Agro Bali : Agricultural Journal
Vol. 9 No. 1: 214-228, March 2026

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

Multidimensional Sustainability Assessment of Maize Farming in Tropical Regions

La Ode Muhammad Iksan Yusuf [1♥], Muhammad Imam Ma'ruf [1], Sarinah[2], Ahmad Faqhruddin Abdur-Rabb[1], Dirmansyah Darwin[1], and Asma Nabila[3]

[1]Development Economics, Faculty of Economics and Business, Makassar State University, Makassar, Indonesia
[2]Administration Study Program, Faculty of Social and Political Sciences, Halu Oleo University, Kendari, Indonesia
[3]Indonesian Oil Palm Research Institute, Bogor, Indonesia

♥Corresponding author email: iksan.yusuf@unm.ac.id

Article history: submitted: January 20, 2026; accepted: March 25, 2026; available online: April 10, 2026

Abstract. This study addresses a critical gap in understanding the multidimensional sustainability of tropical maize farming by simultaneously evaluating economic, ecological, socio-cultural, institutional, technological, and infrastructural dimensions using a Multidimensional Scaling (MDS) approach. Focusing on West Muna Regency, Southeast Sulawesi, Indonesia, data were collected from 150 farmers and 30 farmer group leaders, complemented by secondary sources. The study aims to assess sustainability status, identify sensitive attributes influencing outcomes, and provide evidence-based guidance for interventions. Results show an overall sustainability index of 52.59%, indicating a "moderately sustainable" system, with economic (73.81%), socio-cultural (72.01%), and ecological (55.07%) dimensions performing better than institutional (42.24%), infrastructure (40.28%), and technological (32.15%) dimensions. Leverage analysis identifies 18 key attributes critical to sustainability, highlighting the need for targeted interventions to strengthen institutional frameworks, improve infrastructure, and accelerate technology adoption. Beyond policy generalization, the findings offer practical insights for stakeholders, including development agencies and farmer organizations, to design context-specific, inclusive, and operational strategies that enhance the long-term sustainability of maize farming in tropical regions.

Keywords: maize farming; multidimensional scaling (MDS); RAPFISH analysis; sustainable agriculture; sustainability index

1. Introduction

The pursuit of sustainable agricultural development remains an important agenda in strengthening food security, particularly in developing countries (Viana et al., 2022). The adoption of the Sustainable Development Goals (SDGs), especially Zero Hunger (SDG 2) and Life on Land (SDG 15), highlights the need to ensure both food availability and environmental sustainability (Guo, 2024; Halkos & Gkampoura, 2021; Hurduzeu et al., 2022). However, despite various policy interventions, global food systems continue to face persistent challenges, including food insecurity, resource degradation, and climate-related risks (FAO, 2020; Nations & Development, 2025; Althani et al., 2025; Yuan et al., 2024). These challenges are particularly relevant in tropical agricultural systems, where increasing production demands must be balanced with sustainability concerns.

Tropical agriculture, characterized by favorable climatic conditions, offers significant potential for food production, particularly for strategic commodities such as maize (Zea mays L) (Ariningsih et al., 2021; Colombo et al., 2021; Kang, 2024; Taiwo & Musonge, 2024). In Indonesia, maize plays a crucial role not only as a food crop but also as a key input for feed and industry, leading to continuous efforts to increase its production (Garfansa et al., 2022; Padrilah et al., 2024; Vieira et al., 2025). One of the important production centers is West Muna Regency in Southeast Sulawesi, where maize production has shown a generally increasing trend and significantly outperforms other local commodities (Salun et al., 2024; Yusuf et al., 2025). Despite its considerable potential, maize farming in West Muna Regency faces complex and interrelated constraints, including price volatility, stringent quality standards (e.g., 14% moisture content),

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

uneven infrastructure, pest infestations, limited access to agricultural inputs, and weak institutional support among farmers (Lairez et al., 2023). These challenges indicate that the sustainability of maize farming systems is shaped not only by biophysical factors but also by broader socio-economic, institutional, and technological dimensions.

