of biofuels (Adopted from Quevedo-Amador et al., 2024)

5.2 Agronomic practices

Agronomic practices such as crop rotation, intercropping, and precision agriculture play a vital role in optimizing energy crop cultivation. Crop rotation and intercropping can improve soil health and reduce pest and disease incidence, thereby enhancing crop yields. For example, combining triticale or wheat with maize in rotation systems has been shown to achieve high biomass yields while improving the environmental profile of the cropping systems (González-García et al., 2013). Precision agriculture techniques, including the use of advanced sensors and data analytics, can optimize input use (e.g., water, fertilizers) and improve crop management practices, leading to higher productivity and sustainability.

5.3 Soil and water management techniques

Effective soil and water management techniques are essential for the sustainable cultivation of energy crops. Practices such as the use of cover crops, reduced tillage, and efficient irrigation systems can enhance soil health and water use efficiency. Growing perennial grasses like Miscanthus and switchgrass on marginal lands has been shown to improve soil properties, reduce soil erosion, and sequester soil organic carbon (SOC) (Abreu et al., 2022). Additionally, the use of geophysical imaging tools to monitor root water uptake and soil moisture can provide valuable insights into optimizing irrigation practices for different energy crops (Kuhl et al., 2021).

5.4 Technological advancements in biofuel conversion processes

Technological advancements in biofuel conversion processes are critical for improving the efficiency and scalability of biofuel production. Recent progress in thermo-bio-chemical processes has enabled the conversion of various biomass feedstocks, including crop residues and microalgae, into biofuels such as biodiesel, ethanol, and syngas (Ambaye et al., 2021) Innovations in metabolic and genetic engineering, coupled with nanotechnology, have further enhanced the efficiency of biofuel production from microalgae. These advancements not only increase biofuel yields but also reduce the environmental impact of biofuel production. The optimization of energy crop cultivation through genetic engineering, agronomic practices, soil and water management, and technological advancements in biofuel conversion processes is essential for achieving sustainable and efficient biofuel production. By integrating these strategies, it is possible to meet the growing demand for renewable energy while minimizing the environmental footprint of biofuel production.

6 Case Studies

6.1 Successful implementation of energy crops in various regions

The successful implementation of energy crops has been documented in various regions, showcasing the potential of these crops to contribute significantly to biofuel production. For instance, in Northern Italy, the cultivation of wheat, maize, and triticale for biogas production has been evaluated. The study highlighted that maize classes 600 and 700 provided the best results in terms of biomass yield and environmental impact, making them suitable for large-scale biogas production in the Po Valley (González-García et al., 2013). Similarly, in Iran, corn silage has been identified as the most effective energy crop for biogas production, with a potential annual yield equivalent to 1515.94 million barrels of oil (Nikkhah et al., 2020). These case studies demonstrate the feasibility and benefits of implementing energy crops in different agricultural settings.

6.2 Comparative analysis of different energy crops in terms of yield and sustainability

A comparative analysis of various energy crops reveals significant differences in yield and sustainability. In Northern Italy, maize outperformed wheat and triticale in terms of biomass yield and environmental profile, particularly when using maize classes 600 and 700 (González-García et al., 2013). Another study compared the production of biogas, bioethanol, and biodiesel from corn silage, corn, and peanuts, respectively, in Iran. The results indicated that biogas production from corn silage was the most energy-efficient and environmentally friendly option, with the lowest greenhouse gas emissions per unit of energy produced (Nikkhah et al., 2020). Additionally, C4 crops such as miscanthus, switchgrass, and sweet sorghum have been shown to produce higher biomass yields and possess greater resistance to aridity compared to C3 crops, making them more sustainable options for biofuel production (Callegari et al., 2020).

