International Journal of Life Science and Agriculture Research

ISSN (Print): 2833-2091, ISSN (Online): 2833-2105

Volume 03 Issue 07 July 2024

DOI: https://doi.org/10.55677/ijlsar/V03I7Y2024-19

Impact Factor: 6.774 , Page No : 625-632

Energy Consumption and Sustainability Analysis in Organic Farming Systems on Arabica Coffee in Rural Farmer Latimojong Mountain in South Sulawesi, Indonesia

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ABSTRACT: This study aims to explore the perception of Arabica coffee farmers in South Swahili regarding the balance of energy consumption with sustainability in organic farming systems. The research method used is a descriptive qualitative approach, with data collected through in-depth interviews and Focus Group Discussions with farmers and local government. Research results show that although farmers have a high awareness of the importance of organic farming practices, they face a variety of constraints, including a lack of technical knowledge and adequate resources. The findings also indicate that manual innovation in the use of organic materials and collaborative efforts among farmers are key strategies in overcoming energy constraints. The study supports the theory of diffusion of innovation and sustainable transitions by emphasizing the need for comprehensive educational interventions as well as proactive policy support. In addition, the research enriches literature on organic farming and provides practical insights for policymakers to develop more effective programmes for Arabica coffee farmers. Recommendations for further research include expanding geographical coverage, using mixed methods, and focusing on the long-term impact of organic farming practices on economic and environmental sustainability.

Published Online: July 30, 2024

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KEYWORDS: Energy Balance, Arabica Coffee Sustainability, Organic Agriculture, Agricultural Policy.

I. INTRODUCTION

The energy efficiency and sustainability of Arabica coffee commodities in organic farming systems is an increasingly important issue amid increasing awareness of the environmental impact of conventional farming practices. Research shows that cultivating Arabica coffee with an organic approach can not only reduce carbon footprint but also improve soil quality and local ecosystem well-being. In this context, growing farmers' understanding of the use of organic fertilizer plays a key role (Rizki et al., 2016). Organic fertilizers, which come from natural materials and agricultural waste, can improve soil structure, increase water retention capacity, and provide sustainable nutrition for coffee crops. Thus, transferring knowledge and technology to farmers about the use of organic fertilizers becomes crucial to ensuring more environmentally friendly and productive agricultural practices. Furthermore, balancing energy consumption and the sustainability of coffee commodities in organic farming systems requires special attention to technological innovation and sustainable education. Technological transformation in agriculture, including the use of renewable energy and energy-saving technologies, can help farmers reduce dependence on fossil resources and optimize production processes. In the context of English language education, the integration of modern technology can improve the accessibility and effectiveness of learning, enabling farmers and rural communities to access the information and training they need in a language they understand (Rieznik & Beom, 2018). Thus, the synergy between educational technology and sustainable agriculture can create a more efficient, sustainable system, supporting food sustainability and the economy in the Arabica coffee-producing region.

Although there are many studies that highlight the benefits of organic farming systems to soil quality and environmental sustainability, studies that specifically investigate energy consumption in organic fertilizer systems are still limited. Most of the

literature today is more focused on the biological and chemical aspects of soil, as well as the ecological impact of the use of organic fertilizer, while in-depth analysis of energy efficiency and resource optimization in organic-fertilizing practices is still rare (Saragih, 2013). In fact, a comprehensive understanding of how energy is used and can be saved in the organic fertilization process is essential to improving the efficiency and sustainability of the agricultural system. This gap highlights the urgent need for research that integrates energy consumption aspects into the evaluation of organic fertilization systems, in order to provide practical and scientific guidance to farmers in reducing the use of fossil energy and maximizing the utilization of available natural resources. Thus, the study aims to fill the gaps in literature by studying energy use in organic-fertilizing systems, as well as providing recommendations that can improve energy efficiency and the sustainability of biological farming practices.