However, existing studies on maize farming predominantly focus on partial aspects, such as productivity and economic performance, with limited attention to comprehensive multidimensional sustainability assessments, particularly in tropical agricultural contexts (Ehlers et al., 2021; Simane et al., 2025; Thabane et al., 2025). This indicates a clear research gap in evaluating maize sustainability using an integrated analytical framework that simultaneously incorporates ecological, economic, socio-cultural, institutional, technological, and infrastructural dimensions. Previous studies in developing and Asian agricultural systems also highlight that fragmented approaches often fail to capture the complex trade-offs and interdependencies inherent in sustainable farming systems (Halkos & Gkampoura, 2021; Hurduzeu et al., 2022).

Therefore, this study proposes a novel approach by applying an integrated multidimensional sustainability assessment framework to maize farming systems in tropical regions. By incorporating six key dimensions, this approach provides a more holistic understanding of sustainability status and its driving factors, which are often overlooked in conventional analyses. The findings are expected to generate targeted policy recommendations to improve governance, strengthen value chains, and support sustainable food security systems at the regional level.

2. Materials and Methods

2.1 Study Area and Data Collection

This study was conducted in West Muna Regency, Southeast Sulawesi Province, Indonesia. The location was selected purposively based on its status as a region with high maize production, where the crop serves as a primary source of livelihood for the local community.

2.2 Sample preparation

This study utilized both primary and secondary data. Primary data were obtained through direct field observations and structured interviews using a standardized questionnaire. Purposive sampling was employed to select respondents with relevant knowledge and experience in maize farming systems. A total of 150 maize farmers and 30 farmer group leaders were surveyed to ensure adequate representation of cultivation practices and institutional perspectives.

2.3 Sustainability Assessment Method

The sustainability of maize cultivation was assessed using a quantitative modeling analysis with a Multidimensional Scaling (MDS) approach, specifically the Rapid Appraisal for Seaweed technique developed by (Hout et al., 2013). This method is a modification of the Rapid Assessment Technique for Fisheries (RAPFISH) pioneered by T. J. Pitcher and Preikshot (2001) at the University of British Columbia (Pitcher & Kavanagh, 2004) and later adapted for the Indonesian context by Fauzi (2019). MDS is a statistical technique that ordinates objects in a multidimensional space based on similarity assessments of the researched subjects (Jaworska and Chupetlovska-Anastasova, 2009; Pitcher & Kavanagh, 2004). The procedure for analyzing the sustainability status of maize cultivation consisted of the following stages:

1. Determination of Attributes: Sustainability attributes were defined across six dimensions: (1) economic, (2) ecological, (3) socio-cultural, (4) institutional, (5) technological, and (6) infrastructural (Yusuf et al., 2023; Khusni et al., 2024; Latifah & Ekawati, 2023; Rinansi et al., 2025).

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

2. Attribute Scoring: Each attribute was assessed and assigned a score based on a Likert scale from 0 to 3 (Norman, 2010). Standardized measurement scores were assigned to each attribute according to its perceived importance (Fauzi, 2019).
3. RAPFISH Ordination: The RAPFISH ordination using the MDS method was employed to determine a single point value reflecting the position of the measured object. A good analysis result is indicated by a low stress value (S < 0.25) (Fauzi, 2019).
4. Determination of Sustainability Status: The sustainability status was determined using the index values and categories presented in Table 1.

Table 1. Sustainability Index Status

Index Value	Sustainability Status
0.00 - 25.00	Unsustainable
25.01 - 50.00	Less Sustainable
50.01 - 75.00	Moderately Sustainable
75.01 - 100.00	Highly Sustainable

Source: (Pitcher & Kavanagh, 2004)

5. Leverage Analysis: A leverage analysis was conducted to identify dominant (sensitive) attributes. This analysis examines the change in ordination (the shift in position on the "bad-good" axis) when each attribute is removed one at a time. The leverage value typically ranges from 2% to 6%, measured by the change in Root Mean Square (RMS). A larger change in the RMS value indicates a higher sensitivity of the attribute, meaning it has a greater influence on the overall sustainability score (Fauzi, 2019).
6. Monte Carlo Analysis: A Monte Carlo analysis was performed to detect sources of error from data variability (Farrance & Frenkel, 2014). Potential errors in the RAPFISH analysis can arise from several factors: (1) errors in attribute scoring due to insufficient information or misinterpretation; (2) variation in scoring resulting from differing opinions or judgments; (3) data entry errors or missing data; and (4) a high stress value from the MDS analysis.

