Vol. 15, No. 2 (2026): 534 - 542

http://dx.doi.org/10.23960/jtepl.v15i2.534-542

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)

Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Sustainability Analysis of Hybrid Maize Farming in Grogol District, Kediri Regency

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Article History:

Received : 25 March 2025
Revised : 15 April 2025
Accepted : 29 July 2025

Keywords:

Hybrid maize farming, Multidimensional scaling, Sustainable agriculture.

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ABSTRACT

This study aims to evaluate the sustainability of hybrid maize farming in Grogol District, Kediri Regency, by considering economic, ecological, and social aspects that influence farmers' welfare and the resilience of the agricultural system. The research employed observation, structured interviews, and questionnaire distribution, with data analyzed using the Multidimensional Scaling (MDS) method. Instrument reliability was tested through validity and reliability assessments. The findings show that the sustainability status of hybrid maize farming in the study area falls into the less sustainable category, with index scores of 44.11 for the ecological dimension, 49.15 for the economic dimension, and 46.19 for the social dimension. Leverage analysis identified that pest and disease control, market access expansion, and transportation infrastructure were the most sensitive attributes influencing each respective dimension. Moreover, Monte Carlo analysis revealed stress values below 0.5, indicating the accuracy and stability of the MDS results. These findings highlight that improvements in those key attributes are crucial for enhancing sustainability. Therefore, integrated strategies involving extension services, market development, and infrastructure improvement are essential to significantly improve the overall sustainability of hybrid maize farming in the region.

1. INTRODUCTION

Corn (*Zea mays* L.) is the world's leading cereal crop in terms of production volume and global significance. Its strategic role in supporting food security is expected to intensify, with projections indicating that maize production must increase by approximately 50% by 2050 to meet the growing demands of the global population while mitigating environmental degradation (Qu, 2024). In Indonesia, corn serves as a vital agricultural commodity that contributes not only to national food resilience but also to the socio-economic well-being of farming communities. Among the major corn-producing regions, Kediri Regency particularly Grogol District stands out for its reliance on hybrid maize cultivation. This type of maize is widely adopted due to its high yield potential and importance as both food and animal feed. It plays a crucial role in enhancing farmer income and bolstering local food supply chains, while simultaneously supporting the livestock sector through feed production.

Currently, there is a trend towards increasing use of high-yielding corn seeds and hybrid seeds (Behera *et al*., 2017). Hybrid maize varieties have significantly increased agricultural productivity. However, their extended growing periods expose them to higher risks from biotic (pests and diseases) and abiotic (climate, soil) stresses, thus creating sustainability challenges. This is in line with Paulino-Flores *et al*. (2017) who concluded that hybrid corn production systems in Mexico scored higher sustainability on the economic and social dimensions than native corn; although hybrid corn scored lower on ecological dimensions than native corn. Nugaraha *et al*. (2024) emphasizes the need for integrated and holistic strategies to improve sustainable corn production. Understanding the sustainability of hybrid maize farming requires a comprehensive evaluation of its dimensions. The sustainability of corn farming is crucial in supporting food security (Yusuf *et al*., 2025). In this context, Sustainability is evaluated from economic, ecological, and social dimensions (Moldan *et al*., 2012). This study aims to analyze the sustainability index and status of hybrid maize farming by applying a multidimensional approach. The economic dimension includes income levels, production costs, and market access; the ecological dimension examines soil health, input usage, and biodiversity; while the social dimension evaluates education, participation, and welfare. Understanding these interrelated aspects is essential for designing strategies that support long-term agricultural sustainability and rural development (Saragih, 2020; Streimikiene *et al*., 2021).

2. METHODS

The research on the sustainability of hybrid corn farming was conducted from January to March 2023 in Grogol District, Kediri Regency, specifically in Kalipang Village and Grogol Village. These villages were selected because they had the highest productivity and the largest land area for hybrid corn cultivation in the district. Data collection was carried out through several methods, namely observation, structured interviews, and questionnaire distribution. The structured interviews were designed to define clear boundaries for the questions used to explore relevant data. The interview guidelines consisted of several subsections formulated based on research variables (Hakim, 2014; Hartono, 2018). The questionnaire employed a Likert scale to measure the respondents' agreement levels, with scores ranging from 5 (strongly agree) to 1 (strongly disagree), including 4 (agree), 3 (neutral), and 2 (disagree) (Sugiyono, 2019). After data collection, the questionnaire was tested for both validity and reliability to ensure that the instrument accurately measured the intended constructs and produced consistent results.