This research presents a novelty with a focus on the analysis of energy consumption in organic fertilization systems specific to coffee commodities in South Sulawesi, a region famous for high-quality Arabica coffee production. Although there are many studies that evaluate the benefits of organic fertilization in general, very few look at aspects of energy consumption in specific local contexts such as in South Sulawesi (Rahmadani et al., 2020). This research not only fills gaps in the literature about energy efficiency in organic fertilizer systems, but also offers practical insights that are relevant to coffee growers in the area. Using a comprehensive empirical approach, the research will identify sources of energy waste and offer solutions for optimizing energy use, which can improve the sustainability and profitability of organic coffee farms (Rizki et al., 2016). The results of this research are expected to make a significant contribution to a global understanding of organic fertilization and provide a model that can be applied to other coffee-producing regions in the world.

The results of this research are expected to make a significant contribution to a global understanding of organic fertilization and provide a model that can be applied to other coffee-producing regions in the world. Although organic farming systems offer many advantages for sustainability and product quality, Arabica coffee growers often face significant challenges in balancing energy consumption and implementing sustainable practices (Yulia et al., 2017). One of the major problems is the lack of access and knowledge about energy-efficient technologies that can be used in organic production processes. Many farmers still rely on conventional methods that are not energy efficient, thereby increasing operating costs and reducing their competitiveness in global markets. Moreover, the transition to an organic farming system requires a deep understanding of sustainable farming techniques, such as the use of organic fertilizers and natural pest management, which are often lacking in small farmers. Another significant problem is the availability of natural resources that are wasted for free and not optimally utilized by farmers. Agricultural waste that can be processed into organic fertilizer or alternative energy is often not used, resulting in great potential for cost reduction and sustainability improvement wasted in vain. These constraints are exacerbated by a lack of technical and financial support, which impedes farmers' ability to adopt more environmentally friendly and economically profitable practices. Therefore, this study seeks to identify and overcome these barriers, in order to support Arabica coffee growers in achieving optimal energy balance and sustainability in the organic farming system (Susilayati et al., 2022).

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The conceptual framework of this research is based on the theory of agricultural sustainability and energy efficiency, which are integrated to understand the dynamics of energy consumption balance and sustainability in organic Arabica coffee farms in South Sulawesi. The main concepts raised include energy efficiency, which includes the use of energy-efficient technologies and agricultural practices that minimize fossil energy use, as well as environmental sustainability, which emphasizes organic fertilization practices, optimal management of natural resources, and ecosystem conservation (Irmayani & Yusriadi, 2017). The framework also utilizes the theory of innovation adoption to analyse how farmers adopt new technologies and sustainable practices in their local context. By combining these concepts, the research aims to evaluate how Arabica coffee growers in South Sulawesi balance energy needs with sustainable farming practices, as well as identify factors that influence success and challenges in the implementation of

organic farming systems (Alfred et al., 2021). This research is expected to provide significant theoretical contributions as well as practical recommendations to support more sustainable and energy-efficient agriculture.

The research question framework focuses on two major questions relevant to the context of organic Arabica coffee farming in South Sulawesi. First, how do farmers perceive energy consumption in their Arabica coffee farming practices? These questions lead to an understanding of the knowledge and attitudes of farmers towards the use of energy in agricultural processes, as well as the factors that influence the technology choices and energy strategies they adopt. Second, how is the sustainability of Arabica coffee commodity farming in the organic farming system in South Sulawesi? This question aims to evaluate organic farming practices carried out by Arabica coffee growers, including the use of organic fertilizer, soil management, and other sustainable approaches, as well as their impact on the environment and local economies. By exploring this question, the study is expected to provide in-depth insight into the challenges, potential, and solutions in promoting more energy-efficient and sustainable Arabica coffee farming in South Sulawesi (Azis et al., 2022).

The aim of this study is to evaluate and understand the balance of energy consumption as well as the sustainability of Arabica coffee farming within the organic farming system from the perspective of coffee farmers in south Sulawesi. The study aims to identify practices used by farmers for the use of organic fertilizer and energy-saving technologies, and evaluate their perceptions of the effectiveness and sustainability. By mapping the challenges and opportunities faced by coffee farmers in adopting an energy efficient organic agriculture system, this study hopes to provide recommendations that can improve farmers' well-being, enhance environmental sustainability, and encourage more environmentally-friendly, sustainable farming practices. The research also seeks to contribute empirical insights that can be used by policymakers and agricultural practitioners to formulate better strategies in support of organic farming in the region.

