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Analysis of the agribusiness potential of natural dye plants in supporting the environmentally friendly ulos cloth industry in North Sumatra, Indonesia

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ABSTRACT

The aim of this study is to examine the potential of natural dye plant agribusiness in supporting the development of an environmentally friendly ulos cloth industry in Tarutung, North Sumatra. A quantitative approach was applied using Structural Equation Modeling (SEM) with data collected from 142 respondents, including natural dye plant farmers, ulos cloth craftsmen, and related business actors. The analyzed variables include Agribusiness Potential (AP), Availability of Raw Materials (RM), Institutional Support (IS), and Market Access (MA) as mediating variables influencing the development of the environmentally friendly ulos cloth industry (EF). Data were processed using LISREL software. The results show that the availability of raw materials, market access, and training have a significant effect on the potential of natural dye plant agribusiness. Furthermore, agribusiness potential is found to be a strong mediating factor in enhancing the development of the environmentally friendly ulos cloth industry. These findings emphasize the need to strengthen the upstream agribusiness sector through integrated policies, technology, and market strategies to support the sustainability of the traditional textile industry.

1. Introduction

Ulos cloth is a Batak cultural heritage that has high symbolic, aesthetic, and economic value. Ulos cloth production has so far relied on synthetic dyes that contain hazardous chemicals, have the potential to pollute the environment, and have a negative impact on the health of craftsmen and consumers (Hariati and Purwarno, 2024). In the context of sustainable development, the transformation of the traditional textile industry towards an environmentally friendly production system is a must. One approach that can be taken is to develop the use of natural dyes based on local plants (Hasibuan and Rochmat, 2021).

Natural dye plants such as indigofera (*Indigofera tinctoria*), sappan (*Caesalpinia sappan*), and turmeric (*Curcuma longa*) have great potential to replace synthetic dyes because they are biodegradable and have minimal environmental impact. The Tarutung area and its surroundings in North Sumatra have agro-climate potential that supports the cultivation of natural dye plants, but until now their utilization is still limited (Djarwaningsih, 2019). The development of natural dye plant agribusiness not only supports environmental conservation, but can also increase farmers' income and strengthen the value chain of the Ulos cloth industry.

However, the development of natural dye agribusiness is inseparable from various challenges, such as the availability of sustainable raw materials, market access, institutional support, and the skills of farmers and craftsmen in processing natural dyes. Therefore, a comprehensive analysis of the factors that influence the potential of natural dye plant agribusiness with the right approach is needed. In this study, the Structural Equation Modeling (SEM) approach is used as the main analytical tool to simultaneously and in-depth examine the relationship between various variables that influence the development of the natural dye plant business and its contribution to the environmentally friendly ulos cloth industry in Sumatra (Molenaar, 2019; Sitinjak and Malau, 2023).

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This study examines several important factors that play a role in supporting the development of an environmentally friendly Ulos cloth industry in Sumatra. The availability of raw materials for natural dye plants is a fundamental aspect that determines the continuity of sustainable production. In addition, institutional support through policies, mentoring, and strategic partnerships also influences the effectiveness of agribusiness management in this sector. Access to the market is also a crucial factor, because it determines the extent to which natural dye-based products can be accepted and compete in local and global markets (Jiniputri et al., 2021).

This research is important to answer the need for an environmentally based agribusiness model that is able to integrate the agricultural sector and local creative industries. The theory of competitive advantage developed by Porter (1990) explained that the success of an industry is largely determined by its ability to create added value through efficiency, innovation, and broad market access. In the context of natural dye plant agribusiness, competitive advantage can be achieved if farmers and business actors are able to access the market effectively, understand consumer needs, and adjust products to demand trends for environmentally friendly products. Therefore, adaptive marketing strategies and collaboration with textile industries such as Ulos cloth are key factors in creating sustainable competitive advantage in this sector.