3. Results and Discussion

3.1 Sustainability Index and Validation

The sustainability index of maize farming in West Muna Regency is visualized using a spider/radar chart across six dimensions: Economic, Ecological, Socio-Cultural, Institutional, Technological, and Infrastructure. This chart facilitates rapid comparison of the performance of each dimension, as shown in Figure 1.

The results show that the Economic (73.81%) and Socio-Cultural (72.01%) dimensions occupy the highest positions, indicating that aspects such as income, market access, price stability, participation in farmer groups, and community social activities relatively support sustainability. The Ecological dimension (55.07%) occupies a middle position, reflecting challenges related to water availability, pest intensity, and cropping patterns. In contrast, the Institutional (42.24%), Infrastructure (40.28%), and Technological (32.15%) dimensions are the lowest, highlighting vulnerable areas that require attention, including formal and informal institutional strengthening, improvement of roads and storage facilities, and adoption of cultivation and post-harvest technologies.

Table 2 presents the validation results of the six-dimensional sustainability index using Monte Carlo simulations, which serve to assess the robustness of the MDS outcomes against data uncertainty. The original index compared with the Monte Carlo results showed minimal differences (<1.0) across all dimensions, indicating that the sustainability assessment is stable and reliable. Overall, the composite

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

sustainability index was 52.59%, with the Monte Carlo simulation yielding 52.52%. This suggests that maize farming in West Muna Regency can be considered moderately sustainable, and the results are robust to data variability.

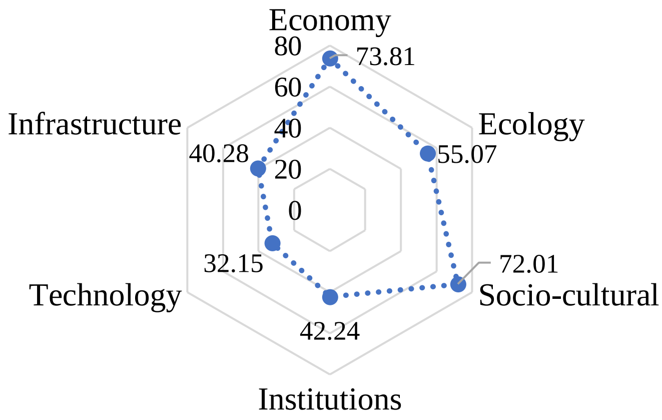

Figure 1. Six-dimensional sustainability index kite diagram.

Table 2. Sustainability index status

Dimension	Index	Monte Carlo	Difference	R^2	Stress
Economy	73.81	73.02	0.79	0.15	0.93
Ecology	55.07	55.18	0.11	0.12	0.98
Socio-Culture	72.01	71.90	0.11	0.15	0.94
Institutional	42.24	41.51	0.73	0.16	0.96
Technology	32.15	32.94	0.79	0.11	0.98
Infrastructure	40.28	40.61	0.33	0.13	0.91
Sustainability Status	52.59	52.52	0.06		

3.2 Leverage Analysis and Sustainability Attributes

To identify the pivotal factors influencing sustainability, a leverage analysis was conducted. This method measures the change in the Root Mean Square (RMS) when an attribute is removed from the model; a higher RMS change denotes a more sensitive attribute that plays a greater role in determining the sustainability status (Pitcher & Kavanagh, 2004). The analysis identified key sensitive attributes across all dimensions that serve as critical leverage points for interventions. The complete list of sustainability attributes assessed in this study is provided in Table 3.

The multidimensional assessment of corn farming sustainability indicates that, overall, the system is reasonably sustainable. However, the degree of sustainability varies considerably across dimensions. The economic, socio-cultural, and ecological dimensions demonstrate relatively stronger performance, whereas the institutional, technological, and infrastructural dimensions remain weak. This pattern underscores the complexity of agricultural sustainability in tropical regions, where biophysical, socioeconomic, and governance factors are closely interlinked in shaping the sustainability of the corn farming sector.

3.2.1. Sensitive Attributes in the Economic Dimension

Leverage analysis for the economic dimension, comprising seven attributes, established a median RMS change of 4.16%. The most sensitive attributes, in descending

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

order, were: Market Access (X1.2) with an RMS change of 7.94%, Farm Income (X1.1) at 6.72%, and Price Stability (X1.3) at 4.86% (Figure 2).