Table 1. Dimensions and indicators of agricultural sustainability

Ecological Dimensions	
1.	Suitability of agricultural land
2.	Intensity of agricultural land conversion
3.	Productivity of hybrid corn commodities
4.	Agricultural land conservation measures
5.	Decrease in soil quality in agricultural land
6.	Control of plant pests and diseases
7.	Type of fertilizer used
8.	Intensity of pesticide use
Economic Dimensions	
1.	Price of input materials
2.	Place to sell harvested produce
3.	Pricing of Hybrid Corn Commodities
4.	Hybrid Corn Commodity Price Stability
5.	Marketing area
6.	Farming profits
7.	Contribution of Hybrid Corn to GRDP
8.	Supporting facilities for running a hybrid corn farming business
Social Dimension	
1.	Intensity of agricultural extension
2.	Labor absorption rate
3.	Knowledge about sustainable Hybrid Corn farming
4.	Adequate transportation facilities and infrastructure
5.	The existence of hybrid corn farmers
6.	The Influence of Hybrid Corn on the Social and Cultural Values of Society
7.	Farmers' last formal education level
8.	Farmers' perceptions of sustainable hybrid corn commodities

Dimensions and indicators of sustainability of hybrid corn farming in Grogol District, Kediri Regency are determined and assessed based on free attributes (open attributes), namely each independent expert is free to provide an assessment, which is then reviewed and determined by researchers based on benchmarks (Pitcher & Preikshot, 2001). According to the attribute assessment guidelines, each indicator within the ecological, economic, and social dimensions was assigned an ordinal score ranging from 1 to 4, where a score of 1 indicated poor conditions and a score of 4 indicated very good conditions (Shaadikin *et al*., 2025; Dewi *et al*., 2025). However, in the results section, some values appear to exceed this range for instance, the "marketing area" attribute in the economic dimension shows a value of 5.06. It is important to clarify that this figure does not represent a direct respondent score but rather the Root Mean Square (RMS) value obtained from the leverage analysis using the Multidimensional Scaling (MDS) method. The RMS reflects the sensitivity or the degree of change in the sustainability index if a particular attribute is removed from the model. Therefore, these values are not limited to the original 1–4 scale. The figure of 5.06, for example, indicates that the "marketing area" attribute had a strong influence on the economic sustainability index. Thus, there is no inconsistency in the scoring system; the difference lies in the interpretation between the initial ordinal scores and the statistical RMS values used in the advanced analysis phase.

The research method was designed to identify key components by analyzing both qualitative and quantitative data as evidence to support the study's objectives. The data were processed using Multidimensional Scaling (MDS), a multivariate statistical technique used to assess sustainability status across multiple dimensions. MDS was applied to evaluate the sustainability index of hybrid corn farming based on three main dimensions: ecological, economic, and social. The sustainability index values ranged from 0% to 100%, which were then classified into four categories following the original classification proposed by Kavanagh & Pitcher (2004). The index ranges were as follows: 0.00–

Table 2. Sustainability index values based on RAPFISH analysis

Index Value (%)	**Category**	**Mark**
0.00% to 25.00%	Poor	Unsustainable
25.01% to 50.00%	Insufficient	Less sustainable
50.01% to 75.00%	Adequate	Moderately sustainable
75.01% to 100.00%	Good	Highly sustainable

Table 3. Validity test

Variable	**Items**	**R-count**	**R-table**	**Information**
X1 Ecology	X1.1	0.657	0.2006	Valid
	X1.2	0.672	0.2006	Valid
	X1.3	0.719	0.2006	Valid
	X1.4	0.743	0.2006	Valid
	X1.5	0.684	0.2006	Valid
	X1.6	0.603	0.2006	Valid
	X1.7	0.751	0.2006	Valid
	X1.8	0.712	0.2006	Valid
X2 Economy	X2.1	0.538	0.2006	Valid
	X2.2	0.362	0.2006	Valid
	X2.3	0.554	0.2006	Valid
	X2.4	0.692	0.2006	Valid
	X2.5	0.380	0.2006	Valid
	X2.6	0.631	0.2006	Valid
	X2.7	0.564	0.2006	Valid
	X2.8	0.698	0.2006	Valid
X3 Social	X3.1	0.669	0.2006	Valid
	X3.2	0.395	0.2006	Valid
	X3.3	0.813	0.2006	Valid
	X3.4	0.788	0.2006	Valid
	X3.5	0.498	0.2006	Valid
	X3.6	0.663	0.2006	Valid
	X3.7	0.554	0.2006	Valid
	X3.8	0.394	0.2006	Valid

25.00 (unsustainable), 25.01–50.00 (less sustainable), 50.01–75.00 (moderately sustainable), and 75.01–100.00 (highly sustainable). These classifications provided a framework for interpreting the composite sustainability scores derived from the attribute-based analysis in each dimension.