II. RESEARCH METHODS

In the design of this qualitative research, the main focus is to deepen farmers' perceptions related to balancing energy consumption and sustainability in Arabica coffee production using organic farming systems in South Sulawesi. The method used will dig deep understanding through in-depth interviews with farmers, focused group discussions, and participatory observations to gather data on their views on organic farming practices as well as their impact on the environment and their socio-economic lives. This approach allows researchers to capture the complexity of local contexts and social dynamics that affect the acceptance and implementation of sustainable practices in Arabica coffee cultivation. Careful qualitative data analysis will produce a deep understanding of the factors that drive or hinder the adoption of organic farming technologies and practices in the field, as well as provide valuable insights for policymakers, agricultural practitioners, and academics in promoting more sustainable farming in the future (Nurdin & Hartati, 2019).

The subject of this study, the subject of focus is Arabica coffee farmers in South Sulawesi, especially those who have 26 years of experience in cultivation and settle in the interior of Latimojong Mountain. Key respondents consisted of seven farmers selected on the basis of their long experience in organic farming practices, providing in-depth insight into the challenges, practices and impact of Arabica coffee cultivation in their local context. In addition, the study also involved two respondents from the Regional Government, a farmer and head of the Agriculture Service, who provided policy perspectives and institutional support for organic farming practices in the area. The use of these key informants is expected to generate rich and in-depth data on their perceptions, experiences, and understanding of the balance between energy consumption and sustainability in the Arabica coffee industry (Irmayani et al., 2022). The active participation of these various parties will provide a holistic view and strong relevance to the implementation of organic farming practices in an effort to more sustainable and competitive agriculture in South Sulawesi.

The main instruments used are deep interviews, which are designed to dig into in-depth information about balancing energy consumption using organic materials and the sustainability of coffee production in organic farming systems. The deep interview was chosen for its ability to explore the respondent's understanding, perception, and immediate experience, which not only provides a detailed overview of organic farming practices but also allows researchers to capture complex local nuances and contexts. In addition, deep interviews can produce rich and in-depth qualitative data on the challenges, opportunities, and factors that influence the acceptance and implementation of sustainable practices in the field. The type of data collected through deep interviews includes subjective views and empirical experiences of Arabica coffee farmers in South Sulawesi, as well as views of farmers and related government officials (Rizki et al., 2016). The use of these instruments is expected to provide a comprehensive and relevant understanding of the dynamics of organic farming systems in a unique local context, which can make a significant contribution to the development of more sustainable agricultural policies and practices in the future.

The data collection procedure for this study, is carried out through two main methods, namely deep interviews and focused group discussions. Deep interviews were conducted to gain an in-depth and detailed understanding of balancing energy consumption using organic materials as well as the sustainability of coffee production in organic farming systems. This method allows researchers to explore the views, perceptions, and real experiences of respondents individually, thus obtaining a comprehensive picture of the issues discussed. Furthermore, FGD is used to expand the data coverage by involving a number of responders in focused discussions,

allowing different perspectives and experiences from various stakeholders to be explained and discussed more widely (Efendy dan Yanter Hutapea,2010). The steps in this procedure involve the selection of representative respondents, the development of interview guides and discussion guidelines, as well as in-depth analysis of the results of interviews and discussions to identify patterns, themes, and key findings relevant to the research objectives. This approach is expected to produce accurate, comprehensive, and reliable data to support analysis and conclusions in this research, as well as make significant contributions to future sustainable agricultural literature and policy (Dolorosa et al., 2018).

In the analysis of the research data, a qualitative descriptive approach is carried out thematically using agricultural sustainability theory as a framework for analysis. Data obtained from in-depth interviews and focused group discussions with Arabica coffee growers in South Sulawesi were thoroughly analyzed to identify emerging thematic patterns. This analysis involves data encoding processes to organize and group information based on key themes, such as organic farming practices, sustainable energy use, challenges faced by farmers, and their impact on the environment and local socio-economic. Subsequently, data is linked to agricultural sustainability theory to interpret the findings and provide in-depth understanding of how organic farming practices can support sustainability aspects in this specific context. This analytical approach is expected to provide valuable insights into scientific literature on the implementation of sustainable agricultural practices, as well as provide relevant recommendations to practitioners and policymakers in an effort to improve the sustainability of Arabica coffee farming in South Sulawesi.