Table 3. Sustainability index status

Dimension	Sustainability Attributes
Economic	(X1.1) Farm income, (X1.2) Market access, (X1.3) Price stability, (X1.4) Access to capital/credit, (X1.5) Ease of access to farming inputs, (X1.6) Labor absorption, (X1.7) Land ownership
Ecological	(X2.1) Water availability, (X2.2) Pest and disease intensity, (X2.3) Use of fertilizers and pesticides, (X2.4) Land/soil quality, (X2.5) Application of planting season/cropping patterns, (X2.6) Land slope, (X2.7) Implementation of conservation practices (contouring, terracing)
Socio-Cultural	(X3.1) Farmer group activity, (X3.2) Gender role in farming, (X3.3) Farming experience, (X3.4) Participation in extension and training programs, (X3.5) Conflicts among farmers, (X3.6) Intensity of farmer group meetings, (X3.7) Education level
Institutional	(X4.1) Availability of formal and informal regulations, (X4.2) Presence of marketing institutions, (X4.3) Existence of farmer groups, (X4.4) MoU or cooperation in farm development, (X4.5) Customary cultural rules in farming, (X4.6) Financial institutions
Technological	(X5.1) Application of cultivation technology, (X5.2) Level of technology adoption, (X5.3) Availability of traditional and modern farm machinery, (X5.4) Post-harvest technology, (X5.5) Fertilizer production technology, (X5.6) Acceptance of new innovations and technologies, (X5.7) Processing of production output
Infrastructural	(X6.1) Storage warehouses, (X6.2) Farm road infrastructure, (X6.3) Road quality (asphalt, dirt, gravel), (X6.4) Availability of irrigation (rivers, reservoirs, ponds, bore wells), (X6.5) Drying facilities (sun-drying, mechanical dryers), (X6.6) Access to electricity for agricultural activities

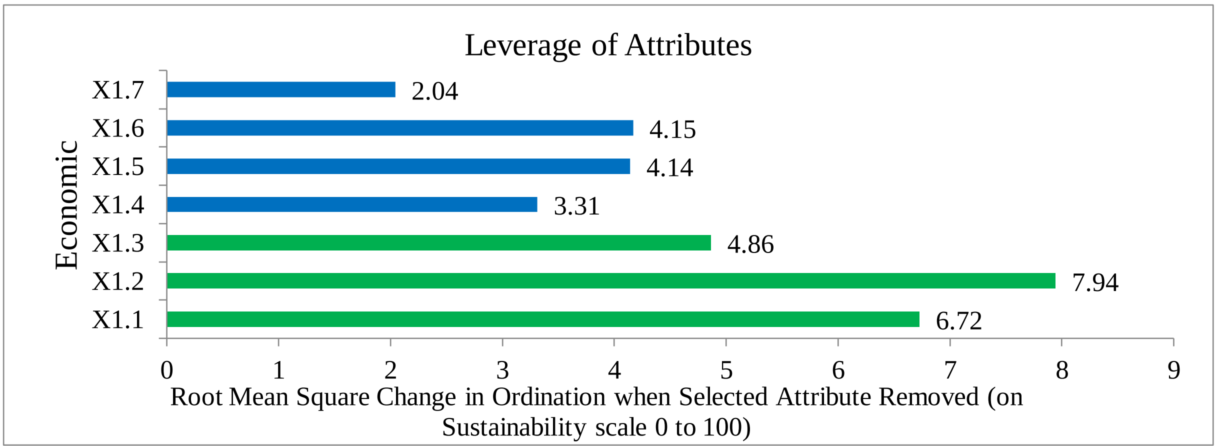

Figure 2. Leverage Analysis of Attributes in the Economic Dimension

The prominence of these attributes aligns with the empirical conditions faced by maize farmers in West Muna. Farmers contend with highly volatile prices from local middlemen, typically ranging from IDR 2,500 to IDR 4,000 per kg depending on the season. In contrast, the state-owned logistics agency (BULOG) offers a more stable price of approximately IDR 5,000 per kg but imposes stringent quality

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

requirements, including a maximum moisture content of 15% and a maximum of 5% damaged kernels, which are often difficult for farmers to meet. This price disparity and market structure significantly undermine the economic sustainability of maize farming, highlighting the urgent need for government-backed price guarantees that are accessible to all farmers.

