Analysis of the Role of Bioeconomy in Enhancing the Added Value of Agricultural Products in Maluku 2020-2024

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Abstract. This study focuses on how the bioeconomy contributes to increasing the added value of agricultural products in Maluku during 2020–2022. A descriptive quantitative method with value-added analysis was applied, using official data from BPS, the Ministry of Agriculture, and local agencies. The findings show that Maluku's main commodities—nutmeg, cloves, coconut, and sago—have seen growth in both production and harvested area, although productivity is still affected by climate and input availability. Turning raw products into processed ones has proven to boost farmers' income. For example, nutmeg oil can add up to IDR 335,000 per kilogram compared to raw nutmeg. Similar trends are found in sago, coconut, and cloves through diversification and downstream processing. These results are supported by macro indicators, such as the rise of Maluku's GRDP from IDR 54.62 trillion in 2020 to IDR 72.35 trillion in 2024, and an improvement in the Farmers' Exchange Rate from 99.2 to 106.5. Agricultural investment also increased, showing strong confidence in the sector. Overall, this study highlights that the bioeconomy is not just an academic concept but a practical approach to building an inclusive, competitive, and sustainable agricultural system in Maluku.

Keywords: Bioeconomy, Agricultural Value Added, Downstreaming, Sustainable Development, Maluku.

1 Introduction

The agricultural sector has long been one of the main foundations of Indonesia's economy. Its role is not limited to food supply but also extends to being a source of income and employment for a large portion of the population. In Maluku Province, with its archipelagic geography and abundant natural resources, agriculture carries a particularly vital function. Maluku is historically recognized for several key commodities such as nutmeg, cloves, and coconuts—products with strong economic as well as cultural significance. Despite this potential, the region's agricultural contribution remains below expectations. Most outputs are still marketed in raw form with minimal processing, leading to limited added value. Consequently, the agricultural sector's share in Maluku's Gross Regional Domestic Product (GRDP) remains relatively small compared to its available resources [1].

The low added value of Maluku's agricultural products can be traced to several structural challenges. First, post-harvest processing facilities are underdeveloped, preventing efficient value chain integration. Second, restricted market access and reliance on traditional distribution channels reduce price stability and competitiveness. Third, limited innovation in product diversification, along with weak access to technology and information, hampers the region's ability to compete both nationally and globally. As a result, farming practices remain largely traditional and unable to substantially improve farmer welfare.

Against this backdrop, the bioeconomy framework emerges as a strategic alternative. Bioeconomy refers to the sustainable use of renewable biological resources through science, technology, and innovation to produce food, energy, and other high-value goods and services [2]. This approach focuses on transforming raw biological materials into higher-value derivatives, spanning food, energy, pharmaceuticals, and industrial applications. For instance, coconut waste can be turned into charcoal briquettes or vegetable oil, while nutmeg and cloves can be processed into essential oils with significant commercial potential. Through bioeconomy, agriculture is not only a source of raw materials but also a driver of efficiency, market expansion, and competitiveness. This perspective aligns with Bugge, Hansen, and Klitkou [3], who argued that bioeconomy contributes to economic transformation by fostering life science–based innovation.

The bioeconomy is a contemporary development paradigm that integrates economic, ecological, and technological dimensions in the utilization of biological resources. This approach emphasizes that agricultural commodities should not merely be evaluated from the production perspective, but also through their potential transformation into higher value-added products via industrialization, downstream

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processing, and product diversification. In the case of Maluku, the bioeconomy has become increasingly significant due to the region's abundance of unique agricultural resources such as nutmeg, cloves, coconuts, and sago.

Data from the Central Bureau of Statistics (BPS) of Maluku indicate an overall increase in agricultural output between 2020 and 2024, although productivity levels of several commodities have fluctuated during the same period. The Farmers' Exchange Rate (NTP) has also shown improvement, reflecting the rising purchasing power of farmers in line with policies supporting the bioeconomy and downstream processing. A systematic review of existing literature is therefore necessary to examine how the concept of bioeconomy has been studied, the extent to which its implementation has enhanced the value-added of agricultural products, and what research gaps still remain.

