

Dynamic System Scenarios for Local Wisdom-Based Taro Agribusiness towards SDGs

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Abstract. Taro (*Colocasia esculenta*) has great potential as a local food source and agribusiness commodity in Indonesia, particularly in West Papua. Still, its development is constrained by low productivity, limited market access, and a lack of agro-industrial support, while local wisdom, expressed through traditional agricultural practices and cultural values, offers a sustainable foundation that remains underutilized. This research aims to provide a model scenario for a taro agribusiness system grounded in local wisdom to achieve the Sustainable Development Goals (SDGs). The research method uses a dynamic systems approach, with scenario analysis based on primary data (interviews, focus group discussions, and field observations) and secondary data (government reports, academic literature, and statistical databases) to build and validate the model. The basic results show that moderate and optimistic scenarios involving the practice of local wisdom produce the most favorable outcomes, both in terms of increased productivity, farmers' welfare, and environmental sustainability. Of course, this proves that integrating local wisdom with agribusiness strategies offers a strong pathway to sustainable taro agribusiness and a meaningful contribution to the theoretical development and formulation of policies aligned with the SDGs.

1 Introduction

The achievement of the SDGs goals can only be achieved if the food system built is not only to preserve the environment, but also fair, open to all groups, and truly supports a more prosperous life for the community. Food systems need a policy frame that acknowledges the interdependence of humans and the rest of nature to enable inclusiveness and justice, holding space for a more inclusive, resilient, local, small-ecological food model. Research shows the necessity of sustainable diets, multiple agroecological practices, and holistic assessments, including in less-considered regions [1], [2]. The global food situation underscores the urgency of creating a food system that supports sustainability, fairness, and the participation of all stakeholders to achieve the SDGs.

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In the face of increasing global challenges, there is a critical need to optimize local food systems to ensure food security and sustainable community empowerment. Global issues such as population growth, the pressure exerted by climate change, competition for natural resources, and the pace of urbanization make the attainment of SDG2 (No Hunger) even more urgent. Adopting a plant-based diet and increasing support for smallholders are usually recommended as among the few positive measures towards a better food system [3], [4]. The local food movement may address different problems and revitalize community spirit by developing shorter supply chains and promoting multiple uses of resources. Overreliance on the world food system can be detrimental to the environment and does not necessarily ensure that safe food is available. Alternatively, supporting the local food system can be an eco-friendly option that addresses global challenges and sustains a community's economic viability.

In terms of local food, taro, an agricultural product, has been eaten for a very long time and is recognized worldwide, such as in Indonesia and Papua. Taro is a rich source of proteins, dietary fibre, minerals, and bioactive phytochemicals; thus, it has become an indispensable starch and micronutrient supplier for human health and has so far shown many medicinal virtues like Anti-cancerous, Antibacterial, anti-diabetic, Hepatoprotective, immunomodulatory, etc., dozens of pharmacological properties due to its active bio-phytochemical content. Taro is also salinity-tolerant and therefore a likely candidate for significant improvements in food security in a climate-changed world. Taro plays an essential role in both local and global food systems, with several million tons produced annually, while it is continuously threatened by pest attacks, reducing yields and farmers' incomes. Taro plays an important role in food security, medicine, and the economy, and is required for sustainable management and development.

One overlooked potential strength in developing taro agribusiness is local wisdom, which is indeed valuable. Local wisdom serves as social control and moral capital that keeps a balance between the needs of people's lives and ecological sustainability and assures the sustainability of agriculture and forests. Local wisdom is considered a sustainable strategic innovation that can drive business acceleration, enhance sales value, and fortify social entrepreneurship [5], [6]. The agribusiness of taro, based on local wisdom, can be seen as an intermediate alternative for food security and the preservation of cultural heritage.