Improved market access enables farmers to sell their harvest at better prices and reduces their dependence on intermediaries. Farm income serves as a direct indicator of business viability, where gains in productivity and cost efficiency directly impact farmer welfare. Concurrently, price stability is crucial for ensuring economic predictability, as price fluctuations can severely diminish farmers' motivation to sustain their operations. These findings corroborate previous research. Ismail (2022) emphasized that market access is highly dependent on the efficiency of the supply chain in mitigating market failures. Similarly, Suh et al., (2025) and Viganò et al., (2022) found that cooperatives significantly enhance household income and price stability, even amidst deteriorating food security conditions, and that support from non-governmental organizations plays a vital role in facilitating farmer participation in such schemes.

3.2.2. Sensitive Attributes in the Economic Dimension

Leverage analysis for the ecological dimension, comprising seven attributes (X2.1) Water availability, (X2.2) Intensity of pest and disease attacks, (X2.3) Use of fertilizers and pesticides, (X2.4) Land/soil quality, (X2.5) Application of planting season/cropping patterns, (X2.6) Land slope, and (X2.7) Implementation of conservation practices (contouring, terracing) revealed a median Root Mean Square (RMS) change of 4.11%. The most sensitive attributes influencing sustainability were, in order: the application of planting season/cropping patterns (X2.5) with an RMS change of 6.14%, followed by the intensity of pest and disease attacks (X2.2) at 5.19%, and water availability (X2.1) at 4.72% (Figure 3).

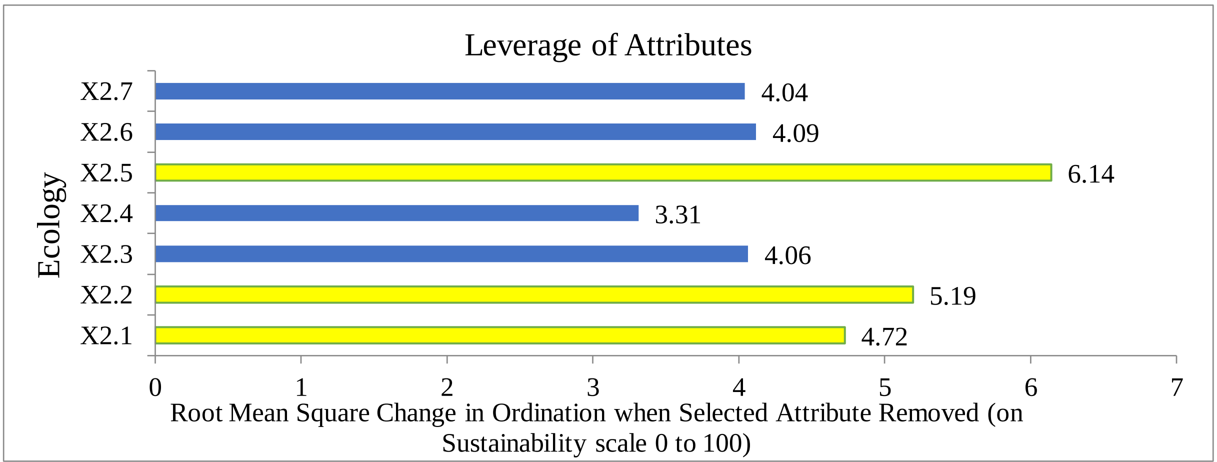

Figure 3. Leverage Analysis of Attributes in the Ecological Dimension

Implementing appropriate cropping patterns tailored to local climatic conditions is a critical determinant of production success. Furthermore, high incidences of pests and diseases can significantly reduce yield and degrade crop quality. Concurrently, water availability is a cornerstone of productivity, especially during extended dry seasons. These three factors are interconnected in maintaining agricultural sustainability and food security.

The local ecological context fundamentally determines agricultural sustainability. West Muna Regency is predominantly characterized by lowland

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

topography with unpredictable rainy and dry seasons. Consequently, the timing and type of cropping patterns, such as the intercropping of maize with other horticultural plants, must be adapted to rainfall conditions to mitigate risks. This finding aligns with Marcos-Garcia et al. (2024), who emphasized that aligning planting seasons with dry and wet periods is a key driver of high yields. Additionally, pest and disease outbreaks, such as the fall armyworm, can be triggered by environmental factors, making production systems highly vulnerable. This corresponds with Mrope & Kigodi, (2024), who found that pest and disease infestations directly impact production quality. Moreover, the availability and quality of surface/groundwater in several river basins are under stress (characterized by declining quality and limited supply during the dry season). Consequently, water reserves for rain-fed irrigation and seasonal crop needs are often inadequate. This exacerbates the impact of non-adaptive cropping patterns and increases the likelihood of crop failure. These findings are consistent with Ortez et al., (2023) and Caparas et al., (2021), who reported that long-term weather patterns and environmental stresses lasting more than ten days can potentially affect the growth, development, and yield of maize.