III. RESULT AND DISCUSSION

Energy Balance in Arabica Coffee in the Latimojong Mountain Rural Area, South Sulawesi. Indonesia

Research findings identify important findings about energy balance in organic farming practices in Arabica coffee cultivation in South Sulawesi. First, farmers rely on the observation of plant damage after the application of natural pesticides as the primary method for evaluating and managing energy consumption. However, they face significant constraints associated with a lack of competent resources in providing knowledge about energy balance. Efforts to overcome these constraints involve coordination with the peasant group to seek additional knowledge from more experienced members (Arsal et al., 2023). In addition, innovative approaches used by farmers include the manual collection of organic materials such as straw, leaves, and coffee leaves for processing into organic fertilizer through compositing techniques, which directly contribute to reduced energy consumption and improved energy efficiency in their agricultural activities. It is based on the results of in-depth interviews with Arabica Coffee farmers that: 1. The way farmers evaluate and manage energy consumption in your organic farming practices, especially in terms of the use of organic materials such as natural fertilizers and pesticides is by observing plant damage after the application of natural pesticide using raw materials from nature (the smell of lemongrass leaves), 2. The main obstacle faced by farmers in achieving optimal energy balance in organic Arabica coffee cultivation, and the way to overcome it is not available competent resources to provide knowledge of existing energy balancers, 3. A farmer's approach to innovation and new technologies that can help in reducing energy consumption or improving energy efficiency in organic farming activities is to manually collect organic materials such as silk garbage, leaf-leaf garbages, coffee leather garbs etc., plants that are processed into organic fertilizer with compositing techniques.

The key findings of this study reveal that Arabica coffee farmers in South Sulawesi face a number of significant challenges in energy balance and the implementation of organic farming practices. Farmers tend to use observational methods to evaluate the impact of natural pesticides, but they lack the competent resources to provide in-depth knowledge about energy balance. Innovations in energy management are done manually, including collecting organic materials such as straw and leaves to be processed into composite fertilizer, which shows farmers' efforts to improve energy efficiency even in traditional ways (Ndlovu et al., 2022). From a sustainability perspective, the importance of government support in providing education and training for farmers is identified as a key factor for long-term sustainability. Although organic farming practices have proven to produce healthier coffee with better scents, the lack of interest of farmers in this system due to long and labor-intensive processes remains a major challenge. The proposed solutions include strengthening the role of peasant groups and community participation in managing agricultural waste for organic fertilizer, with the aim of improving the sustainability and efficiency of organic farming practices in the region.

Sustainability Concept of Coffee Arabica based Organic Farming in the Latimojong Mountain Rural Area, South Sulawesi

In the context of sustainability of coffee Arabica, farmers emphasize the importance of sustainable action for the future of coffee commodities, with a key sustainability indicator being government involvement in preparing human resources capable of providing new knowledge to farmers. (Purnama et al., 2023)Organic farming practices are recognized to have a positive impact on local environmental and economic sustainability, with healthier Arabica coffee crop yields and better coffee scents. However, the main challenge faced was the lack of interest of farmers in implementing organic farming systems due to long yields and the process of making compost fertilizers that required hard work. To address this challenge, the proposed solutions include enriching farmers and involving community elements in collecting coffee farming waste for processing into organic fertilizer, with the aim of improving efficiency and sustainability in organic farming practices. The results of in-depth interviews found several findings as follows: 1. The opinion of Arabica Coffee farmers on the sustainability of organic farming practices in Arabica coffee cultivation

in Southern Sulawesi and the main indicators of sustainability in coffee farming efforts are 2. The impact of Organic Farming Practices on the environmental sustainability and local economy in the farming area is the production of healthier arabica coffee plants and the coffee produced has a better aroma of coffee 3. The biggest challenge the sustainable use of coffee in the organic agriculture system, and the solution that farmers propose to cope with the challenge is that the farmers are less interested in doing organic farm systems because of the long-term impact produced and requires hard work in making composite fertilizer. The solution to the challenge is to enrich the farmers and involve the society to insist on collecting coffee farming waste to be processed into organic fertilizer (Pratiwi, 2016).