3. RESULTS AND DISCUSSION

3.1. Validity and Reliability of Questionnaire

The collected questionnaires were subjected to validity and reliability testing. Validity serves as a fundamental requirement to assess the accuracy of research variables, indicating how well an instrument measures the intended constructs (Triana & Widyarto, 2013). Meanwhile, reliability testing was performed to evaluate the consistency of the quantitative questionnaire. An instrument is considered reliable if it produces stable and consistent results across repeated measurements, even when conducted at different times. The results of this validity test analysis provide a strong basis for interpreting research data and ensure that the findings obtained are reliable and relevant in the context being studied. In the study, the results of the validity test calculations from the three dimensions, namely the ecological, economic, and social dimensions, have valid results as shown in Table 3:

Table 4. Reliability test

Variable	Cronbach's alpha	Information
X1 Ecology	0.749	Reliable
X2 Economy	0.649	Reliable
X3 Social	0.749	Reliable

Reliability tests using SPSS show that the Cronbach's Alpha value for each dimension (ecology, economy, and social) is more than 0.5, so it can be said that all dimensions are reliable and can be used in sustainability status tests. Cronbach's Alpha values less than 0.5 are generally unacceptable (Arulogun *et al*., 2020). The results of this reliability test provide an overview of the reliability of the instruments used in collecting data, as well as ensuring that the results obtained from the questionnaire can be trusted for further analysis.

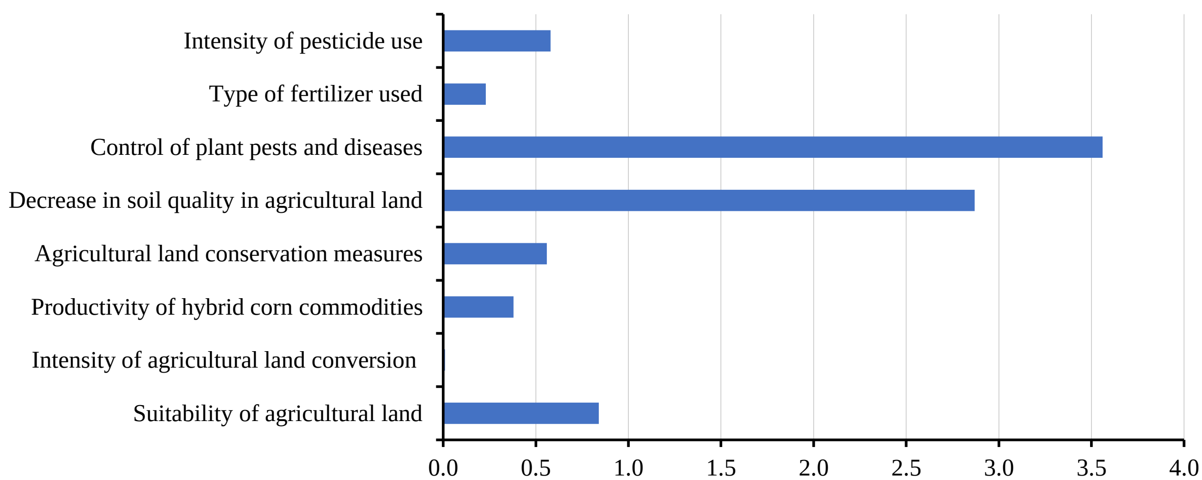

Figure 1. Results of the analysis of leverage for ecological dimension attributes

3.2. Sustainable Agriculture Sustainability Index

3.2.1. Ecological Dimensions

The results of the ecological dimension leverage analysis (Figure 1) show that of the 8 attributes analyzed, there are two attributes that are sensitive in influencing sustainable farming of hybrid corn farming in Grogol District, Kediri

Regency. The ecological dimension of the sustainability of hybrid corn farming in Grogol District is represented by several attributes or factors that support the ecological sustainability of hybrid corn farming in Grogol District, and statistically these attributes are easy to assess. Attributes that are sensitive in influencing the ecological dimension sustainability index are subjected to Leverage analysis. Mahida (2020) stated that the sensitive attributes in the Leverage analysis have the highest Root Mean Square (RMS) value.