3.2.3. Sensitive Attributes of the Socio-Cultural Dimension

The leverage analysis for the socio-cultural dimension, which includes seven attributes (X3.1) Farmer group activity, (X3.2) Gender role in farming, (X3.3) Farming experience, (X3.4) Participation in extension and training programs, (X3.5) Conflicts among farmers, (X3.6) Intensity of farmer group meetings, and (X3.7) Education level yielded a median RMS change of 3.09%. The most sensitive attributes were: participation in extension and training programs (X3.4) with an RMS change of 5.11%, conflicts among farmers (X3.5) at 4.14%, and the intensity of farmer group meetings (X3.6) at 4.12% (Figure 4).

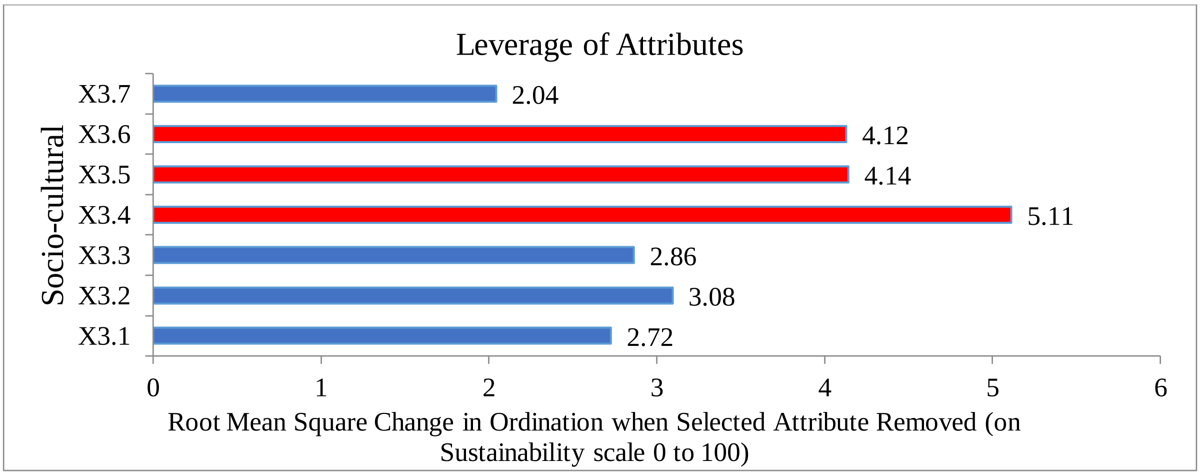

Figure 4. Leverage Analysis of Attributes in the Socio-Cultural Dimension

From this perspective, farming sustainability is heavily influenced by farmer engagement in extension services and training, which are crucial for enhancing capacity and knowledge in farm management. However, conflicts among farmers persist, often related to competition over resources or differing interests, potentially weakening cooperation and solidarity within groups. Furthermore, the frequency of farmer group meetings plays a strategic role, as regular gatherings foster coordination, camaraderie, and the exchange of information and experiences.

Strengthening extension programs, conflict resolution, and optimizing farmer

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

group meetings are essential attributes for reinforcing the socio-cultural aspect to support farming sustainability. This is supported by the findings of Wossen et al. (2017) and Antwi-Agyei & Stringer, (2021), who demonstrated that enhanced extension and training improve farmer capacity through technology transfer and group learning, leading to faster innovation adoption and increased productivity. The attribute of conflict among farmers also plays a significant role.

Competition over land, access to subsidized fertilizers, or market share often creates friction at the grassroots level. Poorly managed conflicts can diminish cooperative spirit and collective efficiency among farmers (Salun et al., 2024). Subsequently, the intensity of farmer group meetings is also crucial. Regular meetings enable members to share market information, technologies, and input prices, thereby building social solidarity (Hasrida et al., 2023). According to Wossen et al. (2017), active participation in farmer groups is positively correlated with the adoption of new technologies, which can enhance household income.