6.3 Lessons learned and best practices

Several lessons and best practices have emerged from the successful implementation and comparative analysis of energy crops. One key lesson is the importance of selecting the appropriate crop varieties and management practices to optimize yield and minimize environmental impact. For example, the use of calcium ammonium nitrate instead of urea as a fertilizer has been shown to improve the environmental profile of energy crops in Northern Italy (González-García et al., 2013). Additionally, the integration of best management practices, such as minimal tillage and the use of enhanced efficiency fertilizers, can further enhance the sustainability of biofuel feedstock production (Nikkhah et al., 2020). Furthermore, the cultivation of energy crops on marginal lands, as opposed to fertile agricultural lands, can help mitigate the competition with food production and improve soil properties, thereby contributing to overall environmental sustainability (Callegari et al., 2020). These best practices and lessons learned can guide future efforts in optimizing the production and sustainability of energy crops for biofuel production.

7 Challenges and Limitations

7.1 Technical challenges in crop cultivation and biofuel conversion

The cultivation of energy crops and the conversion of biomass into biofuels face several technical challenges. One significant issue is the optimization of crop yields to ensure a consistent and high-quality feedstock supply. Advances in genetic engineering have shown promise in enhancing crop productivity and resilience, but large-scale implementation remains difficult due to the complexity of genetic modifications and regulatory hurdles (Ambaye et al., 2021). Additionally, the conversion processes, such as thermo-bio-chemical methods, require further development to improve efficiency and scalability. The integration of novel technologies is essential to increase biofuel production and meet current and future energy demands (Ambaye et al., 2021).

7.2 Environmental impacts and sustainability concerns

The environmental impacts of biofuel production are a major concern, particularly regarding land use changes and carbon emissions. Converting natural ecosystems like rainforests, peatlands, and savannas into biofuel crop plantations can result in a significant "biofuel carbon debt," where the carbon released during land conversion far exceeds the greenhouse gas (GHG) savings from using biofuels instead of fossil fuels (Fargione et al., 2008). Sustainable biofuel production should focus on utilizing waste biomass or cultivating energy crops on degraded and abandoned agricultural lands to minimize carbon debt and provide immediate GHG benefits (Fargione et al., 2008).

7.3 Economic barriers and policy issues

Economic barriers to biofuel production include the high costs associated with crop cultivation, harvesting, and conversion technologies. The initial investment and operational costs can be prohibitive, especially for small-scale producers. Policy issues also play a critical role in the development of the biofuel industry. Inconsistent or insufficient government policies and subsidies can hinder the growth of biofuel markets. Effective policy frameworks are needed to support research and development, provide financial incentives, and ensure market stability for biofuels (Ambaye et al., 2021).

7.4 Socio-economic implications and food vs. fuel debate

The socio-economic implications of biofuel production are multifaceted. One of the most contentious issues is the food vs. fuel debate, where the allocation of arable land for energy crops can compete with food production, potentially leading to food shortages and increased prices. This competition can have severe impacts on food security, particularly in developing countries. Balancing the need for renewable energy sources with the necessity of maintaining food supplies is a critical challenge that requires careful consideration and strategic planning (Fargione et al., 2008). Additionally, the development of biofuel industries can create economic opportunities and jobs, but these benefits must be weighed against the potential negative impacts on food availability and prices.

8 Future Prospects and Research Directions

8.1 Emerging trends in energy crop research

Recent advancements in energy crop research have highlighted the potential of various crops to serve as sustainable biofuel sources. Notably, C_4 crops such as miscanthus, switchgrass, and sweet sorghum have garnered attention due to their high biomass yield, resistance to aridity, and efficient CO_2 capture capabilities, even on infertile lands. Additionally, the use of genetic engineering to enhance biofuel production from energy crops and microalgae has shown promising results, although large-scale production remains a challenge (Ambaye et al., 2021). The focus on sustainable farming practices and the quantification of nitrous oxide (N_2O) emissions from different feedstocks are also critical areas of ongoing research (Grosso et al., 2014).

