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Optimization of risk management in red chili agribusiness through factoring financing using a system dynamics approach in Aceh Tengah Regency

Agustina Arida [1], Lukman Hakim [2*]
[1,2] Department of Agribusiness, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia
*Email correspondence: lukman.hakim.sp.mp@usk.ac.id

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ABSTRACT

Introduction: The production and marketing of red chili in Aceh Tengah Regency face significant risks, particularly financial constraints that limit liquidity and undermine the sustainability of farming systems. Prolonged receivable structures remain a major challenge, restricting farmers' working capital and reducing supply chain efficiency. This study aims to optimize financial risk management in red chili agribusiness through the application of factoring as an alternative financing scheme, using a system dynamics approach. **Methods:** A system dynamics approach was employed to analyze the role of factoring as an alternative financing mechanism in red chili agribusiness. The research was conducted in the main chili production centers of Aceh Tengah Regency using a mixed-method design that combined literature review, field observations, and in-depth interviews with farmers, cooperatives, financial institutions, and policymakers. Primary and secondary data were integrated into a dynamic simulation model using Vensim software to assess the impact of factoring on cash flow, liquidity, and system sustainability. **Results:** The simulation results demonstrate that factoring effectively accelerates cash inflows, thereby strengthening farmers' liquidity compared to delayed payments of up to 30 days under conventional arrangements. Enhanced liquidity enables farmers to finance production inputs, labor, and crop maintenance more efficiently, while cooperatives benefit from more stable cash flows to ensure timely payments to members. Additional advantages include improved sales administration and collection systems, reduced credit default risk, and greater competitiveness without collateral requirements. **Conclusion:** Factoring is proven to be a viable financing strategy that enhances the resilience and sustainability of red chili farming systems by improving liquidity and supply chain efficiency. Policy implications include the need to establish supportive regulations, promote transparency in factoring costs, and encourage cooperative-based financing schemes to facilitate wider adoption among smallholder farmers.

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INTRODUCTION

Red chili production in Aceh Tengah Regency plays a strategic role in both the local and national economy. As one of the major red chili production centers in Aceh Province, this region contributes significantly to Indonesia's chili supply. However, farmers in the area often face multiple challenges, particularly in financial management and risk control. Prolonged receivable structures and limited liquidity represent major obstacles in maintaining farmers' working capital cycles, ultimately reducing production efficiency and affecting market price stability.

Factoring is considered an important alternative financing instrument to address liquidity constraints in agribusiness. It allows farmers to convert accounts receivable into immediate cash, thereby maintaining cash flow and ensuring uninterrupted operations (Gunawan, 2001). Nevertheless, the implementation of factoring in Indonesia still faces major regulatory barriers. Although Presidential Decree No. 61/1988 recognizes factoring as part of financial institutions, more detailed regulations on its operational mechanisms remain absent. The lack of a clear legal framework creates regulatory gaps that lead to uncertainty for stakeholders (Lestari, 2023). International studies also emphasize the importance of strong legal frameworks: Kouvelis and Xu (2021) highlighted that flexible financing such as factoring enhances financial efficiency in supply chains; Ambler et al. (2022) demonstrated that robust legal frameworks foster factoring adoption in European agriculture; Mishra et al. (2021) found that standardized documentation accelerates adoption in emerging markets; and the Asian Development Bank (2022) identified regulatory ambiguity as a key obstacle

to reverse factoring in Asia. Accordingly, the urgency of this study lies not only in the technical aspects of financing but also in providing an analytical foundation to strengthen policy recommendations and close regulatory gaps.

Previous studies have demonstrated that the implementation of factoring has a positive impact on liquidity and the operational efficiency of agribusiness actors. Mamesah (2015) emphasized that factoring helps overcome delays in consumer payments, leading to smoother cash flows, while Diansari and Adhivinna (2019) noted that its low adoption in Indonesia is largely due to limited awareness among SMEs. Sudjana (2019) further stressed the importance of clear contractual agreements to minimize legal disputes, given the absence of specific regulations. International findings reinforce these arguments: Luo et al. (2025) demonstrated that supply chain finance, including factoring, improves agribusiness productivity through digitalization; Xia *et al*. (2022) showed that sustainable approaches in supply chain finance support credit risk assessment for farmers; Guo et al. (2025) highlighted the role of reverse factoring in mitigating agricultural supply chain risks; and Yu and Huang (2025) found that smart finance and digital technologies accelerate the efficiency of agribusiness financing. Thus, this study not only examines the technical effectiveness of factoring but also seeks to contribute to policy development by reducing regulatory uncertainty in the agribusiness sector.