3.2.4. Sensitive Attributes of the Institutional Dimension

The leverage analysis for the institutional dimension, encompassing six attributes (X4.1) Availability of formal and informal regulations, (X4.2) Availability of marketing institutions, (X4.3) Availability of farmer groups, (X4.4) MoU or cooperation in farm development, (X4.5) Customary cultural rules in farming, and (X4.6) Financial institutions resulted in a median RMS change of 2.97%. The three most sensitive attributes were: Memorandum of Understanding (MoU) or cooperation in farm development (X4.4) with an RMS change of 5.25%, the availability of formal and informal regulations (X4.1) at 4.11%, and the availability of marketing institutions (X4.2) at 3.72% (Figure 5).

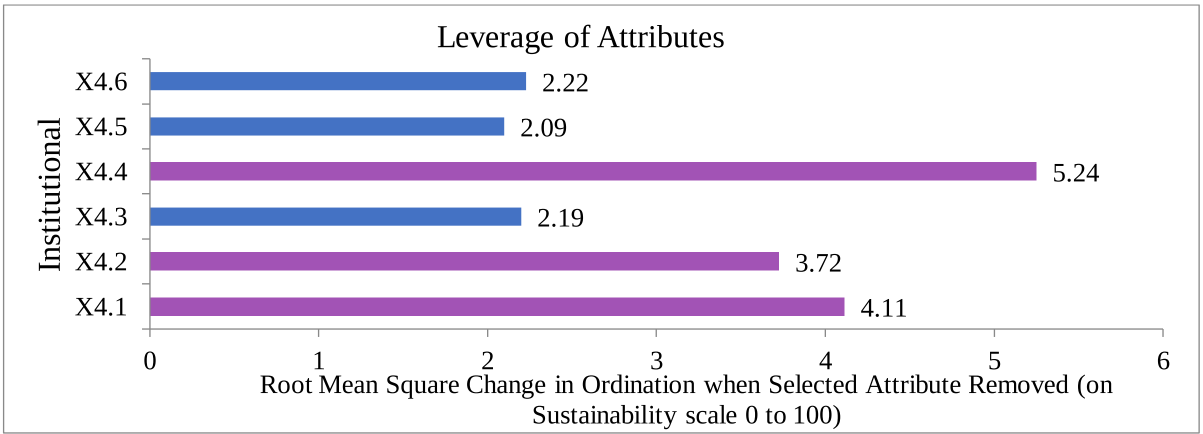

Figure 5. Leverage Analysis of Attributes in the Institutional Dimension

The high sensitivity of MoUs or cooperation indicates that formal collaboration between farmers and government agencies, private entities, or industry players is a critical determinant of sustainability. Overall, the institutional performance is hampered by weak formal collaboration, insufficient regulatory support, and the suboptimal function of farmer groups. Improvements in these three aspects are vital to elevate the institutional dimension from its current "Less Sustainable" status.

In practice, formal cooperation remains limited in West Muna Regency, leaving farmers without guaranteed access to markets or production inputs. According to Wossen et

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

al. (2017), formal cooperation mechanisms can strengthen the governance of agricultural value chains and reduce market risks. Furthermore, the availability of formal and informal regulations is also sensitive. Weak local rules or formal regulations governing maize trade, minimum prices, and quality standards leave farmers inadequately protected in market transactions. This condition aligns with Fauzi (2019), who asserted that institutional regulations are a crucial instrument for ensuring the sustainability of farming businesses. Moreover, farmer groups also emerge as a sensitive attribute requiring attention. Although numerous farmer groups exist, their role remains largely administrative, often serving primarily as a requirement to access government aid. Few groups function as collective platforms for joint marketing, providing production inputs, or conducting technology training in West Muna Regency. The success of farmer groups in enhancing sustainability is highly dependent on managerial capacity, meeting frequency, and adaptation to market dynamics (Efrina, 2022; Suh et al., 2025).

3.2.5. Sensitive Attributes of the Technological Dimension

Leverage analysis for the technological dimension, encompassing seven attributes (X5.1) Application of cultivation technology, (X5.2) Level of technology adoption, (X5.3) Availability of traditional and modern agricultural tools and machinery, (X5.4) Post-harvest technology, (X5.5) Fertilizer production technology, (X5.6) Acceptance of new innovations and technologies, and (X5.7) Processing of production output revealed a median Root Mean Square (RMS) change of 1.19. Among the seven attributes analyzed, three were identified as the most sensitive in influencing sustainability: fertilizer production technology (X5.5) with an RMS change of 4.54%, post-harvest technology (X5.4) at 3.31%, and application of cultivation technology (X5.1) at 2.72% (Figure 6).