The Ulos fabric industry in Tarutung plays an important role in preserving Batak cultural heritage as well as being a source of livelihood for the local community. However, the production process still largely relies on synthetic dyes that are not environmentally friendly and pose a risk to the health of craftsmen and the pollution of the surrounding environment. On the other hand, the Tarutung area has agricultural potential that allows for the cultivation of plants producing natural dyes. Unfortunately, this potential has not been optimally utilized, either in terms of cultivation, processing, or integration into the Ulos industry supply chain.

Problems arise when the availability of natural dye raw materials has not been guaranteed sustainably, farmers' and craftsmen's knowledge of natural dye processing techniques is still limited (Naibaho et al., 2024), and support from related institutions, including markets and training, has not been optimal. This has caused the natural dye agribusiness to not develop significantly and has not been able to support the Ulos cloth industry to be more environmentally friendly and competitive (Sugito et al., 2025).

With these conditions, this study attempts to answer the main problem regarding the extent to which the potential of natural dye plant agribusiness can be developed, as well as what factors influence its success in supporting the transformation of the environmentally friendly Ulos cloth industry in Tarutung. A quantitative approach through Structural Equation Modeling (SEM) is used to analyze the relationship between variables such as raw material availability, institutional support, market access, training, and agribusiness potential towards the development of the environmentally-based traditional textile industry.

In facing global environmental challenges and increasing consumer awareness of environmentally friendly products, traditional textile industries such as Ulos cloth need to adapt to more sustainable innovations. One strategic step is to replace hazardous synthetic dyes with natural dyes based on local plants. Tarutung, North Sumatra, has agricultural potential that supports the development of natural dye plants, but its utilization is still not optimal. This is thought to be caused by various factors such as inconsistent availability of raw materials, lack of institutional support, limited market access, and low intensity of training and technology transfer to farmers and craftsmen. Therefore, this study was conducted to identify and analyze various factors that influence the potential of natural dye plant agribusiness and its relationship to the development of an environmentally friendly Ulos cloth industry. This study uses a quantitative approach through the Structural Equation modeling (SEM) method to obtain a comprehensive understanding of the relationship between variables.

This study aims to analyze various factors that influence the development of natural dye plant agribusiness (PA) in North Sumatra and its contribution to the environmentally friendly Ulos cloth industry (EF). The main focus of the study includes the analysis of the influence of raw material availability (RM), institutional support (IS), market access (AP), and training and technology transfer (TT) on the potential for developing natural dye plant agribusiness. Furthermore, this study also examines the extent to which natural dye plant agribusiness plays a role in encouraging the growth of the environmentally friendly Ulos cloth industry in the region.

To empirically test the relationship between these variables, this study uses a quantitative approach with the Structural Equation Modeling (SEM) method. By using SEM, direct and indirect relationships between variables can be analyzed comprehensively and simultaneously. Based on the conceptual framework, the following hypotheses are formulated:

H1: The availability of raw materials has a positive and significant effect on the agribusiness potential of natural dye plants.

The availability of stable and sustainable raw materials is an important factor in building an agribusiness based on local commodities. Elsahida et al. (2020) explained that natural dye plants such as indigofera, secang, and turmeric have great potential to be cultivated in tropical areas, but their productivity is highly dependent on the sustainability of raw material supplies. Without adequate supplies, agribusiness actors have

difficulty maintaining production continuity and meeting industry demand (Naibaho et al., 2024).

H2: Institutional support has a positive and significant influence on the agribusiness potential of natural dye plants.

Musyoki et al. (2012) stated that government institutions, cooperatives, and non-governmental organizations have a strategic role in fostering farmers and business actors through regulation, mentoring, and providing facilities such as business credit and access to training. Strong institutional support will create a more dynamic and adaptive agribusiness ecosystem to market and technological changes.

H3: Market access has a positive and significant impact on the agribusiness potential of natural dye plants.