3.2.2. Economic Dimensions

Leverage analysis of the economic dimension attributes is used to determine the sensitivity of each attribute to the sustainability index value of the economic dimension of hybrid corn farming. Leverage analysis conducted on the eight economic dimension attributes shows that the marketing area attribute (5.06) is the attribute in the economic dimension with the highest level of sensitivity (Figure 2). Meanwhile, the attribute that obtained the lowest sensitivity value was supporting facilities for running a hybrid corn farming business (0.08). As comparison, Ridwan *et al*. (2025), reported recently that corn price is economic attribute with the highest leverage value of 7.30, which indicated that stability of corn prices greatly affect the economic sustainability of farmers.

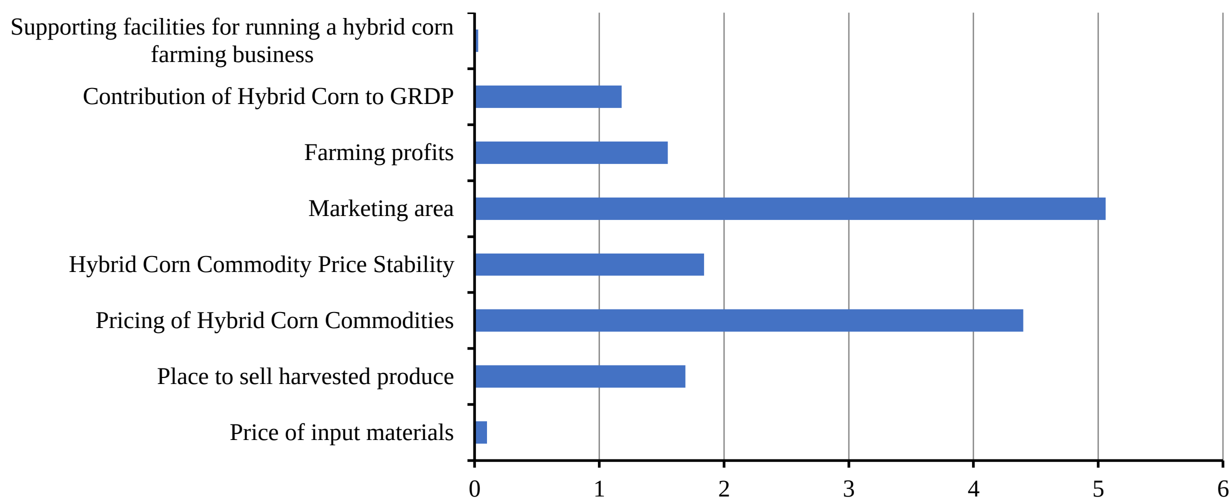

Figure 2. Analysis results of leverage for economic dimension attributes

In the methodology section, it was stated that each sustainability attribute—across ecological, economic, and social dimensions—was scored on an ordinal scale ranging from 1 to 4, where 1 indicates a poor condition and 4 indicates a very good condition. This scale was applied during the initial data collection phase based on farmer perceptions using structured questionnaires. However, the values shown on the X-axis in Figure 2, such as 5.06 for the "marketing area" attribute and values less than 1 for other attributes, are not these original scores. Instead, they represent sensitivity values derived from leverage analysis using the Multidimensional Scaling (MDS) technique.

The X-axis in Figure 2 reflects the Root Mean Square (RMS) value, which quantifies how much the sustainability index would change if a specific attribute were removed from the analysis. Because RMS is a statistical measure of influence or sensitivity not a respondent score it is not constrained to the original 1–4 range. Therefore, sensitivity values can exceed 4 or fall below 1, depending on the extent to which an attribute contributes to the variability of the sustainability index. For instance, a value of 5.06 for "marketing area" indicates a high impact on the economic dimension's index, while a value less than 1 reflects relatively minimal influence. This distinction should be clearly noted to avoid misinterpretation between ordinal scores and leverage-based sensitivity values.

3.2.3. Social Dimension

The results of the MDS analysis indicate that the social dimension falls into a less sustainable category, with a sustainability index value of 40.00. This index is influenced by eight key attributes. A leverage analysis was carried out to determine which attributes are most sensitive in affecting the sustainability index of the social dimension. The selected attributes are those with the highest Root Mean Square (RMS) values. Greater changes in RMS leverage values reflect a higher level of sensitivity of an attribute in contributing to improvements in the sustainability score. The results of the leverage analysis of the attributes in the social dimension can be seen in Figure 3.