There is actually little progress on the ground: taro cultivators face numerous difficulties in implementing modern agribusiness for taro production. Farmers struggle with market absenteeism and poor marketing systems and have limited access to credit. Soil degradation diminishes soil fertility and crop production, resulting in food security vulnerability. Climate-induced calamities, such as drought or extreme weather events, also reduce farmers' returns. Other challenges to osmotically treated foods include rural poverty, the disintegration of traditional farming practices, and deficiencies in land conservation and post-harvest management that lead to low productivity and reduced product quality [7], [8]. And too, there are those without infrastructure and capital, and who are susceptible to the vagaries of climate change and environmental destruction that smallholders in Indonesia face. Limited access to technology, new farming practices, and inadequate research collaboration have also hampered farmers' efforts in Indonesia and Papua to improve productivity and competitiveness. To this could be added the locally based negative effects of oil palm expansion on vulnerability and household-level

conflicts, as a consequence of socio-economic situations in West Papua. Cultural methods, low yields, and the lack of an agro-industry still pose the greatest threats to crop sustainability.

Addressing the above problems, there is no question that a comprehensive policy strategy for taro agribusiness needs to be pursued. Scenarios: Dynamic systems modelling with a scenario approach can help policy scenarios address these challenges. This explanatory modeling is strengthened when using a scenario-based approach, in which different scenarios can be simulated and the inherent causes of system behaviour identified, thereby enabling consensus among stakeholders for more effective policies [9], [10]. Furthermore, the computation of computational schemes and methodologies is required for real-time virtual replication to operate, enabling the massive exploration, analysis, and prediction of such complex behaviors in science and engineering. Dynamic system writing with the scenario process is an appropriate method in dynamic systems analysis because it maps cause-and-effect relationships, identifies leverage points for implementing policy instruments, and simulates the long-run effects of a policy.

Despite the strategic importance of taro for food security and rural livelihoods, there is currently no integrative and dynamic modeling framework that systematically links local wisdom, agribusiness subsystems, ecological sustainability, and SDGs targets in an integrated analytical structure. The absence of such a framework limits policymakers' ability to design evidence-based, context-sensitive, and long-term, sustainable interventions to develop taro agribusiness in West Papua.

Research Contribution and Novelty: This study addresses the above gaps by developing a dynamic model of the taro agribusiness system based on local wisdom and oriented towards achieving the SDGs. First, this study operationalizes local wisdom as an endogenous component within the framework of system dynamics, rather than treating it solely as a qualitative or cultural variable. Local wisdom is modeled as influencing land management practices, resource conservation, production stability, and community resilience. Second, this model integrates upstream (inputs and capital), production on farms, downstream (processing and marketing), socio-economic factors, and environmental dynamics into an integrated stock and flow structure. Fourth, this study localizes the operationalization of the SDGs by translating global sustainability goals into measurable system variables at the regional level in West Papua. This helps bridge the gap between global sustainability discourse and local agricultural development practices. By integrating agroecology, socio-cultural capital, agribusiness systems, and dynamic modeling, the study advances theoretical and practical understanding of sustainable local crop development. The resulting model provides a strategic simulation framework to improve farmers' welfare, strengthen ecological resilience, preserve cultural identity, and support the achievement of the SDGs in West Papua.

2 Methods and materials

This study was conducted in one such bright spot of the taro-growing and consuming area. In West Papua Province, Indonesia, taro is not only a staple food for local people but also holds social, cultural, and economic value for society. Besides that, conventional farming management and practice contain plenty of local wisdom, which is a specific

background for sustainable agriculture development. The study adopts a mixed qualitative–quantitative research design grounded in the System Dynamics (SD) approach in order to analyze the complexity of the taro agribusiness system and its long-term sustainability.

The data used in this research are primary data collected through in-depth interviews with farmers, farmer communities, agricultural extension officers, and traditional leaders, to understand the practice of local wisdom in taro breeding. (1) The results of FGD were complemented also by information on problems, opportunities, and strategies in the development of Taro agribusiness; (2) secondary data: data from official publications from local governments, reports from BPS, agricultural policy documents, and academic literature on Taro agribusiness, dynamic systems, and methods of research for SDGs.