In the framework of competitive advantage theory, good access to the market is an important component in the success of the agribusiness value chain. When farmers or business actors have wide distribution channels and clear demand from industries such as textiles, the agribusiness they run tends to develop more (Mutambo et al., 2024). This also applies in the context of the Ulos cloth industry which requires a consistent supply of natural dye raw materials and high quality (Siregar et al., 2023).

H4: Training and technology transfer have a positive and significant impact on the agribusiness potential of natural dye plants.

According to Dissanayake et al. (2022), in their theory of innovation diffusion, the level of technology adoption in the agricultural sector is highly dependent on the availability of applicable and relevant training. Good training not only improves the technical skills of farmers and craftsmen in managing natural dye crops, but also helps them understand the quality standards required by the industry.

H5: The potential of natural dye plant agribusiness has a positive and significant impact on the development of the environmentally friendly Ulos cloth industry.

Naibaho (2019) emphasized that the strength of the upstream sector, such as local plant agribusiness, is the backbone in supporting the culture-based creative industry. When the potential of agribusiness is managed well, from cultivation to processing, then the downstream industry, such as Ulos cloth crafts, will benefit from a supply of sustainable, natural materials, in accordance with global market trends that lead to environmentally friendly products.

In SEM methodology, Hair et al. (2019) stated that mediating variables function to explain how and why the influence between independent and dependent variables occurs. In this context, the potential of natural dye plant agribusiness is believed to be an important bridge connecting external factors (such as raw materials, institutional support, and training) to the successful development of a more ecological Ulos cloth industry.

2. Research methods

This study employs an explanatory method and a quantitative approach to describe the causal relationship between variables that affect the potential of natural dye plant agriculture in promoting the growth of an eco-friendly Ulos textile industry. This approach was chosen in order to simultaneously and comprehensively examine the influence of independent variables such as the availability of raw materials, institutional support, market access, and training and technology transfer on mediating variables, namely agribusiness potential, which ultimately contributes to the development of the Ulos cloth industry. The relationship model between variables was analyzed using Structural Equation Modeling (SEM), which allows testing direct and indirect relationships statistically.

When testing the hypotheses in this study, we established several crucial assumptions. These are not mere technicalities, but rather key factors that ensure the validity and reliability of the results of our Structural Equation Modeling (SEM) analysis. Understanding and acknowledging these assumptions is vital for the integrity of our research. First, it is assumed that the relationships between latent variables and their indicators are linear and can be explained through the specified model. This means that any change in an independent variable is assumed to have a proportional effect on its dependent variable. Second, it is assumed that the data used follow a multivariate normal distribution. This assumption is crucial because the Maximum Likelihood (ML) estimation method applied in SEM requires normality to produce unbiased and efficient parameter estimates. Third, it is assumed that there is no high multicollinearity among independent variables. Low multicollinearity ensures that each independent variable contributes uniquely to explaining the dependent variable, thereby improving the accuracy of the estimated relationships. Fourth, the research model is assumed to be recursive, meaning that relationships among variables occur in one direction without any feedback loops. With this assumption, the hypothesized causal directions can be tested more clearly. In addition, it is assumed that the sample size is adequate to meet the requirements of SEM analysis, namely, at least 5–10 times the number of estimated parameters. An adequate sample size ensures the stability of parameter estimates and increases the statistical power in hypothesis testing. With these assumptions met, the results of hypothesis testing in this study can be interpreted validly and are scientifically defensible. It is now in

the hands of the researchers, students, and academics reading this to apply and uphold these assumptions in their own SEM analyses.

The population in this study was the actors involved in the natural dye agribusiness ecosystem and Ulos cloth production in the North Sumatra region, including farmers, craftsmen, and other supporting business actors. A total of 142 respondents were selected as samples using purposive sampling techniques, namely sampling techniques based on certain criteria. The selected respondents were those who had been active for at least one year in the cultivation or processing of natural dye plants or the Ulos industry, domiciled in areas in North Sumatra such as North Tapanuli Regency, Samosir Regency, and surrounding areas, and were willing to provide information according to research needs. Data collection was carried out through the distribution of structured questionnaires consisting of two parts, namely respondent identity and perceptions of research variables. The measurement scale used was a five-point Likert scale.