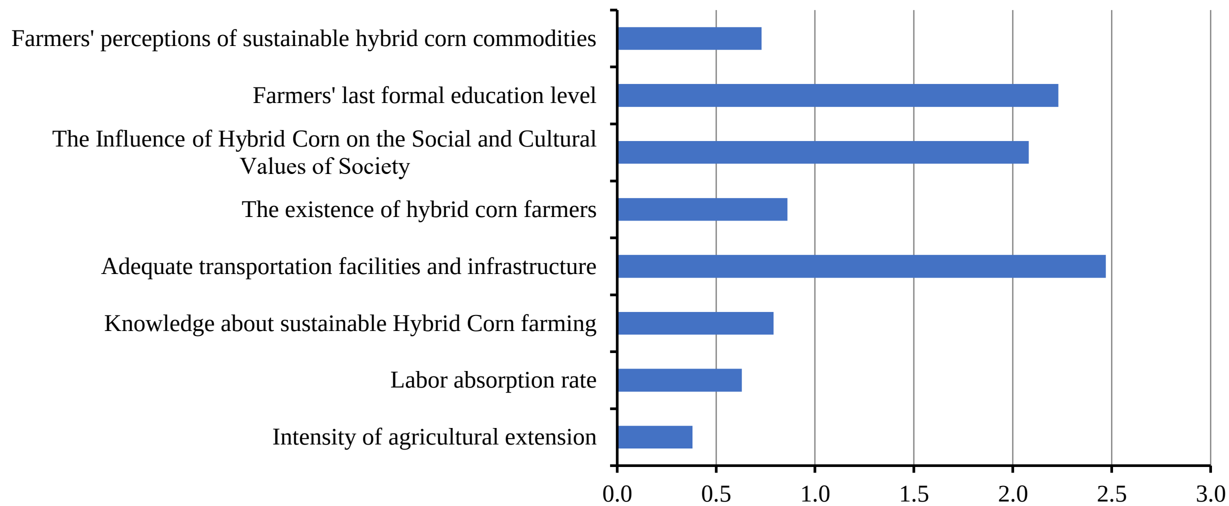

Figure 3. Results of leverage analysis for social dimension attributes

In the methods section, it was clearly stated that each sustainability attribute was assessed using an ordinal scale ranging from 1 (poor) to 4 (very good), based on respondents' perceptions during the data collection process. This fixed scoring system was used for all dimensions, including the social dimension. However, the values shown on the X-axis in Figure 3 such as the sensitivity value of 2.47 for the "transportation facilities and infrastructure" attribute—do not represent the original ordinal scores. Instead, they are the Root Mean Square (RMS) values resulting from the leverage analysis conducted through the Multidimensional Scaling (MDS) technique.

The X-axis in Figure 3 illustrates the sensitivity level of each attribute, i.e., how much the sustainability index would change if a particular attribute were excluded from the model. These RMS-based sensitivity values are not bound to the 1–4 scale used in the initial attribute scoring; they are statistical values that can be greater than 4 or less than 1 depending on the magnitude of influence each attribute has on the index calculation. Thus, a value of 2.47 does not indicate that the attribute was scored above the ordinal limit, but rather reflects the extent of its contribution to the variability in the social sustainability index. This clarification is essential to avoid confusion between perceived attribute scores and analytical sensitivity values.

3.3. Sustainability Status of Hybrid Corn Farming

The sustainability position of hybrid corn farming in Grogol District, Kediri Regency can be seen based on the results of the three-dimensional analysis that has been used. The results of the analysis show that all dimensions studied, namely the dimensions of ecology, economy, socio-institutions and technology have fairly accurate and accountable results. The sustainability status position of hybrid corn farming in Grogol District, Kediri Regency can be seen in Figure 4. Based on the above flyover diagram, it can be seen that the three-dimensional sustainability index value used to determine the sustainability status of hybrid corn farming in Grogol District, Kediri Regency. Overall, it can be seen that all dimension values are below 50%, so the dimensions of the system being assessed can be categorized as less sustainable with values in the ecological dimension (44.11), economic dimension (49.15) and social dimension (46.19). This value differs slightly from the results of the Anwar & Galib (2022), who reported a sustainability value of corn in Herlang District, Bulukumba Regency with score of 61.1% for the ecological dimension, 53.73% for the social dimension, and 40.15% for the economic dimension. Meanwhile, Barokah *et al*. (2019) reported a total index of