Previous studies reinforce the relevance of bioeconomy in agricultural development. Smith [4], examining European cases, found that bioeconomy strengthens agricultural competitiveness through biotechnology and waste utilization. In Indonesia, Sari and Prasetyo [5] highlighted its contribution to food security and new business opportunities in rural areas with an agro-industrial base. Mustofa [6] further emphasized bioeconomy's alignment with sustainable development goals (SDGs), balancing economic, social, and environmental dimensions. However, most existing research has focused on regions with stronger infrastructure and market access, such as Java and Sumatra. Studies specifically exploring bioeconomy's role in enhancing Maluku's agricultural value remain limited.

This gap highlights the urgency of further inquiry. Maluku's unique archipelagic conditions present both challenges and opportunities for advancing a bioeconomy-based strategy. Accordingly, this study seeks to examine: (1) the current state of agricultural product management in Maluku Province, (2) the extent to which bioeconomy principles can be applied in the region's agricultural sector, and (3) the role of bioeconomy in enhancing agricultural value-added as part of regional economic development.

The contributions of this study are threefold. Theoretically, it enriches the literature on bioeconomy, particularly in the context of archipelagic regions. Practically, the findings can inform local governments, businesses, and communities in designing bioeconomy-driven agricultural strategies. From a policy standpoint, the study provides recommendations for sustainable agricultural development in Maluku that align with national development agendas. Thus, the research is expected to deliver meaningful academic and practical contributions to strengthening competitiveness and improving community welfare.

1.2 Bioeconomy and Agricultural Downstreaming

Downstream processing represents one of the central pillars of the bioeconomy framework. This concept highlights the transformation of raw agricultural products into high value-added processed goods. According to Purwanto [19], the industrialization process of raw materials into processed commodities can increase value by 300–500 percent. This is particularly relevant in Maluku, where raw nutmeg, originally valued at approximately IDR 65,000/kg, may rise to around IDR 400,000/kg when processed into nutmeg oil. Such an increase not only delivers substantial financial benefits to farmers and local entrepreneurs, but also creates opportunities for entry into international export markets.

Research by Hidayat et al. [15] further underscores this argument by demonstrating that derivative products of nutmeg, cloves, and coconuts—such as essential oils, copra, and sago flour—possess significant potential to integrate into global value chains. Nevertheless, this requires improvements in product quality standards, international certification, and efficient logistics connectivity. Maluku faces critical challenges in this regard, given its geographic isolation and high logistical costs. Without policy interventions that address infrastructure and institutional support, the prospects of downstream processing may not be fully realized. Thus, the literature emphasizes that downstreaming is not solely about processing technology but also about enabling policies, investments, and market linkages to ensure sustainability.

1.3 Bioeconomy and Local Food Security

Another strategic dimension of the bioeconomy lies in strengthening locally based food security. Maluku is rich in sago, which has long been embedded within the cultural identity and staple diet of its people. According to Riry et al. [20], product diversification derived from sago—such as sago-based noodles, cookies, and fermented beverages—not only widens consumer choices but also reduces dependence on imported rice, which remains vulnerable to global price fluctuations.

From a global perspective, the Food and Agriculture Organization [13] stresses the importance of sustainable food systems grounded in local resources. By maximizing sago utilization, Maluku can develop a more resilient food system capable of withstanding climate change impacts, distribution disruptions, and global food crises. Moreover, bioeconomy-oriented local food development provides

opportunities for small and medium-sized culinary enterprises to innovate and expand through sago-based products. However, the literature also points out that limited efforts in standardizing sago-based products constrain their competitiveness both domestically and internationally. Another challenge arises from shifting consumption patterns among younger generations, who increasingly prefer instant foods made from rice or wheat. Consequently, efforts to advance a sago-based bioeconomy must be complemented by consumer education, nutritional promotion of local food, and innovations in food technology.

1.4 Bioeconomy, Economic Growth, and Investment

The development of the bioeconomy in Maluku also reveals a strong correlation with regional economic growth. Data from BPS show that Maluku's Gross Regional Domestic Product (GRDP) increased from IDR 54.62 trillion in 2020 to IDR 72.35 trillion in 2024. Much of this growth was driven by the agricultural sector, which has been undergoing transformation supported by investments and downstream policies. Investment in agriculture rose from IDR 310 billion to IDR 390 billion over this period, reflecting growing investor interest in developing processed products under the bioeconomy framework.