The interpretation of these findings suggests that although Arabica coffee farmers in South Sulawesi have adopted some innovative and organic farming practices in energy balance, they still face major challenges in terms of knowledge and adequate resources. The lack of support and education from competent parties makes their efforts in improving energy efficiency and agricultural sustainability less optimal. Nonetheless, manual initiatives such as the collection and processing of organic material for fertilizer demonstrate their commitment to sustainable practices. The positive impact of organic farming on the quality and aroma of coffee shows the great potential of this system, however, to wider sustainability, more structured support from governments and related agencies is essential (Dixon, 2024). Strengthening peasant groups and community participation in agricultural waste management is also important to overcome existing barriers and encourage wider adoption of efficient and sustainable organic farming practices.

The findings of this study suggest that Arabica coffee growers in South Sulawesi face similar challenges identified in previous studies, but also offer new insights that broaden our understanding of organic farming practices. Research by Barrett et al. (2020) highlights the importance of government support in educating farmers about sustainable practices, which is in line with our finding that the lack of knowledge and competent resources is a major obstacle. On the other hand, a study by Smith et al. (2019) showed that the use of organic material for fertilizer can significantly reduce agricultural carbon footprint, supporting our findings about farmers' innovation in managing organic materials manually. However, unlike the findings from Jones et al. (2018) showing the rapid adoption of energy-saving technologies in organic farming in other regions, this study reveals the resistance of farmers in South Sulawesi to such practices due to the time and effort it takes. Thus, the findings not only support existing knowledge about the challenges and potential of organic farming but also broaden understanding of the local context and specific needs that must be met for the successful adoption of sustainable farming practices in South Sulawesi.

The findings of this research have a significant impact on the existing theories in the fields of organic farming and energy sustainability. In general, these findings support the current theories, in particular the theories that emphasize the importance of education and technical support for farmers in adopting sustainable practices. (Barrett et al., 2020). According to Rogers' theory of innovation diffusion (2003), the adoption of new technologies and sustainable practices is heavily influenced by access to information and technical support. Our findings that show a lack of knowledge and competent resources among Arabica coffee farmers in South Sulawesi support this premises, highlighting the urgent need for stronger educational and technical intervention. However, these findings also challenge some aspects of existing theory. For example, the theory of sustainable transition often assumes that the economic and environmental benefits of organic farming practices will automatically drive widespread adoption. (Smith et al., 2019). Our findings show that although there are obvious benefits, practical barriers such as a time-consuming process for making composite fertilizers can hinder adoption. It indicates that existing technology adoption models need to take into account deeper social and operational factors, in a unique local context.

This research contributes to the field of theoretical development by offering new insights into the importance of local contextualization in the application of sustainability theory and technology adoption. It affirms that in order to sustainability in organic farming, a more holistic and integrated approach that combines technical, educational, and social support is essential. Thus, this research not only strengthens existing theories but also expands them by adding new layers of complexity that need to be considered in the implementation of sustainable practices in various local contexts.

The results of this research can be applied in practice by guiding industrial and agricultural policies to develop more comprehensive support and education programmes for Arabica coffee farmers in South Sulawesi (Rieznik & Beom, 2018). These policies may include the provision of ongoing training on organic farming techniques and energy balancing, as well as the establishment of resource that provide the information and tools needed for sustainable practices. Moreover, governments and industry stakeholders can encourage collaboration between farmers and agronomists to address knowledge gaps and optimize the use of organic materials. Implementation of energy-efficient technologies can also be facilitated through subsidies or incentives for innovation in agricultural waste management (Dubey et al., 2023). Overall, the policies designed on the basis of these findings will help improve energy efficiency, environmental sustainability, and the economic well-being of coffee farmers, which ultimately supports sustainable development goals in the agricultural sector.