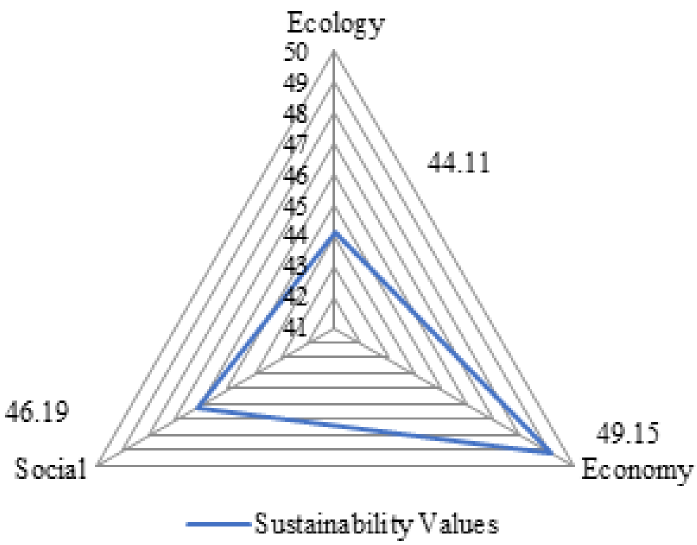

Figure 4. Flyover diagram for hybrid corn sustainability in Grogol District, Kediri Regency

Table 5. Monte carlo analysis results and multidimensional stress values

No.	Dimensions	Sustainability Values	Monte Carlo Values	Stress <5
1.	Ecology	44.11	43.756	0.354
2.	Economy	49.15	48.7445	0.40
3.	Social	46.19	46.0141	0.18

51.15% (moderately sustainable) for maize cultivation in Grobogan Regency. Thus, the previous discussion can be seen that the fourth hypothesis regarding hybrid corn farming in Grogol District, Kediri Regency is accepted because hybrid corn farming in Grogol District, Kediri Regency is in a less sustainable status.

The results obtained from the Rap-MDS analysis required further evaluation to assess the potential influence of random errors. For this purpose, Monte Carlo analysis was conducted. This statistical method was used to validate the robustness of the Multidimensional Scaling (MDS) results by simulating repeated computations under randomized input conditions. The Monte Carlo simulation aimed to detect the impact of potential scoring errors, variations in respondent judgements, instability in the MDS algorithm, and possible data entry mistakes or missing values. By comparing the sustainability index values produced by the Monte Carlo simulation with the original MDS outputs, the analysis assessed the consistency and reliability of the model. A small difference between the two values and a stress value of less than 0.5 indicate that the model is stable and the results are statistically reliable. The outcomes of the Monte Carlo analysis for each sustainability dimension are presented in the following table.

4. CONCLUSION

The sustainability status of hybrid corn farming in Grogol District, Kediri Regency was found to be less sustainable across all three assessed dimensions. The ecological, economic, and social indices scored below 50%, indicating that the current farming practices are not yet optimal in ensuring long-term agricultural, economic, and community resilience. The most critical factors affecting sustainability were pest and disease control (ecological), market access (economic), and transportation infrastructure (social). To address these challenges, several strategic steps should be prioritized. Improvements in pest and disease management are essential to safeguard crop productivity and ecological balance. Expanding marketing areas can enhance income stability and reduce economic vulnerability for farmers. Furthermore, strengthening transportation infrastructure will improve access to markets and agricultural services, thereby supporting the social and economic dimensions of sustainability. These measures, supported by agricultural extension services and local government collaboration, can significantly improve the overall sustainability of hybrid corn farming in the region. Given the findings, future research should explore the role of institutional support, such as farmer cooperatives, supply chain integration, and access to financing, which were not extensively examined in this study. Investigating these institutional and governance factors may provide deeper insights and practical policy recommendations to strengthen the long-term sustainability of hybrid corn farming systems.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
TS	✓	✓			✓	✓		✓	✓	✓				
RP	✓									✓		✓		
FM	✓									✓		✓		
DRA										✓				
BS										✓				

C: Conceptualization	Fo: Formal Analysis	O: Writing - Original Draft	Fu: Funding Acquisition
M: Methodology	I: Investigation	E: Writing - Review & Editing	P: Project Administration
So: Software	D: Data Curation	Vi: Visualization	
Va: Validation	R: Resources	Su: Supervision	

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