Suyanto [24] argues that investments in the bioeconomy not only enhance productivity but also strengthen the competitiveness of commodities in global markets. In Maluku, nutmeg downstreaming and sago industry development have contributed not only to higher Farmers' Exchange Rates (NTP) but also to broader multiplier effects across trade, transportation, and service sectors. Looking forward, investment prospects appear increasingly favorable, supported by growing international demand for natural and environmentally friendly products. Nonetheless, critical challenges remain in regulatory certainty and the provision of basic infrastructure such as electricity, clean water, and reliable transportation, particularly across the region's small islands. Consequently, the literature highlights the necessity of synergy among government, private investors, and local communities in fostering a conducive investment climate for the bioeconomy.

1.5 Bioeconomy and the Multiplier Effect

The impact of the bioeconomy extends beyond the agricultural sector, generating wide-ranging multiplier effects across the regional economy. Research by Sitorus [22] indicates that agricultural downstreaming stimulates the development of supporting sectors, including logistics, trade, banking, and small-scale agro-processing enterprises. This is evident in Maluku, where rising demand for nutmeg and sago-based products has created new business opportunities and absorbed labor from diverse social groups.

Moreover, the multiplier effect of the bioeconomy also manifests in the social sphere. Nasution [17] highlights that cooperative-based bioeconomy models empower small farmers by strengthening their bargaining position within supply chains. Through cooperatives, the benefits of downstreaming are not confined to large industries but are distributed more equitably among farmers and local workers. Furthermore, bioeconomy initiatives have the potential to promote gender inclusion by encouraging women's participation in food processing industries and micro-enterprises. Nevertheless, the literature also notes potential inequalities. High-value commodities such as nutmeg and cloves tend to advance more rapidly, while sago and coconut lag behind, potentially widening disparities among commodities, regions, and farming households. Therefore, further research is required to design strategies ensuring that the multiplier effects of the bioeconomy are distributed more equitably and sustainably.

2 Methodology

This study applies a descriptive quantitative design with a bioeconomic analytical approach to examine the increase in value-added agricultural products in Maluku. The research aims to present data on production, prices, value-added, macroeconomic indicators, and bioeconomic programs for the period 2020–2024. The quantitative method was chosen because the data are numerical, allowing the analysis of figures and trends that reflect the development of Maluku's main agricultural commodities. Bioeconomic analysis is used to assess the contribution of downstream activities to value-added growth. Through this method, the relationships between production data, prices, GRDP, farmers' terms of trade (NTP), and bioeconomic policies can be identified. This ensures that the findings rest on a solid conceptual basis. Accordingly, the study combines statistical analysis with theoretical interpretation to provide a comprehensive picture of the role of bioeconomy in Maluku.

Maluku Province was selected as the research focus because of its strong agricultural potential, particularly nutmeg, cloves, coconuts, sago, and rice, which are vital to the regional economy. The 2020–2024 period was chosen based on the latest statistical releases from BPS Maluku, the Ministry of Agriculture, and the Provincial Agriculture Office, with five years considered sufficient to capture medium-term trends. Data were obtained entirely from official government publications, ensuring

scientific validity. Maluku's bioeconomic programs—such as coconut and nutmeg downstreaming and sago industry development—were also considered in site selection. Given Maluku's archipelagic geography, this approach allows contextual analysis of infrastructure, agricultural processing, and distribution challenges, strengthening the validity of results.

The research relies on secondary data from government sources. Production, harvested area, and productivity data were obtained from BPS Maluku. Price data for raw and processed products came from the Ministry of Agriculture and recorded local markets. Macroeconomic indicators—including agricultural investment, farmers' terms of trade, farming households, and GRDP—were drawn from BKPM and BPS. Bioeconomic program data were collected from the Ministry of Agriculture and the Maluku Agriculture Office. Documentation methods were used, including the review of reports, official publications, and policy documents, supported by a literature review on bioeconomy and sustainable agriculture. To ensure reliability, all data were verified for authenticity. Since the study is macro-analytical rather than experimental, secondary data were deemed appropriate for bioeconomic analysis.