The methodology used in this paper is based on dynamic systems analysis and develops the interconnections among components in the taro value chain. It was generated by considering factors such as production, distribution, consumption, policy support, and local wisdom. The method used in this study was System Dynamics (SD), a modeling approach for analyzing the relationships among variables in complex systems.

The dynamic system modeling procedures based on a general scenarios approach include: identification of the problem, formulation of dynamic hypotheses, development of a conceptual model (flow and stock), establishment of the quantitative model, value setting/scenarios design, application software like Powersim construction models and validation models, and use of constructed models to implement policy simulations or scenario analysis. The system dynamics model was prepared using the Powersim Studio 10 Academic software. For this article, the study results focus on model validation and scenario modeling.

The analysis is carried out based on opinions that generally describe seven stages in analyzing a problem using the system dynamics approach, starting from system understanding, problem identification and definition, system conceptualization, model formulation, simulation and validation, policy analysis, improvement, and modeling implementation.

Scenario development followed a general scenario approach, including a business-as-usual scenario, an enhanced input and capital support scenario, an agroindustry development scenario, a local wisdom strengthening scenario, and an integrated policy scenario combining multiple interventions. Each scenario was simulated over a long-term time horizon to capture dynamic behavioral patterns and cumulative effects. The performance of each scenario was evaluated using indicators aligned with SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible Consumption and Production), including production growth, food availability, farmer income, employment generation, resource efficiency, and sustainable land management indicators.

3 Results

The results of the study focus on the validation stages of the taro agribusiness model and on a scenario based on local wisdom, which aims to test the model's reliability while

exploring policies to increase productivity, market access, and the sustainability of taro agribusiness.

3.1 Model Validation

The results of the dynamic system analysis show that the behavior of the taro agribusiness development model based on local wisdom in West Papua can be achieved, provided that the model structure has been validated to ensure the adequacy and consistency of the resulting behavior.

Testing using MAPE (Mean Absolute Percentage Error) was applied to taro production, productivity, and consumption data for 2020-2022, yielding values of 7.2%, 1.3%, and 0.1%, respectively (attached). Based on the accuracy criteria of the MAPE value model for the two variables tested, the calculated MAPE values were below 10%, indicating that the model is quite accurate and feasible to use.

3.2 Model Scenario

The model scenario was simulated using controlled inputs, which served as the primary lever to ensure the sustainability of taro agribusiness development in West Papua Province, grounded in local wisdom. The black box diagram (input-output) in West Papua can be seen in **Fig. 1**.

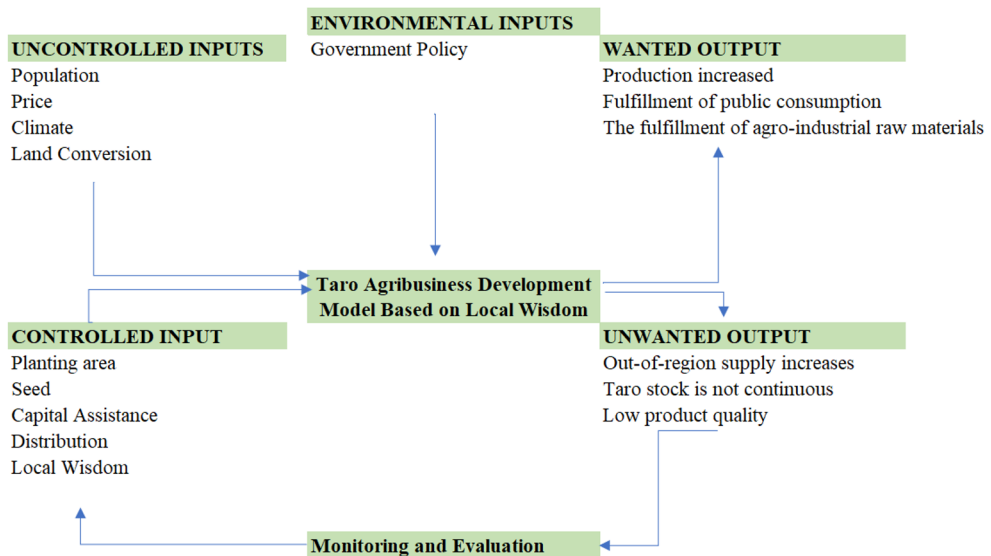


Fig. 1. Black box diagram (input-output) of the taro agribusiness development model based on local wisdom in West Papua

The factors that have the greatest influence on model behavior, as well as the main needs of stakeholders in the taro agribusiness development system based on local wisdom, include: (1) the planting area, (2) seeds, (3) capital assistance, (4) distribution, and (5) local wisdom.