A system dynamics approach is applied to capture the complex interactions among components in red chili agribusiness. This methodology enables dynamic analysis of system behavior by modeling causal relationships among variables. Forrester (1961), in *Industrial* Dynamics, emphasized that system dynamics helps explain both the structure and behavior of industrial systems, including agriculture. Policy simulations, such as the introduction of factoring schemes, allow researchers to evaluate their impact on liquidity and the sustainability of farming systems. Therefore, this study is not limited to financial evaluations but also aims to provide empirical evidence to inform policy recommendations in agricultural finance.

Globally, factoring has proven effective in improving liquidity and supply chain efficiency in agribusiness. According to the Global Factoring Association (2020), countries such as the United States and the United Kingdom have long utilized factoring as a reliable financial instrument in the agricultural sector. These experiences offer valuable lessons for Indonesia in designing factoring mechanisms for strategic commodities such as red chili. Likewise, system dynamics approaches have been widely used in risk management research. Sterman (2000), in *Business Dynamics: Systems Thinking and Modeling for a Complex World*, emphasized that this approach enables a deeper understanding of complex business interactions and supports simulation-based decision-making.

In Indonesia, the application of system dynamics in agribusiness research is still limited but gradually expanding. For instance, Suryani et al. (2014) applied system dynamics to analyze national food security, while Widhianthini (2018) demonstrated its usefulness in developing adaptive financial policy models. In the context of red chili production in Aceh Tengah, this approach is particularly relevant given the sector's dependence on external factors such as weather, price fluctuations, and working capital availability. Dynamic simulations can thus be employed to test various policy scenarios, including factoring, and assess their implications for liquidity and supply chain sustainability.

Moreover, access to innovative financing plays a critical role in strengthening farmers' economic resilience. Setiawati and Permana (2025) argued that financing flexibility is a key factor in improving farmers' competitiveness. Therefore, the integration of innovative financing instruments such as factoring with system dynamics analysis offers a promising strategy for agribusiness risk management. Government authorities and financial institutions play a critical role in facilitating this process. As highlighted by Kementerian Pertanian Republik Indonesia (2024), limited financial literacy and restricted access to modern financial instruments continue to pose significant challenges within the agricultural sector.

Overall, this study contributes to a better understanding of the interplay between financial and operational factors in red chili agribusiness. By applying a system dynamics approach, it evaluates factoring scenarios as potential solutions to liquidity constraints faced by farmers in Aceh Tengah. Furthermore, the findings are expected to serve as a reference for policymakers in formulating more effective financing strategies and policy recommendations to close regulatory gaps and reduce legal uncertainty, thereby enabling more optimal and sustainable implementation of factoring in agribusiness.

METHODS

Research location

This study was conducted in Aceh Tengah Regency, a key production center of red chili in Aceh Province. The location was selected due to its significant contribution to the national red chili supply and the financial challenges faced by local farmers. Despite its importance in the supply chain, farmers in Aceh Tengah often experience liquidity issues because of long receivable periods, which delay payments for their products. These challenges hinder farmers' ability to reinvest in their operations, affecting the sustainability and growth of red chili farming in the region. This study aims to explore

potential solutions, particularly through factoring financing, to improve cash flow and support the financial stability of local farmers.

Data sources and collection techniques

Data were obtained from a combination of primary and secondary sources. Primary data were collected through field observations to map the production and distribution flows of red chili, in-depth interviews with farmers, traders, financial institutions, factoring companies, agribusiness actors, cooperatives, and relevant policymakers. Additionally, focus group discussions (FGDs) were conducted with practitioners and farmer associations to validate field information and enrich insights into decision-making dynamics within the red chili agribusiness system.

Secondary data were gathered from scientific publications, official government documents such as BPS (Statistics Indonesia) reports and Ministry of Agriculture publications, regulations on financial institutions, and industry reports from the Global Factoring Association and other financial bodies. The types of data analyzed included numerical data, written (literature) data, and mental data. Numerical data contained quantitative parameters related to the physical structure and decision-making processes in the red chili agribusiness system, particularly regarding receivable flows, cash flow, and farmers' working capital turnover. Written data were obtained from journals, articles, research reports, and books relevant to agribusiness financing and factoring practices. Mental data reflected the mindset, perceptions, and decision-making rules of key stakeholders, including red chili farmers, middlemen, distributors, marketers, financing institutions, and local government agencies such as the Department of Agriculture.