Data analysis was conducted with the help of LISREL software through the SEM approach. The analysis stages include model feasibility testing (Goodness of Fit), construct validity testing, and path analysis to see the direct and indirect effects between variables (Molenaar, 2019). Thus, the results of this study are expected to provide empirical contributions to strengthening the agribusiness sector and creative industries based on local culture in North Sumatra.

3. Results and discussion

In this study, the researcher utilized the purposive sampling method, a technique that selects participants based on their unique insights relevant to the research objectives. The samples were chosen from groups directly involved in the value chain of the natural dye plant agribusiness and the ulos cloth industry in the North Sumatra region. These groups, particularly those in areas known as ulos craftsmen centers like the North Tapanuli Regency, were selected for their potential to provide unique and intriguing perspectives.

Validity in this study shows the extent to which the indicators used can measure the intended construct or latent variable accurately. Based on the results of the analysis, all indicators have a loading factor value above 0.50, as shown in Table 1.

Table 1: Validity of indicators or latent variables

Indicator	Validity	Value
Y11	Good	0.72
Y12	Good	0.85
Y13	Good	0.67
Y14	Good	0.89
Y21	Good	0.75
Y22	Good	0.81
Y23	Good	0.63
Y24	Good	0.77
X11	Good	0.83
X12	Good	0.70,
X13	Good	0.66
X21	Good	0.90
X22	Good	0.79
X23	Good	0.87
X24	Good	0.68
X21	Good	0.74
X2	Good	0.82
X23	Good	0.88
X24	Good	0.71
X31	Good	0.70,
X32	Good	0.70
X33	Good	0.88
X34	Good	0.67
X41	Good	0.65
X42	Good	0.76
X43	Good	0.77
X44	Good	0.78

Based on the results of the measurement model analysis, all indicators used in this study have loading factor values above the minimum threshold of 0.50, indicating that the criteria for convergent validity have been met, as all constructs have AVE values higher than the threshold of 0.5, as proposed by Bagozzi et al. (1991), and indicates that each indicator is significantly able to reflect the construct or latent variable it signifies. Thus, it can be concluded that the instrument used has met the convergent validity criteria and is suitable for use in further structural model testing.

Construct reliability is evaluated using the Construct Reliability (CR) and Average Variance Extracted (AVE) values (Table 2). A construct is said to be reliable if the CR value is at least 0.70 and the AVE is at least 0.50. Thus, this reliability test is important to ensure that the variables in the model have high internal consistency and are suitable for use in testing the structural relationship between constructs.

Table 2: Construct reliability analysis

Variable	Convergent validity	Recommendation
Availability of raw materials (RM)	Good	Maintained
Institutional support (IS)	Good	Maintained
Market access (MA)	Good	Maintained
Training and technology transfer (TT)	Good	Maintained
Agribusiness potential (AP)	Good	Maintained
Environmentally friendly (EF)	Good	Maintained

Based on the results of the convergent validity analysis through the loading factor values on each indicator in the SEM measurement model, all variables in this study showed good results, with the majority of loading factor values above 0.50. The results of Cronbach's alpha also indicate good reliability, with values above 0.7. Several researchers argue that composite reliability (CR) is a better indicator for measuring internal consistency. The threshold for CR is 0.7, and all variables or

constructs in this study meet this threshold. which means that these indicators are able to represent their constructs adequately. Therefore, Agribusiness Potential (AP), Environmentally Friendly (EF), Availability of Raw Materials (RM), Institutional Support (IS), and Market Access (MA). Training and Technology Transfer (TT) can be retained in the model for further analysis, as it meets the requirements of good convergent validity. Based on the results of the Structural Equation Modeling (SEM) analysis shown in Fig. 1, a number of important findings were obtained regarding the relationship between various variables that influence the development of the environmentally friendly Ulos cloth industry through the potential of natural dye plant agribusiness in Tarutung.