Three scenarios were developed in this study, including the existing scenario, the moderate scenario, and the optimistic scenario. The existing scenario is built according to the current field conditions, without any effort, so that the production process runs as it does under those conditions. A moderate and optimistic scenario is built by expanding planting areas and improving agricultural facilities as factors of production to increase production value, improve distribution, and maintain local wisdom.

Model simulation scenarios are designed under various leverage-factor conditions. The development of the scenario starts from existing to moderate, then from moderate to optimistic, with the order of policies in the simulation presented in **Table 1**.

Table 1. Scenario of taro agribusiness development model based on local wisdom in West Papua

Leverage Factors	Existing	Condition (state) in the period coming	
		Moderate	Optimistic
Planting area	Fixed (growth of 13.09%/year)	Moderate increase (14.09%/year)	Significant increase (15.09%/year, intensive expansion)
Seed	Potted local seeds (20%)	Superior seeds are introduced (22% use)	Superior seedlings are dominant (>25% of use)
Capital Assistance	Limited, own capital (10%)	There is an Intervention of NGOs and local governments (12%)	Fully supported by provincial programs and private CSR (15%)
Distribution of taro products	Manual, long distance (30%)	Already using organized local transport (25%)	Adoption of local digital distribution and e-commerce systems (20%)
Local Wisdom	Still dominant but undocumented (90%)	Partially documented and retrained (92%)	Integrated into formal training and farmer curriculum (95%)

The simulation results, derived from a combination of factors, are used to compare scenarios that represent the dominant conditions in the coming period. The existing scenario illustrates the conditions for the effective and efficient use of seedlings, capital assistance for the expansion of planting areas, distribution, and local wisdom in West Papua. Moderate and optimistic scenarios consider increasing these values to increase taro productivity, which will affect the projected value of total production in the coming period, and increasing per capita taro consumption to increase the number of taro consumption needs in the study area.

3.2.1 Increased Production

Simulations of taro production in three scenarios (existing, moderate, and optimistic) show a consistent upward trend throughout the 2020–2030 period. The availability of production factors and local wisdom influences this production growth. The difference between scenarios is evident in the speed and magnitude of production increases, with the optimistic scenario yielding the most significant results in closing the gap between

current conditions and reference targets. The results of the taro production simulation are presented in **Fig. 2**.