System dynamics approach and analytical tools

This research employed a modeling approach based on systems thinking using the system dynamics methodology, which emphasizes inter-variable linkages, feedback mechanisms, and delays in decision-making processes. The main focus of the analysis was to optimize risk management in red chili agribusiness through factoring financing scenarios using a system dynamics approach.

Data from multiple sources including mental models, written literature, and numerical data were integrated into the model design using the system dynamics methodology (Figure 1). The modeling process involved developing causal loop diagrams, stock–flow diagrams, and sub-models (levels and rates) that represented the dynamics of the red chili agribusiness system. The subsequent steps included model development, assumption testing, and simulation to ensure the validity of the system representation (Tasrif, 2016).

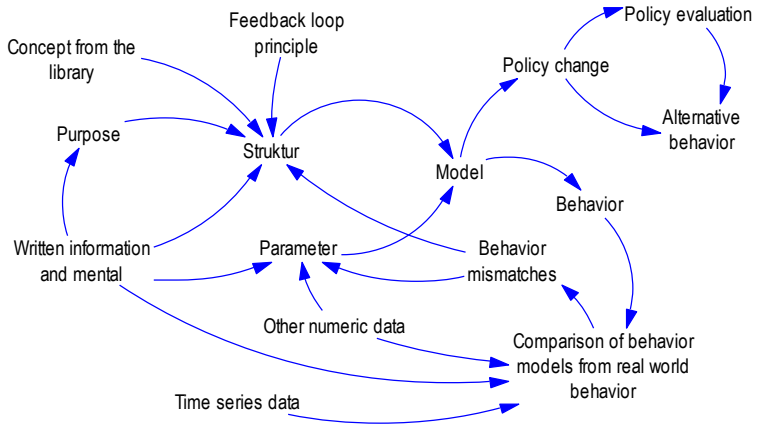

Figure 1. Design of the system dynamics model

Model formulation and data analysis were conducted using Vensim PLE software, selected for its capability to visualize complex causal relationships among variables and support simulation-based analysis. The developed model was evaluated by comparing simulation results with empirical field conditions, thereby providing a more accurate representation of the red chili agribusiness system.

The simulation process in this study was carried out in three main stages: (1) Baseline Simulation, which involved running the model using default parameters that reflected actual conditions, such as a 30 day payment period, a 5% service charge, and a 70% discount charge on receivables, to generate an initial comparison pattern; (2) Policy Scenario Simulation, which examined variations in key parameters including payment periods of 30, 20, and 10 days, service charges of 5%, 3%, and 2%, and discount charges of 70%, 65%, and 60% to evaluate the effects of financing policies on farmers' and cooperatives' cash flow; and (3) Sensitivity Analysis, which tested the robustness of simulation results under external changes, such as a 10% increase in production input costs combined with a shortened payment period of 15 days. Through these stages, the model provided a comprehensive picture of the impacts of factoring policies on

cash flow, liquidity, and the sustainability of red chili agribusiness, serving as the basis for formulating more targeted financing policy recommendations for farmers in Aceh Tengah Regency.

Model testing

A model, as a representation of the actual system, requires validation testing to ensure its credibility. This validation is conducted by comparing the simulated behavior generated by the model with the real system's behavior reflected in empirical data. When the outcomes show alignment with empirical evidence, the model can be regarded as valid and capable of replicating the real-world system.

Model validation can be performed through two main approaches. The first approach involves comparing the simulation outcomes with statistical data, where both empirical observations and simulation results are presented together in a single graph. The second approach relies on statistical testing, such as Theil's inequality statistics. In this method, the error is quantified using the Mean Square Error (MSE), as formulated in the equation proposed by Sterman (2000):

$$MSE = {}^{1}\!/_{n} \sum_{n=1}^{n} [(S_t - A_t)/\, A_t]^2$$

A lower MSE value reflects a smaller magnitude of error, while a higher MSE value corresponds to a greater error level. To further interpret simulation accuracy, the Root Mean Square Percent Error (RMSPE) can be applied. RMSPE is defined as the square root of the mean percentage error, which is determined using the following equation:

$$RMSPE = \sqrt{\frac{1}{n} \sum_{n=1}^{n} [(S_t - A_t)/\, A_t]^2}$$

Errors within the model can be grouped into three distinct categories: bias proportion (U^M), variance proportion (U^S), and covariance proportion (U^C). An optimal model is expected to exhibit minimal errors, with the majority concentrated in variance (U^S) and covariance (U^C) components. Nevertheless, the level of significance and the acceptable tolerance for each error type are determined by the objectives of the model and the nature of the dataset employed. The bias proportion (U^M) can be calculated using the following equation:

$$U^M = \frac{(S - A)^2}{1/n \sum_{n=1}^{n} [S_t - A_t]^2}$$

The variance proportion (U^S) is defined as the ratio between the difference in variance of the model outputs and the variance of the observed data, relative to the difference between predicted and observed values. Since variance is obtained as the square of the standard deviation (S^2), (U^S) is commonly expressed as the squared difference between the standard deviation of the model results and that of the empirical data, divided by the mean squared difference between model predictions and actual observations. The value of (U^S) can be determined using the following equation:

$$U^S = \frac{(S_S - S_A)^2}{1/n \sum_{n=1}^{n} [S_t - A_t]^2}$$

The covariance proportion (U^C) reflects the degree of association between two variables. A higher covariance value indicates a stronger relationship, which is equivalent to a higher correlation coefficient (r). Consequently, a model is regarded as more valid when the covariance proportion (U^C) accounts for a larger share of the error. The (U^C) value can be computed using the following equation:

$$U^C = \frac{2(1 - r) S_S \cdot S_A}{1/n \sum_{n=1}^{n} [S_t - A_t]^2}$$

Mathematically, the relationship among the three proportion values can be expressed as follows:

$$U^M + U^S + U^C = 1 \text{ atau } U = 1(U^M + U^S)$$

The smaller the proportion of unequal bias (U^M) and unequal variance (U^S), the larger the proportion of unequal covariance (U^C). An ideal model should exhibit a very small level of error or bias, with the remaining discrepancies concentrated in unequal variance (U^S) and unequal covariance (U^C).

RESULTS AND DISCUSSION

Financing policy scenarios through factoring

The modeling results indicate that the implementation of financing scenarios through factoring can generate a significant impact on improving liquidity within the red chili agribusiness system, particularly for farmers engaged in partnerships with agro-industries through cooperatives. Although traditionally applied more extensively in export–

import transactions, the factoring mechanism has proven to be effectively adaptable in horticultural agribusiness as a means of addressing farmers' liquidity constraints. By accelerating the payment of harvest revenues, farmers gain more stable working capital, thereby enabling them to sustainably enhance farm productivity.

In practice, financing companies purchase farmers' receivables channeled through cooperatives to agro-industries, thereby creating a scheme that provides dual benefits for both parties. For cooperatives, this mechanism not only improves the stability of cash flows but also strengthens their role as financial intermediaries in agribusiness. As illustrated in Figure 2, the system dynamics sub-model structure shows the cash flow of cooperatives under the factoring scheme, where cooperative cash is positioned as the main stock variable. The cash flow is influenced by inflows in the form of payments from factoring institutions and agro-industries, as well as outflows in the form of obligations to pay farmers and cover operational costs. Consequently, cooperatives become more adaptive in managing liquidity while maintaining the continuity of financial relationships with both farmers and agro-industries.