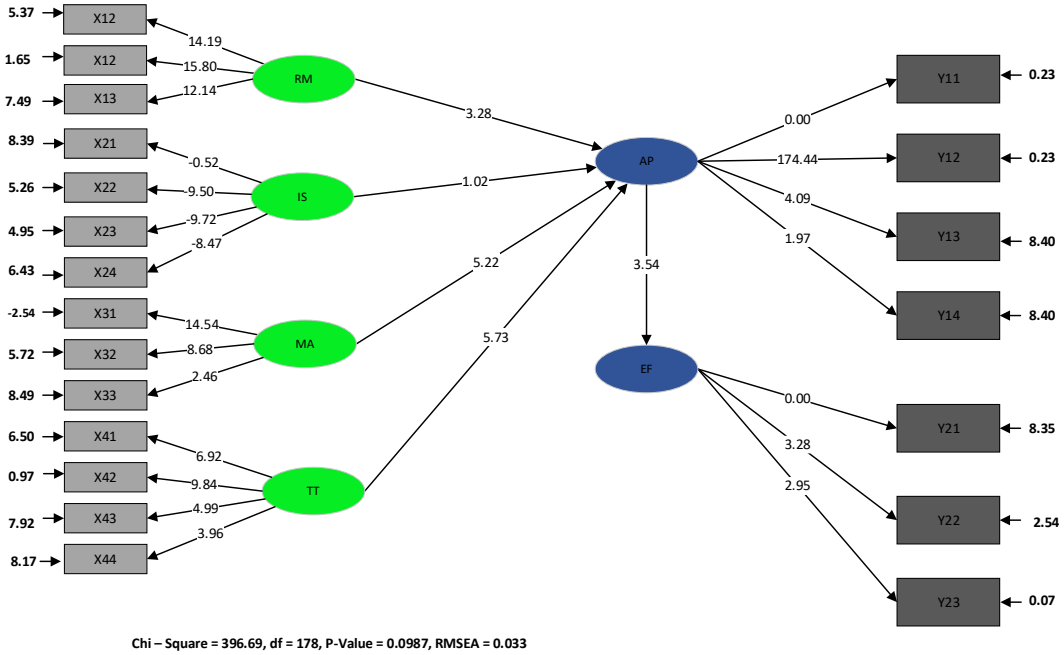

Fig. 1: Structural equation model results with t-values

The model used shows good feasibility with a Chi-Square value of 396.69 and a p-value of 0.0987 (>0.05), and an RMSEA value of 0.033, which is below the threshold of 0.08, indicating that the overall model has adequate goodness of fit. This means that the relationship between the variables in the model is statistically acceptable and valid for use in drawing conclusions. The results of data processing using Structural Equation Modeling (SEM) with LISREL software show that the research model has good feasibility. Goodness of Fit values such as Chi-square, RMSEA, CFI, and TLI are within acceptable limits, indicating that the model is significantly able to explain the relationship between the variables analyzed. The results of the path analysis show that:

1. The availability of raw materials (RM) has a significant positive effect on agribusiness potential (AP) with a coefficient value of 3.28. This indicates that the availability of adequate raw materials is an important factor in increasing agribusiness potential in the Ulos cloth industry sector.
2. Institutional support (IS) shows a negative and insignificant influence on (AP) (coefficient = –1.03), which indicates that the role of supporting institutions or institutions is currently not optimal in supporting the development of agribusiness potential.
3. Market access (MA) has a significant positive influence on agribusiness potential (AP) (coefficient = 5.22). This means that the more open and broader the market access is, the greater the agribusiness potential that can be developed.
4. Training and technology transfer (TT) also has a significant positive effect on agribusiness potential (AP) with a coefficient = 5.73, which shows that increasing human resource capacity through training and technology transfer greatly contributes to strengthening agribusiness potential.