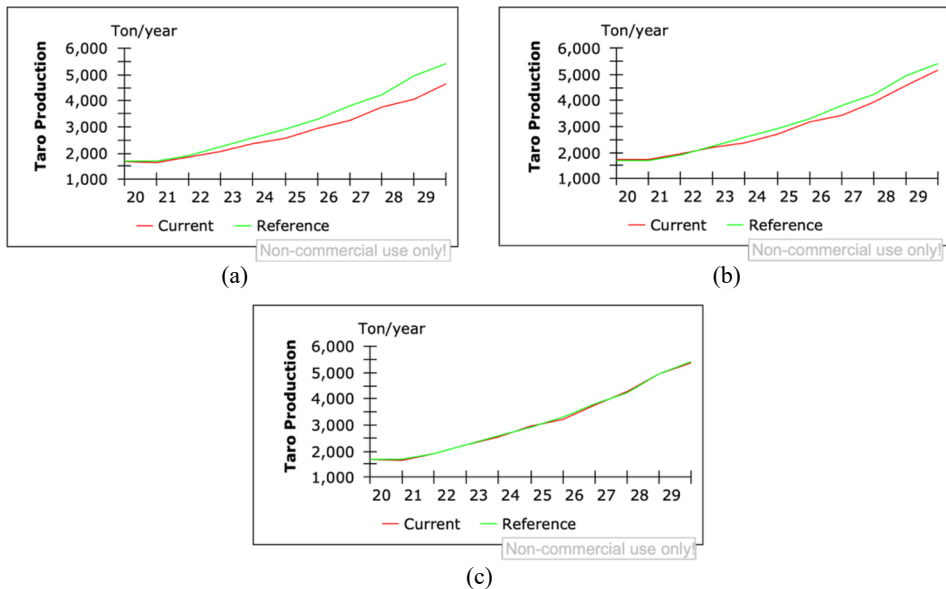


Fig. 2. Simulating scenarios (a) Existing; (b) Moderate; (c) Optimistic

Based on the simulation results across all three scenarios, there is a tendency for taro production to increase from 2020 to 2030. In the existing scenario (a), taro production has increased quite steadily, but the gap between the actual conditions and the reference target is still quite wide, especially in the final years of the simulation. This shows that if taro agribusiness management continues without major innovations, production has indeed increased, but it has not kept pace with expected development targets. Thus, this scenario guarantees only natural growth without significant acceleration.

In the moderate (b) and optimistic (c) scenarios, taro production shows a more rapid increase, with the gap to the reference target narrowing. A moderate scenario consistently approaches the target, while an optimistic scenario is even closer to matching the baseline by 2029. With the right strategy, taro agribusiness can be developed into a leading sector that supports food security and the local economies of communities.

3.2.2 Fulfillment of Taro Consumption

The simulation of taro consumption across three scenarios (existing, moderate, and optimistic) shows how people's consumption needs can be met in line with the expected target. Taro consumption in this case reflects the role of taro as both a staple and a complementary food, and this role continues to increase with population growth and changing consumption preferences. The comparison between current conditions and reference targets indicates the extent to which the taro agribusiness system can meet public consumption needs from 2020 to 2030. The results of the taro consumption simulation are presented in **Fig. 3**.

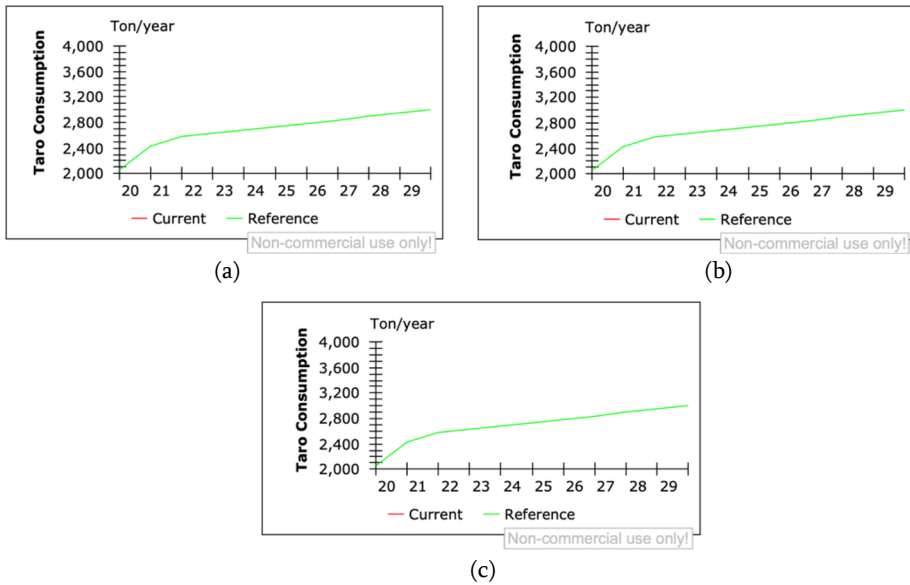


Fig. 3. Simulating scenarios (a) Existing; (b) Moderate; (c) Optimistic Consumption

Based on the results of the taro consumption simulation in the three scenarios, it can be seen that the demand growth pattern is relatively the same between the existing (a), moderate (b), and optimistic (c) scenarios. In the existing scenario (a), taro consumption is relatively stable and close to the reference target. However, at the beginning of the period, there is a slight gap between the actual and reference conditions. However, after 2023, actual conditions and reference targets show almost identical trends, indicating that consumption needs can be well met even with only natural growth, without major interventions.