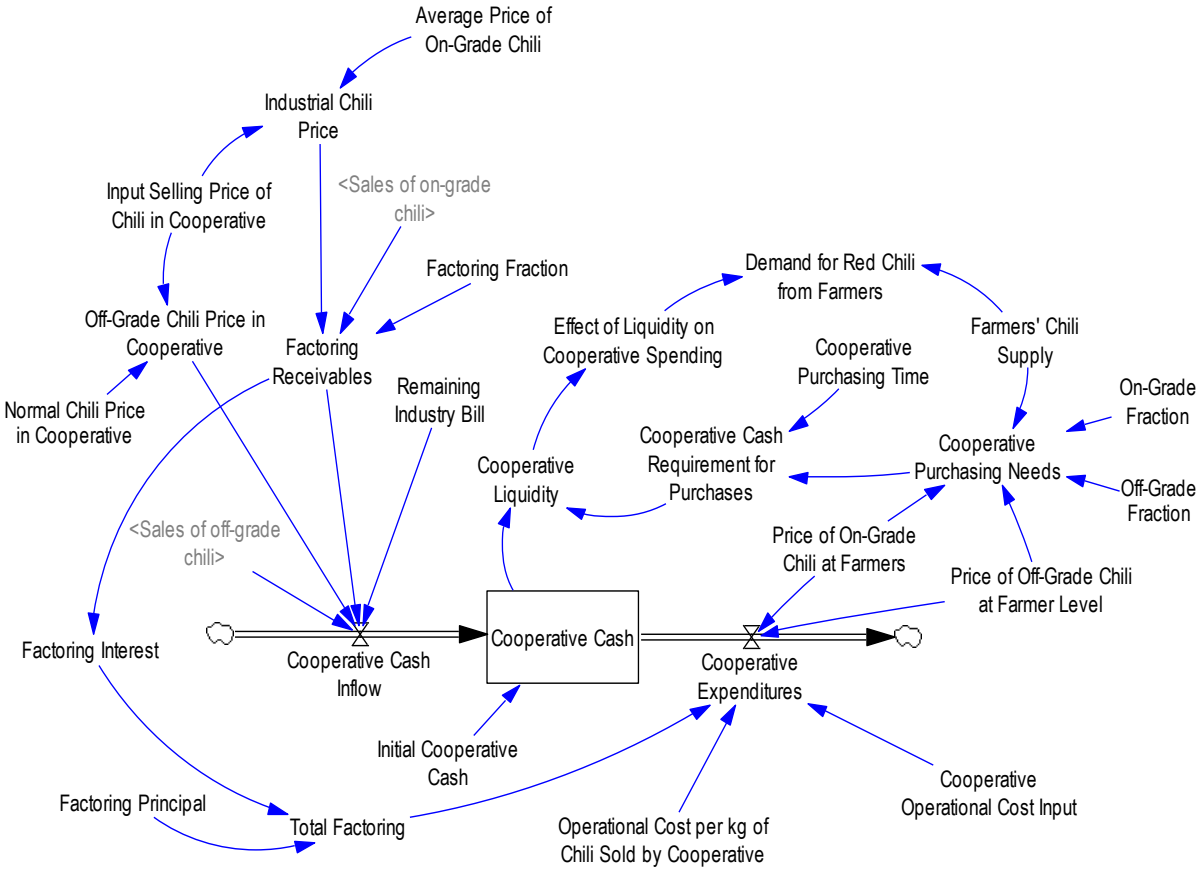

Figure 2. Diagram sub-model of cooperative cash flow in the factoring scenario

The causal relationships are illustrated through interconnected causal loops. When the factoring fraction increases, cooperative cash inflows rise as a result of accelerated payments that were previously delayed by the agro-industry. This improvement enhances cooperative liquidity and strengthens its capacity to meet expenditure requirements, including timely payments to farmers. Conversely, interest charges and administrative fees associated with factoring function as reducing elements that may weaken cooperative cash flow if not managed effectively. Moreover, this sub-model highlights the linkage between cooperative cash flow and the dynamics of both on-grade and off-grade red chili prices at the farm level. More stable liquidity enables cooperatives to disburse payments in line with the quality and quantity of supply, thereby improving farmers' bargaining position within the supply chain. Positive feedback emerges in the form of greater continuity of red chili supply, which subsequently reinforces cooperative cash flow through increased sales volumes.

Meanwhile, Figure 3 illustrates the sub-model of farmers' cash flow dynamics in the factoring scenario. This diagram demonstrates how farmers' liquidity is shaped by the interaction between cash inflows and expenditures for red chili production costs. Prior to the implementation of the factoring scheme, farmers' cash flow was often constrained due to delayed payments from the agro-industry, with operational funds becoming available only after 30 days. This condition created liquidity limitations that directly affected farmers' ability to finance timely production needs, such as purchasing agricultural inputs, covering labor costs, and maintaining crop management.