This research has some limitations that need to be acknowledged to maintain transparency and integrity in the research process and provide a better context for readers in assessing the validity and reliability of findings. First, research samples limited to Arabica coffee growers in the interior of Latimojong Mountain, South Sulawesi, may not fully represent the entire coffee grower

population in the region or elsewhere. Second, the use of in-depth interview methods and FGD (Focus Group Discussion) may present a bias of subjectivity, as respondent responses can be influenced by personal and social factors (Haile & Whakeshum, 2020). In addition, time and resource constraints in data collection can affect the depth and extent of information obtained. Finally, although efforts have been made to ensure the accuracy and reliability of the data, the interpretation of the results can still be influenced by the perspective of the researcher. These limitations are important to consider when applying these research findings in a broader context, and stress the need for advanced research with larger samples and more diverse methods to reinforce the results obtained.

Based on the findings and limitations identified in this study, the recommendation for further research is to expand the sample coverage to include more Arabica coffee farmers in various areas of South Sulawesi and other regions, in order to obtain a more comprehensive and representative picture. Advanced research is also suggested to use mixed methods, including quantitative surveys and secondary data analysis, to reduce bias of subjectivity and strengthen the validity of findings (Irmayani et al., 2015). In addition, focusing on the long-term impact of organic farming practices on productivity, economic sustainability, and the environment is crucial to measuring the effectiveness of policies and program implemented. Further research also needs to explore the role of information technology and education in supporting the adoption of sustainable practices, as well as evaluating government policies that can drive innovation and energy efficiency in the organic farming sector.

IV. CONCLUSION

This study reveals that although Arabica coffee growers in South Sulawesi are aware of the importance of energy balance and sustainability practices in the organic farming system, they face a variety of challenges, including a lack of technical knowledge and adequate resources. The findings support the theory of diffusion of innovation and sustainable transitions, but also highlight the need for a more holistic and contextual approach in the application of sustainable agricultural practices. The study emphasizes the urgency of more comprehensive educational and technical interventions as well as proactive policy support to encourage the adoption of energy-efficient technologies and sustainable organic practices. Thus, the research not only enriches literature on organic farming and energy sustainability but also offers practical insights to policymakers and stakeholders in developing more effective support program for Arabica coffee growers.

Based on the findings and limitations identified in this study, it is recommended that further research extend the geographical and demographic coverage of the sample to cover various areas in South Sulawesi and other regions, in order to gain a more comprehensive and representative understanding of energy balancing practices and the sustainability of Arabica coffee farming in organic systems. Future research should also consider using mixed methods, which combine quantitative surveys with qualitative interviews and secondary data analysis. This approach will help reduce the bias of subjectivity and improve the validity and reliability of the findings, providing a more holistic view of the dynamics of organic farming in various local contexts. Furthermore, future research should focus on longitudinal analysis to evaluate the long-term impact of organic farming practices on productivity, economic sustainability, and ecosystem health. Further exploration of the role of information and communication technology (ICT) in supporting the adoption of sustainable practices is also important, including how digital platforms can be used to spread knowledge and innovation to farmers. In addition, researchers need to assess the effectiveness of government policies and support program in promoting energy-efficient organic farming practices. In-depth research in this area will not only strengthen existing literature but also provide practical insights for policymakers, investigators, and practitioners in a collective effort to promote sustainable and highly competitive farming.

AKCNOWLEDGMENT

We say thanks to Majelis Dikti Litbang PP Muhammadiyah through the funding of the Research Grant 2024 Batch VII that has funded this research. The same goes for the Arabica coffee growers in Latimojong Mountain, South Sulawesi, who have been willing to spend their time and share their valuable experience as respondents in this study. We also express our appreciation to the Regional Government, in particular the Agriculture Commissioner and the Chief of the Agricultural Service, for their very meaningful support and contribution in providing additional insights. Nor would this research be completed without the help and guidance of the various parties that have provided technical and academic support, including fellow researchers and academics who have provided constructive input throughout the research process. Finally, we thank the funding institutions and universities that have provided the necessary resources to realize this research. All this help and collaboration is highly appreciated and has made a significant contribution to the achievement of this research.

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