Moderate (b) and optimistic (c) scenarios show better results, with the difference between actual consumption and the reference target being smaller or barely noticeable. This indicates that the strategy of strengthening the production, distribution, and management of taro agribusiness plays an important role in maintaining the stability of fulfilling public consumption.

3.2.3 Fulfillment of Agro-industrial Raw Materials

The simulation of the fulfillment of taro agroindustry raw materials in three scenarios (existing, moderate, and optimistic) illustrates how the availability of taro as an input for the processing industry can support the development of agroindustry in West Papua. The graph compares the current condition with the reference target, showing a trend of increasing raw material demand that grows with industry development, as well as the production capacity to meet it throughout the 2020-2030 period as shows in **Fig. 4**.

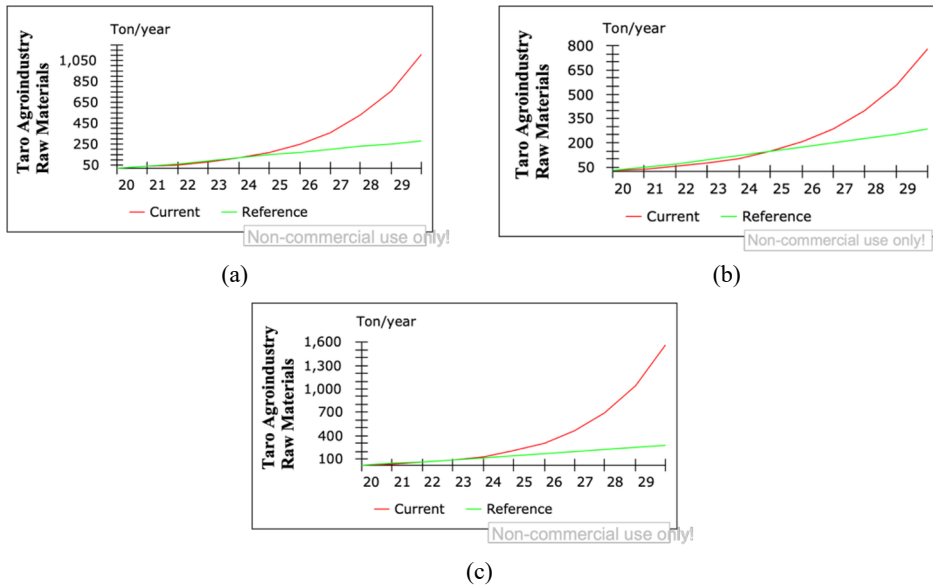


Fig. 4. Simulating scenarios (a) Existing; (b) Moderate; (c) Optimistic of Agroindustry Raw Materials

Based on the results of the taro consumption simulation across the three scenarios, it can be seen that in the existing scenario (a), the availability of agro-industrial raw materials increases year by year, but actual growth exceeds the reference target. This indicates a potential surplus of taro supply that can be used to strengthen local industries' capacity. However, without good management, this condition risks causing an imbalance between industrial capacity and available raw materials, so it is necessary to have a policy that directs surplus to the diversification of processed products.

In the moderate (b) and optimistic (c) scenarios, the growth trend of agro-industrial raw materials is increasingly clear, with a sharp increase in actual production compared to the reference target. This opens up great opportunities for the development of a taro-based agroindustry, both for domestic consumption and as a leading export commodity, provided it is supported by strengthening the value chain, improving processing technology, and securing sustainable market access.