Furthermore, the potential of agribusiness (AP) has a significant positive influence on the development of the environmentally friendly Ulos cloth industry (EF), with a coefficient value of 2.94. This shows that the potential of agribusiness acts as a strong mediating variable in the relationship between external factors and industrial development.

4. Discussion

In addition to being a key factor in agribusiness sustainability, the availability of local raw materials such as *Indigofera tinctoria* L. also plays an important role in supporting the environmentally friendly ulos industry in North Sumatra, Indonesia. The natural dyes derived from this plant not only reduce dependence on synthetic dyes that have the potential to pollute the environment but also add value to ulos products through their unique, vibrant

colors and production processes deeply rooted in local wisdom. This is in line with the global trend toward a green economy and sustainable fashion, in which consumers are increasingly intrigued by the unique aspects of the values above textile products they use (Chen et al., 2015; Merli et al., 2019). The results of the analysis show that the availability of raw materials (RM) has a positive and significant influence on the potential of natural dye plant agribusiness. This emphasizes that the abundance of local raw materials such as *Indigofera tinctoria* L. leaves, roots, and bark in the Tarutung area is a fundamental factor in supporting the sustainability of natural dye agribusiness. This finding is consistent with the study of Djarwaningsih (2019), which identified the potential of natural dye plants in the Lake Toba area as an important asset that has not been optimally developed. The use of salaon leaves (Indigofera) as a natural dye for ulos is a form of cultural preservation that also increases local economic value. This reinforces the idea that the availability of local raw materials is the basis for the development of sustainable supply chains (Kaplinsky and Morris, 2000). By optimizing the use of local resources, communities in Tarutung and its surroundings can create a more efficient supply chain, reduce raw material transportation costs, and significantly strengthen the regional economy. Furthermore, the sustainable management of raw material sources such as *Indigofera* can serve as a model for integrating environmental conservation, cultural preservation, and community economic empowerment. Based on these results, the Indonesian government can support the development of the natural dye plant agribusiness ecosystem by facilitating research and development (R&D) to enhance the productivity of natural dye plants, offering incentives to entrepreneurs who adopt environmentally friendly practices, and assisting Ulos SMEs in expanding their market access both nationally and internationally.

However, institutional support (IS) did not show a significant influence. Although there are various institutions, such as cooperatives, agricultural services, and NGOs, their contributions have not been able to mobilize business actors effectively. This shows a gap between the existence of institutions and the effectiveness of their empowerment programs. In contrast to the findings of Prajapati et al. (2025), who emphasized the importance of institutions in strengthening the position of farmers, this condition reflects the weak integration of institutions with real needs in the field. Pardosi et al. (2024) stated that the weakness of institutional networks is an obstacle to making ulos a leading product of Lake Toba tourism. The pressing issue of weak institutional support is a significant barrier to fully harnessing the agribusiness potential of natural dye plants. This support is crucial for the environmentally friendly ulos industry in North Sumatra. Institutions play a vital role in coordinating supply chains, providing capital access, offering training, and expanding marketing networks. They should effectively bridge the gap between business actors, farmers, the government, and the market. Revitalizing institutional functions is a pressing need. Breakthrough efforts are required to restore their essential role and fully utilize local raw materials such as *Indigofera tinctoria* L. This is crucial to enhance the ulos industry's competitiveness in both domestic and international markets. The government can provide support through regulations, incentives, and policies that encourage collaboration between cooperatives, technical agencies, universities, and market actors. This will further strengthen the position of ulos as a leading environmentally friendly product with high economic value.