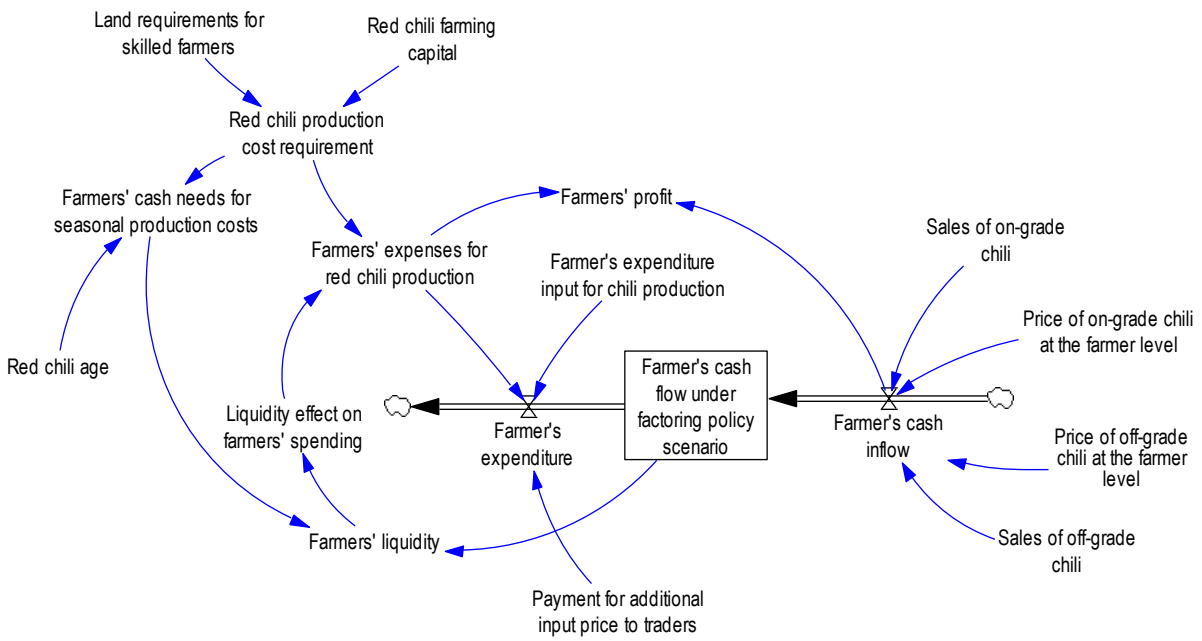

Figure 3. Diagram sub-model of farmers' cash flow in the factoring scenario

Through the implementation of the factoring scenario, farmers' cash flow demonstrates significant improvement. Sales revenues can be immediately liquidated through financial institutions, thereby increasing and accelerating farmers' cash inflows. This liquidity acceleration enables farmers to procure production inputs in a timely manner, reducing the risks of delayed planting or crop maintenance, and supporting the continuity of the production cycle. The diagram also illustrates the presence of feedback loops, whereby improved liquidity enhances farmers' purchasing capacity, which in turn contributes to greater productivity and profitability in red chili farming.

Overall, the two sub-models confirm that the implementation of factoring not only strengthens short-term cash flow but also establishes positive feedback mechanisms that support the sustainability of cooperative functions and the stability of farmers' enterprises. These findings are consistent with previous studies by Dekrita and Samosir (2022), Hakimah *et al*. (2023), and Ariani (2022), all of which emphasized that accelerated cash flow is a strategic factor in maintaining cooperative financial performance as well as ensuring continuous payments to members.

The acceleration of cash flow at the farm level also contributes to production stability and the continuity of red chili supply in the market, both in terms of quality and quantity. This result aligns with the findings of Permana (2017), which demonstrated that eliminating delayed payment systems and replacing them with cash payments significantly improved farmers' cash positions. Farmers with access to rapid payment mechanisms were shown to maintain more stable liquidity compared to those tied to agro-industry partners with deferred payment schemes. Therefore, the implementation of factoring at the level of red chili farmers has the potential to enhance cash sufficiency while simultaneously supporting productivity and farm sustainability.

Nevertheless, the factoring mechanism is not without cost burdens that must be carefully considered. Factoring companies generally impose two types of fees, namely a service charge (approximately 1–3% of the invoice value) and a discount charge that depends on the level of risk and the speed of payment. Wulandari *et al*. (2021) found that although factoring improved cash flow and income stability among horticultural farmers in Central Java, administrative costs and interest charges reduced profit margins by up to 12% within a single harvest cycle. Similarly, research by Karyani *et al*. (2015) on red chili farmers in West Java revealed that high service charges and discount charges, reaching up to 5% of the total invoice, constituted the main barrier to adoption. Furthermore, Abubakar and Handayani (2020) emphasized that factoring practices in Indonesia remain largely dominated by the 'with recourse' model due to weak contractual arrangements, which means that the risk of default may ultimately revert back to the farmers.