8.2 Innovations in biofuel production technologies

Innovations in biofuel production technologies are pivotal for optimizing the conversion of biomass into biofuels. Thermo-bio-chemical processes, including the production of biodiesel, ethanol, bio-oil, syngas, Fischer-Tropsch H_2, and methane from crop residues and other biomass wastes, have been identified as eco-friendly routes for energy production (Ambaye et al., 2021). The development of closed-loop systems and efficient utilization of co-products are essential for minimizing environmental impacts and enhancing the sustainability of biofuel production (Guddaraddi et al., 2023). Furthermore, advancements in process technologies and the integration of life cycle assessments (LCA) are crucial for reducing greenhouse gas emissions and improving water conservation.

8.3 Policy recommendations for promoting sustainable biofuel production

To promote sustainable biofuel production, several policy recommendations are essential. Policies should incentivize research and development in biofuel technologies and support the adoption of best management practices, such as the use of enhanced efficiency fertilizers and minimal tillage (Grosso et al., 2014). Additionally, policies should encourage the use of marginal lands and the cultivation of high-yield, non-food energy crops to avoid competition with food production (Cao et al., 2021). Regular monitoring and evaluation of biofuel production processes, along with the promotion of sustainable farming practices, are necessary to ensure environmental and economic benefits (Guddaraddi et al., 2023). Moreover, international collaborations and frameworks are needed to address regulatory hurdles and economic constraints (Guddaraddi et al., 2023).

8.4 Potential areas for future research

Future research should focus on several key areas to advance the field of biofuels. First, there is a need to better quantify N2O emissions from different feedstocks grown in various regions and to develop strategies for mitigating these emissions (Ambaye et al., 2021). Second, research should explore the potential of marginal lands and increased crop yields to supply biomass for biofuel production (Grosso et al., 2014). Third, the development of novel technologies to enhance the efficiency and scalability of biofuel production processes is crucial (Ambaye et al., 2021). Additionally, studies should investigate the long-term impacts of climate change on the distribution and productivity of biofuel crops, particularly in regions with high potential for industrial cultivation. Finally, a comprehensive assessment of the economic, environmental, and social implications of biofuel production from agricultural residues and other biomass sources is necessary to inform policy and practice (Guddaraddi et al., 2023). By addressing these emerging trends, innovations, policy recommendations, and potential research areas, the future of biofuel production from agricultural sources can be significantly optimized, contributing to a sustainable energy future.

9 Concluding Remarks

This study has explored various agricultural sources of biofuels, focusing on the selection and optimization of energy crops such as maize, switchgrass, and Miscanthus. Key findings indicate that Miscanthus and switchgrass are promising alternatives to maize due to their higher biomass yield and lower environmental impact. Miscanthus, in particular, has shown superior biofuel production capacity and resource use efficiency, requiring significantly less land and water compared to maize. Additionally, perennial grasses like Miscanthus and switchgrass have demonstrated potential for improving the sustainability of biogas production and reducing greenhouse gas emissions.

The findings of this study have significant implications for the biofuel industry and the pursuit of sustainable energy. The adoption of Miscanthus and switchgrass as primary biofuel crops could lead to substantial environmental benefits, including reduced land and water usage, lower nitrogen leaching, and decreased greenhouse gas emissions. These crops also offer the potential for ecological remediation and the reclamation of polluted soils, further enhancing their value as sustainable energy sources. The biofuel industry should consider investing in the development and large-scale cultivation of these perennial grasses to meet renewable energy targets more sustainably.

The transition to Miscanthus and switchgrass as primary biofuel crops presents a viable pathway towards more sustainable biofuel production. Future research should focus on optimizing the genetic improvement and breeding of these crops to enhance their yield and resilience. Additionally, advancements in biofuel conversion technologies are necessary to maximize the efficiency of these feedstocks. Policymakers and industry stakeholders should prioritize the integration of these perennial grasses into existing agricultural systems to achieve long-term sustainability goals in the biofuel sector.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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