Data analysis combined descriptive quantitative techniques with bioeconomic value-added analysis. Descriptive analysis illustrated the development of prices, production, productivity, and macro indicators using tables and graphs. Value-added analysis measured the price differences between raw and processed products of key commodities such as nutmeg, cloves, coconuts, and sago. Farmers' Terms of Trade (NTP) was applied as a standard indicator of farmers' welfare. The data were further linked to bioeconomic programs implemented between 2020 and 2024, including downstreaming and fertilizer subsidies. To enrich the analysis, a qualitative perspective was integrated to connect numerical findings with bioeconomic theory. Thus, the analysis produces not only numerical results but also theoretical and empirical interpretations. In this framework, statistical data serve as inputs, trend and value-added analysis as processes, and empirical insights into bioeconomic roles as outputs. Overall, this approach provides a comprehensive, valid, and relevant understanding of Maluku's agricultural bioeconomy.

3 Result and Discussion

In the context of agricultural development in Maluku, the bioeconomy represents a strategic approach emphasizing the sustainable use of biological resources. This concept goes beyond merely increasing production levels; it prioritizes value creation through industrialization and downstream processing of agricultural commodities. Between 2020 and 2024, Maluku experienced notable shifts as leading commodities such as sago, nutmeg, clove, and coconut demonstrated consistent growth trends. According to BPS Maluku statistics, both harvested areas and production volumes increased, although productivity showed variations. For instance, rice yields reached 3,882 kg/ha in 2023 but slightly declined to 3,806 kg/ha in 2024, reflecting external influences such as climate variability and input availability. Conversely, coconut productivity rose from 1,067 kg/ha in 2020 to 1,094 kg/ha in 2024. This highlights the increasing significance of agricultural sustainability for both food security and regional GDP. Accordingly, bioeconomic analysis extends beyond production data, addressing how economic transformation is driven by value-added processes and how effectively local policies respond to these dynamics.

The production and productivity trends of key commodities reveal diverse patterns with major implications for the regional economy. For example, nutmeg production, a symbolic crop of Maluku, rose from 4,800 tons in 2020 to 5,200 tons in 2023 but declined to 5,000 tons in 2024. This fluctuation underscores the sector's vulnerability to market prices, crop management, and climatic conditions. Yet, nutmeg holds significant downstream potential when processed into nutmeg oil, which reached an added value of IDR 335,000 per kilogram in 2024. Clove production steadily increased from 19,800 tons in 2020 to 22,000 tons in 2024, with productivity reaching 705 kg/ha. Despite relatively stable harvested areas, coconuts demonstrated resilience through higher processing opportunities for derivative products like copra and coconut oil. Sago production, as a culturally strategic staple, climbed to approximately 5,970 tons in 2024, though productivity remained stable at 165–171 kg/ha. These data confirm that the bioeconomy fosters a dual role: strengthening processed industries and supporting consumption, thereby creating a robust foundation for Maluku's competitiveness in domestic and global markets.

From a value-added perspective, the bioeconomic dimension highlights clear distinctions between raw and processed outputs. In 2024, raw nutmeg at the farmer level was priced at about IDR 65,000 per kilogram, whereas its processed form—nutmeg oil—reached IDR 400,000 per kilogram. This IDR 335,000 margin illustrates the transformative role of bioeconomy in boosting rural incomes. Similarly, premium dried cloves reached IDR 160,000/kg compared to IDR 85,000/kg for raw products. Coconut, when processed into copra and oil, generated an additional IDR 12,500 per kilogram in 2024, while sago flour produced a margin of IDR 7,500 per kilogram over its raw equivalent. Such findings indicate that

farmers can strengthen their bargaining power through downstream processing, reducing dependency on raw commodity markets. Bioeconomy, therefore, is not merely a theoretical framework but a practical pathway to address farmers' income constraints. Policies that advance downstream industrialization must thus be prioritized in regional agricultural development.