Therefore, to ensure that factoring schemes deliver maximum benefits without overburdening smallholder farmers, clear supporting policies are required. Regulations should establish limits on factoring service fees, enhance contract transparency, and provide mechanisms such as subsidies or cost incentives for small-scale farmers. Institutional support from cooperatives is also essential to strengthen farmers' bargaining power in negotiations with financing companies. Through a combination of regulation, incentives, and cooperative empowerment, factoring can serve as an alternative financing instrument that not only improves liquidity but also enhances farmers' economic resilience and the overall sustainability of the red chili agribusiness.

The impact of factoring scenarios on red chili agribusiness risks

One of the key strategies to minimize the risks associated with red chili price fluctuations is the establishment of partnerships between farmers organized through cooperatives and agro-processing industries. Such partnership schemes are designed to provide price assurance while maintaining income stability for farmers. Nevertheless, their implementation in the field continues to face several challenges. The main obstacle lies in the limited support from financial institutions, both banks and non-bank entities, which should ideally play a critical role in providing access to working capital. The absence of adequate financial backing has led to delays in realizing these partnerships, thereby preventing farmers from fully capturing their potential benefits. In this context, alternative financing schemes such as factoring hold considerable potential as risk mitigation instruments that can strengthen farmers' position while enhancing the effectiveness of partnerships with the agro-industry.

One of the main challenges faced by farmers in partnership schemes is the delayed payments from agro-industries, which ultimately disrupt liquidity and threaten the sustainability of red chili farming. Factoring can serve as an innovative solution to address this issue through the transfer of farmers' receivables to financial institutions. This mechanism enables farmers to receive payments more quickly, thereby ensuring smoother cash flows. In addition to improving liquidity, the implementation of factoring also contributes to reducing the risk of bad debts and provides farmers with greater flexibility in managing working capital and enhancing production capacity in a sustainable manner. Figure 4 presents the results of modeling and simulation, which demonstrate a more significant increase in farmers' cash compared to the conditions prior to the implementation of the policy.

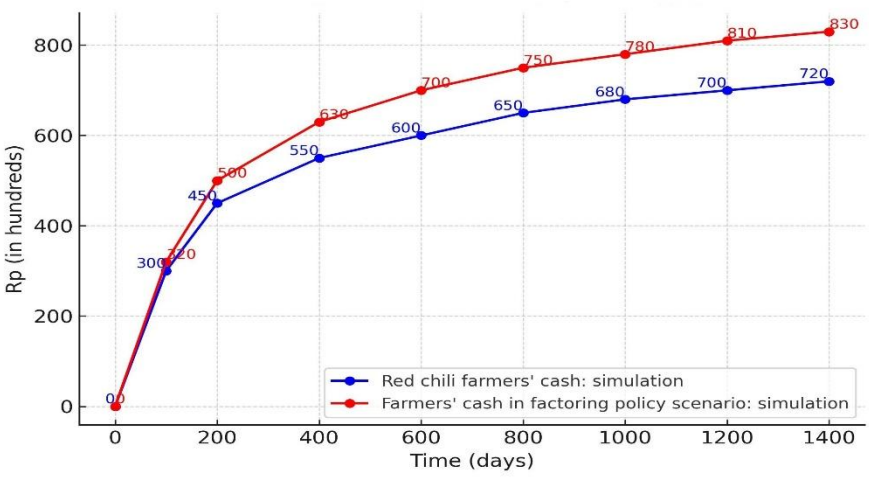

Figure 4. Impact of the factoring scenario on red chili farmers' cash flow

These findings are consistent with the study of Wulandari *et al*. (2021), which revealed that delayed payments for harvested crops are one of the main causes of cash flow instability among horticultural farmers in Central Java, and that alternative financing interventions can help alleviate working capital pressures. Research by Karyani et al. (2015) in West Java also demonstrated that non-conventional financing schemes, including factoring, are effective in accelerating red chili farmers' cash flows, although they continue to face challenges related to service costs. Furthermore, Permana (2017) emphasized the importance of eliminating receivable structures through early payment mechanisms, as this strategy has been proven to enhance the cash adequacy of red chili farmers engaged in partnership schemes with processing industries.

The payment system, which was previously delayed for up to 30 days, often resulted in an accumulation of receivables that disadvantaged farmers. The implementation of the factoring scenario significantly shortens the payment period, thereby providing added value in the form of improved cash flow and strengthened financial positions for farmers (Hakim & Perdana, 2017). This enhanced liquidity enables farmers to conduct operational activities more efficiently, ranging from covering production costs and procuring inputs to maintaining crops in accordance with the applicable standard operating procedures (SOPs).