Market access improvement not only impacts the expansion of product distribution but also directly contributes to the sustainability of the natural dye plant agribusiness supply chain. With increasingly open markets, farmers and entrepreneurs are encouraged to improve the quality and continuity of raw material supply, such as *Indigofera tinctoria L.*, *Morinda citrifolia*, and *Curcuma longa*. Furthermore, market access (MA) has been proven to have a positive and significant influence on the potential of natural dye plant agribusiness. Open distribution channels, demand for environmentally friendly products, and partnerships with textile industry players expand marketing opportunities. This is in line with Porter's (1990) view that access to the market is the main determinant in shaping business competitiveness. A study by Khairani et al. (2023) also showed that strengthening marketing strategies is one of the effective solutions in increasing market penetration of Ulos MSMEs. This support is also strengthened by the digital marketing strategy implemented in several ulos centers, such as in Pematang Siantar (Siregar et al., 2023), which expands consumer reach to the national and global levels. In addition, the global trend toward environmentally friendly products should encourage Ulos MSMEs using natural dyes to enter the international market segment. Strengthening branding that emphasizes tradition, authenticity, and sustainability is key to winning the competition.

Capacity building through training and technology transfer not only enhances technical skills but also empowers farmers and craftsmen to grow and innovate (Sari et al., 2025). The role of technology transfer in this process is crucial, as it introduces modern tools and methods to traditional practices. With improved mastery of natural dyeing technology, they can diversify their products, create new combinations of motifs and colors, and improve the consistency of the quality of their products. Training and Technology Transfer (TT) were also found to have a positive and significant effect. The existence of training and technology transfer has been proven to increase the capacity of farmers and craftsmen in processing natural dye plants into value-added products. Dissanayake et al. (2022) emphasized the importance of technology adoption

in the agricultural sector through participatory involvement of local actors. In the weaving sector, Jiniputri et al. (2021) showed that technology transfer in natural dyeing helps to preserve ulos motif designs and increase production efficiency. There needs to be collaboration between Ulos MSMEs and universities, as well as relevant institutions, to ensure that technological innovation continues to develop through the transfer of knowledge and technology. This will enable the natural dye–based Ulos industry to compete sustainably in both domestic and international markets.

Local wisdom in the use of natural dye plants plays a vital role in supporting the sustainability of the ulos industry. Since ancient times, the Batak indigenous people—recognized as the producers of ulos in Indonesia—have been familiar with various plant species such as *tingi*, *jengkol*, *tarum*, and *jabi-jabi* bark, which are used to produce the distinctive colors of ulos cloth. This knowledge has been passed down through generations, encompassing not only dyeing techniques but also environmentally friendly methods of harvesting raw materials. The natural dyeing process rooted in local wisdom gives ulos a unique and exclusive identity, both in terms of its colors, motifs, and the underlying philosophy. The colors produced carry deep symbolic meanings related to life, blessings, and the social bonds of the Batak community. These cultural values distinguish ulos in global markets and serve as an attraction for consumers who prioritize sustainable products with high cultural value (Sugito et al., 2025). Finally, the results of the study indicate that the potential for natural dye plant agribusiness (EF) has a significant effect on the development of the environmentally friendly ulos cloth industry (AP). This indicates that the greater the potential for agribusiness, the higher the opportunity for developing an environmentally friendly local textile industry. This concept is in line with the Sustainable Value Chain approach from Kaplinsky and Morris (2000), which emphasized the importance of connectivity between the upstream (agriculture) and downstream (creative industry) sectors. Sugito et al. (2025) confirmed that the development of a creative economy based on ulos can be improved through a green digital marketing approach and local wisdom. This is also supported by the findings of Naibaho et al. (2024) which showed that the Holistic Value Chain model in the ulos creative industry is a strategic approach to strengthening competitiveness and maintaining cultural and environmental sustainability. Thus, the results of this study not only show crucial factors in the development of natural dye plant agribusiness, but also emphasize the importance of synergy between local resources, technology training, market access, and the sustainability of cultural values in supporting traditional textile industries such as ulos.