Macroeconomic indicators further reveal that bioeconomy contributes directly to regional growth. At current prices, Maluku's GRDP rose from IDR 54.62 trillion in 2020 to IDR 72.35 trillion in 2024. The agricultural sector was a primary driver of this growth, supported by increased production and industrialization of key commodities. The number of farming households also expanded from 234,000 in 2020 to 241,500 in 2024, underscoring the sector's critical role in labor absorption. Farmers' welfare improved, as reflected in the rise of the Farmer's Exchange Rate (NTP) from 99.2 in 2020 to 106.5 in 2024. This improvement was partly driven by government programs such as fertilizer subsidies and enhanced market access. Simultaneously, agricultural investment grew from IDR 310 billion in 2020 to IDR 390 billion in 2024, reflecting increased investor confidence in the sector. These indicators strengthen the argument that bioeconomy has a significant multiplier effect, advancing both farmer welfare and macroeconomic growth. Consequently, policies supporting bioeconomic strategies should be reinforced as models for other agrarian regions in Indonesia.

Between 2020 and 2024, bioeconomy programs in Maluku produced measurable outcomes. For example, downstream initiatives in nutmeg and coconut boosted exports of processed products such as nutmeg oil and copra. In Central Maluku and Seram, the growth of the sago industry not only addressed local food needs but also opened export opportunities. Fertilizer subsidies until 2023 contributed to a 7% increase in farmers' NTP, confirming that policy interventions can directly enhance welfare. Moreover, local government initiatives demonstrated the synergy between national and regional bioeconomic strategies. Nevertheless, implementation faced obstacles, including inadequate infrastructure, limited skilled labor, and insufficient processing technologies. Supply chain inefficiencies also persisted, particularly in distributing processed goods to broader markets. Therefore, ensuring long-term sustainability requires integrated planning across public, private, and community sectors.

A global market-oriented downstream strategy sheds light on the transformative capacity of bioeconomy for Maluku's agriculture. By advancing downstream activities, commodity competitiveness improves, reducing farmers' reliance on raw commodity price fluctuations. Farmers thus gain bargaining positions within supply chains instead of remaining mere price takers. For instance, the nutmeg industry has strengthened its international presence through diversification into oils, oleoresins, and pharmaceutical derivatives. Similarly, coconut has vast potential for derivative products, including virgin coconut oil (VCO), instant coconut milk, and activated carbon. Such bioeconomic strategies not only generate more sustainable farmer incomes but also align with national green development agendas. In this sense, bioeconomy is both a transformative long-term strategy and an immediate solution for sectoral challenges. If Maluku succeeds in fully optimizing downstream processes, it could serve as a benchmark for bioeconomy-based agriculture across Indonesia.

Beyond agriculture, bioeconomy generates multiplier effects in related sectors. Growth in farming stimulates expansion in transport and logistics services, while local trade benefits from higher demand for processed products. The growing need for working capital among small and medium-scale enterprises in processing also supports financial services growth. This ripple effect creates jobs, helping reduce rural unemployment. At the same time, bioeconomy enhances food security through product diversification based on local resources. For instance, using sago as a substitute for imported staples strengthens Maluku's cultural identity. These outcomes demonstrate that bioeconomy is not merely an agricultural approach but a multidimensional development tool. Strengthening Maluku's economic structure through bioeconomic integration is therefore vital for competitiveness-driven growth rather than consumption-led development.

Despite its potential, Maluku faces persistent challenges in optimizing its bioeconomy. Limited infrastructure in energy and transport remains the primary barrier to distributing processed goods domestically and internationally. Human resource capacity is insufficient to lead the processing industry, while farmers' low technological literacy limits access to bioeconomic opportunities. Private investment in downstream industries also remains constrained, while environmental issues such as land degradation and climate change pose additional risks. These challenges highlight the need for policies that balance economic growth with ecological sustainability. Strong collaboration among public institutions, private investors, academia, and local communities is essential to overcome these barriers. With such efforts, Maluku could position itself as a strategic bioeconomic hub in Eastern Indonesia.