3.3 Contribution to SDGs

The simulation results show that the development of taro agribusiness grounded in local wisdom directly contributes to achieving several Sustainable Development Goals (SDGs). First, in SDG 2 (Zero Hunger), taro agribusiness plays an important role in increasing local food availability while encouraging diversification of food sources, thereby strengthening community food security. Second, in SDG 8 (Decent Work and Economic Growth), this development can increase farmers' income and welfare by fostering a more productive, efficient, and competitive agribusiness system in local and regional markets. Third, under SDG 12 (Sustainable Consumption and Production), the use of sustainable agriculture informed by local wisdom in taro development increases the efficiency of natural resources by minimizing waste and protecting the environment.

Therefore, the application of local wisdom in agribusiness will not only have positive economic implications but also harmonize social, ecological, and sustainable development interests.

4 Discussion

The growth of taro in West Papua has the potential to develop further along natural trends, particularly in moderate and optimistic scenarios. Dynamic systems methodologies are increasingly used to model the relationships among the elements involved and to understand how crop stability could be affected, or not, under moderate and optimistic assumptions. Taro is also a resilient staple crop (the base of the food security pyramid) even under moderate and optimistic growth prospects conditions [13]. Biotic and abiotic factors, such as soil fertility and agroecological zones, also affect the adaptability of taro, leading to differences in the yield performance of varieties, as different cultivars adapt varying strategies in drought tolerance. Production of taro is imperiled by sunshine-dry spores, leaf rot, and soil depletion. This necessitates an investigation into the potential of improved varieties, extensification, and fertilization, as well as cross-breeding for resistant species. This indicates the form of intervention support in nurturing technology, counseling, access to capital, and learning from local wisdom.

Taro needs could be met sustainably in the moderate and optimistic scenarios, creating an opportunity to direct the surplus produced above demand towards the on-farm industrial processing sector or to exchange it for markets outside. The moderate policy pathway focuses on climate-smart agriculture, integrated pest management, soil health improvement, and infrastructure development to support the stable expansion of the bulb industry. The hopeful trend includes the role of the circular economy, the application of food-waste biorefineries (converting sweet potato waste into bioethanol), new green technologies, and infrastructure repositioning towards production efficiency [14], [15]. The present study also highlights the opportunities of biotechnology and nanotechnology developments in converting bulb plant waste into high-value BPs, as well as setting directions for sustainable production techniques. The synergy among environmental governance, technological change, and consumer-led sustainability for the sustainable provisioning of taro as food, with surplus directed towards the industry sector and exports.

The moderate scenario shows a more balanced fulfillment. In contrast, the optimistic scenario shows strong potential for industrial expansion, given the availability of agro-industrial raw materials that exceed reference needs. The application of responsible practices in the agro-industrial sector, supported by an ecological approach, improves product quality and quantity while reducing negative environmental impacts and fostering the development of value-added business units to encourage sustainable industrial growth. The use of agro-industrial waste helps reduce environmental impact and promote circular economy principles. These findings show that the development of taro agribusiness cannot be seen only in terms of productivity but also needs to consider cultural and social factors. The integration of local wisdom proved to be a lever that strengthened the system's sustainability and differentiated this research from other agribusiness studies.

Overall, the findings support the adoption of an integrated, dynamic policy framework for taro agribusiness in West Papua. The moderate scenario appears to provide a stable transition pathway toward sustainability, while the optimistic scenario offers higher economic returns with greater management complexity. The study, therefore, provides evidence that sustainable taro agribusiness development requires balancing productivity enhancement, ecological integrity, cultural continuity, and industrial transformation within a dynamic systems framework.

5 Conclusion

This study shows that the development of taro agribusiness based on local wisdom, using a dynamic system modeling approach with scenario analysis, can provide a comprehensive picture of the interactions among production, distribution, consumption, and policy components. Moderate and optimistic scenarios involving the practice of local wisdom produce the most optimal outcomes, both in increasing productivity, farmers' welfare, and environmental sustainability. The development of taro agribusiness can contribute directly to achieving SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible Consumption and Production). Thus, this study emphasizes the importance of integrating cultural and scientific values in building a sustainable food system.

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