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Analysing Energy Use in Latin American Agriculture:A Banana Plantation Case Study

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Analysing Energy Use in Latin American Agriculture: A Banana Plantation Case Study

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Abstract: This research introduces a novel approach to evaluate energy utilization in agribusiness within a cost-based framework, addressing the complexities associated with uncertain input energy content. The study focuses on the agricultural sector in Latin America, with particular emphasis on banana plantations, examining the sector's growing dependence on energy-intensive methods and inputs. We differentiate between technical and allocative efficiency, employing a frontier-based methodology. The analysis encompasses data from 21 state-owned banana plantations in Latin America, revealing significant room for improvement in energy efficiency. Our findings indicate an average Technical Efficiency of 0.69, Allocative Efficiency of 0.91, and overall Energy Efficiency of 0.59, suggesting potential reductions in input and energy consumption of up to 38%. The study underscores the importance of addressing both input mismanagement and misallocation to enhance energy efficiency. While the proposed methodology offers valuable insights for public sector enterprises, particularly in agriculture, further research is necessary to extend this approach to scenarios with uncertain input energy content, potentially incorporating stochastic frontier analysis or fuzzy logic methodologies.

Keywords: agricultural sustainability; energy optimization; frontier analysis; resource allocation; banana production

Introduction

Agriculture stands out as one of the few industries capable of sustainably generating resources from nature, producing output by leveraging elements found in nature. This sector plays a dual role as both an energy consumer and producer. Modern agribusiness maximises the conversion of natural resources into agricultural assets, such as land, equipment, buildings, structures, procedures, and systems, by applying scientific concepts, with the aim of boosting productivity. The remarkable gains in productivity observed in Latin American agriculture since the 1960s can be attributed to scientific advancements and the widespread adoption of modern techniques. Between 1979 and 2011, the region experienced substantial increases in agricultural output per worker and total factor productivity. These improvements were driven by increased fertilizer usage, increased land yield, and higher investment that extended the per worker cultivated area.

As agriculture in Latin America transitions from subsistence farming to agribusiness, it has grown more reliant on diesel-powered equipment, natural gas, and chemical fertilisers made from fossil fuels. Produce distribution, processing, and storage are frequently energy-intensive tasks as well. Because of this dependency on energy inputs, future productive potential and input productivity may be jeopardised due to the enormous uncertainty around the cost and availability of energy required for agricultural operations and essential inputs like fertilisers and irrigation. As a result, increased energy expenses directly and significantly affect the profitability of agribusinesses. Although the sector is beginning to recognise the significance of energy efficiency, Latin American cultures' economic and cultural constraints prevent the complete implementation of enforcement standards for energy. Additionally, budgetary constraints lead to a lack of human resources, resulting in inefficient monitoring and enforcement systems. The availability and quality of data remain major constraints, often causing decision-makers to hesitate due to lack of precise information. The purpose

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of this research is to provide a cost-based approach to quantifying agricultural energy efficiency while accounting for uncertainty.

Efficiencies—Technical and Allocative

Despite their differences, phrases "energy efficiency" and "energy conservation" are sometimes applied synonymously. Energy efficiency refers to consuming energy efficiently and is mostly a technical improvement; energy conservation, on the other hand, entails making do with less energy and is typically involves a change human behaviour. The term "energy efficiency" usually refers to the conversion of inputs and outputs into energy. The fundamental concept of energy efficiency, defines “energy efficiency” as the ratio of "useful energy outputs to the heat content, or calorific value, of fuel inputs”. Technical efficiency plus allocative efficiency are usually understood to produce overall productive efficiency.

Allocative efficiency evaluates a producer's ability to select an optimal input mix based on their energy content, distinct from technical efficiency which assesses maximum output from given inputs. As some producers fail to optimize, analysis has shifted from traditional production functions to frontier-based approaches that envelop rather than intersect data. This involves using linear programming to construct non-parametric frontiers for measuring and decomposing energy efficiency. Measuring energy efficiency requires assessing direct and indirect energy content of inputs, which is controversial. Life Cycle Energy Assessment (LCEA) is a common method accounting for all energy inputs in production. However, it struggles with issues of energy quality differences stemming from thermodynamic laws, arbitrary value assignments, rigid system boundaries, and data reliability concerns.

When precise input energy content is unknown, energy efficiency can be computed using scenarios with differently sloped iso-energy lines. This can result in varying allocative and energy efficiencies while maintaining the same technical efficiency. A study examined 21 public sector banana plantations in Latin America. Bananas, grown primarily near the equator, are a major export from Ecuador and Colombia to the European Union. The banana industry is characterized by integrated value chains and competitive low-cost exports from Latin America. Monoculture practices have led to increased susceptibility to diseases, resulting in heavy reliance on energy-intensive agrochemicals. This has created a cycle of pesticide resistance, challenging plantation managers attempting to reduce chemical use. The energy content of inputs varies significantly across different studies and regions, with data collected from various locations including Denmark, Iran, India, and Turkey.

The energy consumption for five inputs - farmyard manure, chemical fertilizers, diesel fuel, machinery, and human labor - was analyzed across all farms. The average total input energy was calculated at 50,000 MJ per hectare. Nitrogen and fuel were the most significant energy consumers, accounting for nearly 49% and 40% of the total input energy in banana production, respectively. Other chemicals (Phosphorus and Potassium) and machinery also contributed substantially, while farmyard manure and human labor had minimal impact. This distribution highlights the heavy reliance on chemical inputs in contemporary agricultural practices.

To assess energy efficiency deterministically, linear programming models were employed, assuming constant returns to scale, convexity, and strong disposability for inputs and outputs. Using the energy content values from Table 1, the total energy consumed in MJ was normalized by dividing it by the banana output in kg. The most efficient farm was assigned a score of 1, serving as a benchmark for other farms. The analysis revealed a mean Technical Efficiency of 0.69, Allocative Efficiency of 0.91, and Energy Efficiency of 0.59. These results suggest a potential for reducing inputs and associated energy consumption by approximately 38%.

Conclusion

The study shows that there are two primary causes of energy inefficiency in contemporary agribusiness: improper input allocation and mismanagement. Our examination of Latin American banana plantations shows that there is a lot of room for energy efficiency growth. There is a chance

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to cut input consumption and ensuing energy use by as much as 38% with a mean technical efficiency of 0.69, an allocated efficiency of 0.91, and an overall energy efficiency of 0.59. This study presents a methodology for assessing energy efficiency in public sector organisations, with a focus on the agriculture sector. We are able to evaluate both technical and allocative efficiency by using linear programming to build a non-parametric frontier. This gives us a complete picture of how energy is used in agriculture activities.

It is crucial to remember that this study is just the beginning of tackling the intricate problem of energy efficiency in agriculture. The method described here must be expanded to handle situations in which the inputs' energy content is ambiguous, which occurs frequently in practical applications. Future work should concentrate on creating reliable techniques to deal with this uncertainty, maybe using fuzzy logic or stochastic frontier analysis techniques. In addition, the results highlight the necessity of focused interventions in agricultural practices, policy development, and technology adoption to improve sector energy efficiency. Energy utilisation can be significantly improved, leading to more sustainable and financially successful agriculture enterprises throughout Latin America and beyond, by addressing both management practices and resource allocation.

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