Comparisons with other regions further illustrate bioeconomic opportunities. For instance, North Sulawesi has successfully developed coconut derivatives with high export value, offering lessons on

structured and sustainable farmer–industry partnerships. Similarly, Papua has begun promoting market-oriented sago products, which Maluku could replicate to strengthen its own commodity branding. However, social, economic, and cultural contexts vary across regions, meaning policy adaptations must be carefully contextualized. Lessons from external models must therefore be combined with Maluku's local wisdom to build stronger strategies. This approach shows that Maluku is not simply catching up but has the potential to become a pioneer of bioeconomy in Eastern Indonesia. Benchmarking against other regions thus becomes critical for sound policy formulation.

The integration of agriculture and fisheries is another unique prospect for Maluku's bioeconomy. The province holds the potential to merge land-based bioeconomy with marine-based blue economy, producing innovative products with competitive international advantages. For example, combining coconut with fishery products could create functional foods with high export potential. Moreover, growing global demand for environmentally friendly products offers Maluku the chance to develop sustainable and organic branding based on local uniqueness. Achieving this requires alignment among public policies, industrial innovation, and academic research. With effective management, Maluku's bioeconomy could transition from potential to actual economic power, provided consistent investment and supportive policies are maintained

Policy recommendations include several strategic actions. First, strengthening human resource capacity through training and education in processing technology and supply chain management. Second, accelerating basic infrastructure development, including roads, electricity, and post-harvest facilities. Third, providing incentives for private investment to advance processing industries. Fourth, supporting downstream initiatives via academic research and innovation. Fifth, fostering diversification by integrating bioeconomy with green and blue economies. Sixth, improving governance and regulations to ensure equitable benefits for both large investors and smallholder farmers. Seventh, promoting international trade diplomacy to link Maluku's products with global value chains. Eighth, implementing climate adaptation policies and rehabilitating degraded lands. Ninth, building farmer cooperatives to strengthen bargaining power. Finally, ensuring continuous monitoring and evaluation to assess policy effectiveness.

In conclusion, bioeconomy has proven to play a pivotal role in enhancing the added value of Maluku's agricultural commodities. Evidence from production data, price trends, value-added margins, and macroeconomic indicators shows that bioeconomy contributes significantly to both economic growth and farmer welfare. Nonetheless, these achievements remain partial, necessitating broader policy support. Integrated strategies are essential to address challenges ranging from infrastructure gaps to limited human resource capacity. Moving forward, bioeconomic development should prioritize building globally competitive industries rooted in local strengths. Maluku holds strong prospects if it can synergize land and marine bioeconomy simultaneously. The sustainability of this vision depends on collaboration among public, private, and academic stakeholders. Ultimately, bioeconomy represents not only a key driver of Maluku's agricultural transformation but also a pillar for inclusive and sustainable regional development.

4 Conclusion

According to this study, the advancement of bioeconomy through downstream processing, diversification, and innovation plays a pivotal role in enhancing the added value of Maluku's agricultural products. Findings reveal that staple commodities such as sago, coconut, nutmeg, and clove not only contribute significantly to raw production but also hold considerable potential when developed into high-value derivative products. The positive influence of bioeconomic initiatives is evident in regional growth indicators, particularly in rising agricultural investment, gross regional domestic product (GRDP), and farmers' terms of trade between 2020 and 2024. Moreover, the multiplier effects of bioeconomic activities extend beyond agriculture, stimulating trade, logistics, small and medium enterprises (SMEs), and financial services, thereby reinforcing the overall economic structure of Maluku.

Nevertheless, several structural constraints were also identified, including inadequate infrastructure, limited technological literacy among farmers, restricted access to capital, and potential environmental risks that may undermine long-term sustainability. Addressing these challenges requires an integrated approach built on cross-sector collaboration involving government, academia, private enterprises, and local communities. Both land- and marine-based bioeconomy—often framed as green and blue bioeconomy—offer Maluku an opportunity to enter global markets with a distinctive and sustainable economic identity. This research further establishes a foundation for subsequent inquiries into integrated policy frameworks, local branding strategies, and mechanisms for equitable distribution of value across global supply chains.

Ultimately, the extent to which bioeconomic practices in Maluku can be applied consistently, innovatively, and adaptively to local and international dynamics will shape the trajectory of the region's agricultural sector. In this regard, bioeconomy emerges as a cornerstone for Maluku's economic transformation—an inclusive, sustainable, and globally oriented pathway toward long-term prosperity.

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