Overall, the implementation of factoring in the red chili agribusiness in Aceh Tengah Regency has proven to be a potentially effective strategy for mitigating financial risks. Through this scheme, farmers gain faster and more flexible access to financing, enabling them to maintain liquidity and enhance the long-term sustainability of their farming operations. Moreover, factoring contributes to ensuring the continuity of red chili supply in the market, both in terms of quantity and product quality. To guarantee successful implementation, strong synergies are required among cooperatives, processing industries, and financing institutions in designing mechanisms that are adaptive, transparent,

and equitable. Figure 5 illustrates the trend of farmers' cash flow before and after the implementation of the factoring scenario.

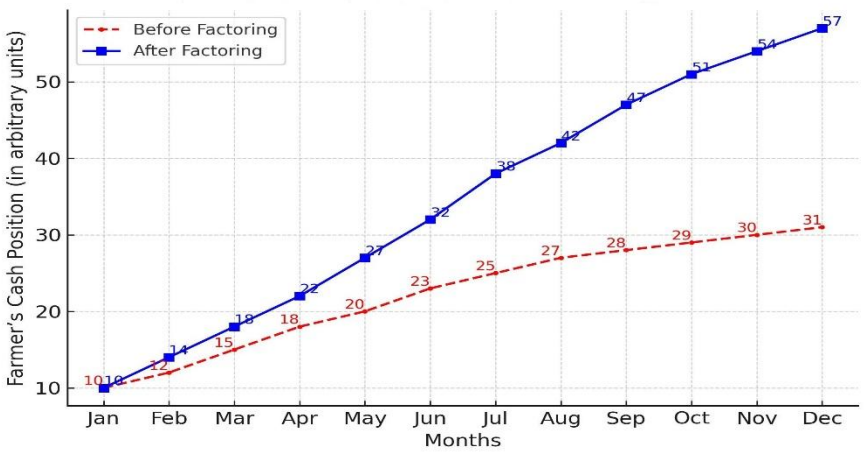

Figure 5. Trend of farmers' cash flow before and after the factoring scenario

The graph illustrates that the red dashed line (before factoring) shows a gradual but slower increase, while the solid blue line (after factoring) rises more rapidly and consistently. This improvement in liquidity enables farmers to manage their farming operations more optimally, enhance production continuity, and strengthen the efficiency of the red chili agribusiness supply chain. These findings are consistent with Permana (2017), who demonstrated that accelerated payments in partnership schemes improved farmers' cash flow and boosted farm productivity. Similarly, Hakim and Perdana (2017) found that faster payment mechanisms significantly reduced accounts receivable accumulation and enhanced the sustainability of horticultural production.

Furthermore, the implementation of the factoring scenario within the red chili agribusiness supply chain generates significant systemic impacts. Improved liquidity enables farmers to sustain their farming activities, enhance product quality, and meet market demand more consistently. This condition also contributes to stabilizing the red chili supply in the market, potentially reducing price fluctuations caused by imbalances between production and demand. Thus, factoring not only benefits farmers individually but also strengthens the overall resilience of the agribusiness sector. Therefore, policy support through clear regulations and the development of institutional infrastructure is required to ensure that this financing mechanism can be implemented widely, effectively, and sustainably in the agricultural sector.

CONCLUSION

The results of modeling and simulation indicate that the implementation of a factoring scenario in the red chili agribusiness in Aceh Tengah Regency can significantly improve farmers' liquidity. This mechanism accelerates payment receipts that were previously delayed for up to 30 days, thereby making farmers' working capital more fluid and stable. Improved liquidity positively impacts farmers' ability to meet production needs on time, ranging from the procurement of agricultural inputs and labor costs to crop maintenance according to standard operating procedures (SOP). In addition, factoring provides further benefits, such as improving sales and billing administration, reducing the risk of bad debt, and increasing business competitiveness without requiring collateral. Overall, this scheme contributes to the sustainability of red chili farming, ensuring continuity of supply with better quality and quantity, while strengthening the efficiency of the agribusiness supply chain. Therefore, factoring can be recommended as a potential alternative financing strategy to enhance farmers' economic resilience and support the sustainable development of red chili agribusiness in Aceh Province. The implication for policymakers is the necessity of regulatory support governing the transparency of factoring service fees, incentives to reduce the financial burden on smallholder farmers, and strengthening the role of cooperatives as intermediaries for factoring schemes, so that this mechanism can be implemented more broadly, fairly, and sustainably in the agricultural sector.

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