Based on the Competitive Advantage Theory proposed by Porter (1990), the competitiveness of a sector is largely determined by its ability to create added value through market access, production efficiency, and innovation. In the context of this study, the results of the analysis show that the market access variable has a positive and significant influence on the potential of natural dye plant agribusiness, which indicates that the more open and wider the distribution channels and market demand for environmentally friendly products, the greater the opportunity for agribusiness to develop and compete. The availability of local raw materials also strengthens the efficiency of production costs, which is one of the bases of competitive advantage, although institutional support has not shown a significant role in this study. Overall, the potential of natural dye plant agribusiness is a key element in creating a competitive advantage that encourages the development of a sustainable, environmentally friendly Ulos cloth industry in North Sumatra.

5. Conclusion

Based on the research results, it can be concluded that the potential of natural dye plant agribusiness in Tarutung is significantly influenced by the availability of raw materials, market access, and training and technology transfer. These three factors play an important role in strengthening the competitiveness and sustainability of the agribusiness sector, especially in the context of utilizing natural dyes to support a more environmentally friendly ulos cloth industry. The existence of abundant local raw materials such as *Indigofera tinctoria*, open distribution channels, and training relevant to technical needs has been shown to positively encourage agribusiness development. On the other hand, institutional support did not show a significant influence, indicating the need to optimize the role of supporting institutions in empowering local farmers and business actors. Furthermore, the potential of natural dye plant agribusiness has been shown to provide a real contribution to the development of the ulos cloth industry that prioritizes the principles of sustainability and cultural preservation. The integration of upstream and downstream sectors through a locally-based agribusiness approach not only supports the preservation of local Batak wisdom but also opens up opportunities to increase the added value of the community's economy. Thus, a natural dye-based development strategy can be an important foundation in strengthening the regional creative economy and supporting environmental and cultural preservation efforts simultaneously.

6. Recommendation

Based on the findings and discussions in this study, here are three suggestions that can be given:

1. There needs to be a strengthening of the role of institutions such as cooperatives, agricultural services, and NGOs to be more active and effective in providing assistance, facilitating access to capital, and ongoing coaching to natural dye plant

agribusiness actors. Strong institutions will strengthen the position of farmers and craftsmen in the overall agribusiness value chain.

2. Regional governments and related agencies are expected to encourage technological innovation and expand training for farmers and ulos cloth industry actors, both in the cultivation of natural dye plants and their processing. This technology transfer will increase production efficiency and the quality of the products produced.
3. An integrated marketing strategy is needed that can open wider market access, including through digital marketing and cultural tourism-based promotions. This will increase the selling value of environmentally friendly ulos cloth while strengthening local cultural identity on a national and international scale.

List of abbreviations

AP	Agribusiness potential
AVE	Average variance extracted
CFI	Comparative fit index
CR	Construct reliability
EF	Environmentally friendly Ulos cloth industry
GOF	Goodness of fit
IS	Institutional support
LISREL	Linear structural relations software
MA	Market access
ML	Maximum likelihood
MSMEs	Micro, small, and medium enterprises
NGOs	Non-governmental organizations
PLS-SEM	Partial least squares structural equation modeling
R&D	Research and development
RM	Availability of raw materials
RMSEA	Root mean square error of approximation
SEM	Structural equation modeling
SMEs	Small and medium enterprises
TLI	Tucker–Lewis index
TT	Training and technology transfer

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Compliance with ethical standards

Ethical considerations

This study involved human participants through the distribution of structured questionnaires to farmers, craftsmen, and business actors engaged in the natural dye plant agribusiness and the ulos cloth industry. Ethical considerations were strictly observed to ensure that the research adhered to the principles of integrity, respect, and confidentiality. Prior to data collection, all participants were informed about the purpose of the study, the voluntary nature of their participation, and their right to withdraw at any stage without any consequences. Informed consent was obtained from all respondents before completing the questionnaire.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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