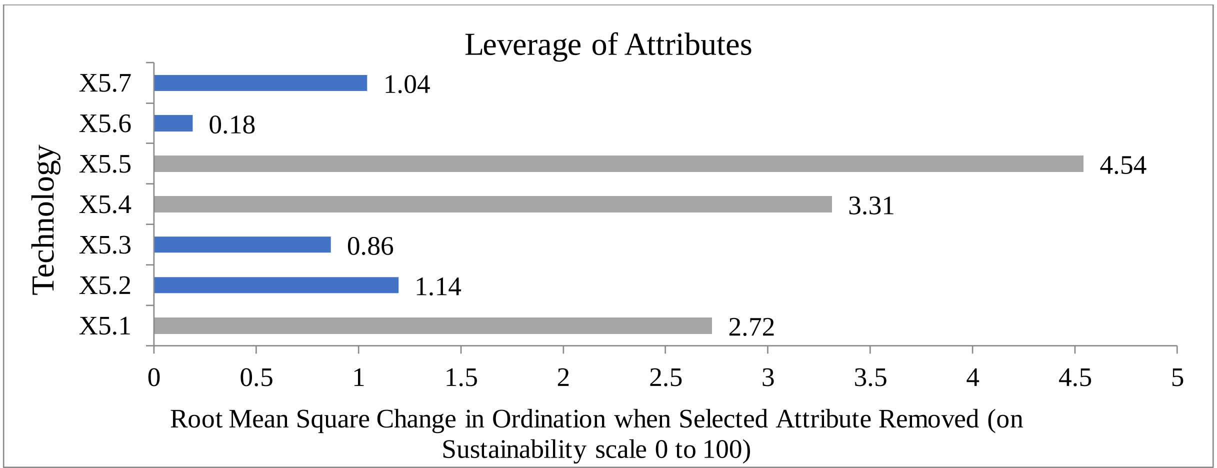

Figure 6. Leverage Analysis of Attributes in the Technological Dimension

Overall, the low sustainability index in the technological dimension is primarily attributed to weak support in fertilizer, post-harvest, and cultivation technologies. Efforts to enhance the availability and adoption of technologies in these three areas are paramount to advancing this dimension from the "Less Sustainable" to the "Moderately Sustainable" category.

Technological support for maize-specific fertilizer production plays a vital role in enhancing productivity while maintaining land sustainability. Utilizing agricultural waste-based organic fertilizers and bio-fertilizers has been proven to reduce input

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

costs, improve soil fertility, and decrease dependence on chemical fertilizers. The application of such technologies enhances fertilization efficiency and improves harvest quality. Recent studies confirm that a combination of chemical, organic, and bio-fertilizers can form an effective technological package for sustainable maize cultivation (Fikri et al., 2023). The attribute of post-harvest technology, including support for drying, storage/warehousing, and processing, is crucial for farmers to maintain quality and market value. This aligns with the study by Ariningsih et al., (2021), which states that post-harvest technology plays a significant role in reducing post-harvest losses and enhancing agricultural product competitiveness. Furthermore, the sensitivity of cultivation technology application aligns with conditions in West Muna Regency, where adoption remains low due to limited technical knowledge and capital. This finding is consistent with Vieira et al., (2025), who reported that increased adoption of modern cultivation technologies contributes to enhanced productivity, market value, and farming efficiency.

3.2.6. Sensitive Attributes of the Infrastructural Dimension

Leverage analysis for the infrastructural dimension, covering six attributes (X6.1) Storage warehouses, (X6.2) Farm road infrastructure, (X6.3) Road quality (asphalt, dirt, gravel), (X6.4) Availability of irrigation (rivers, reservoirs, ponds, bore wells), (X6.5) Drying facilities (sun-drying, mechanical dryers), and (X6.6) Access to electricity for agricultural activities confirms the "Less Sustainable" status of infrastructure for maize farming in West Muna Regency, indicating that basic facilities are not yet optimal in supporting production, distribution, and marketing activities. The results of the leverage analysis are shown below (Figure 7).

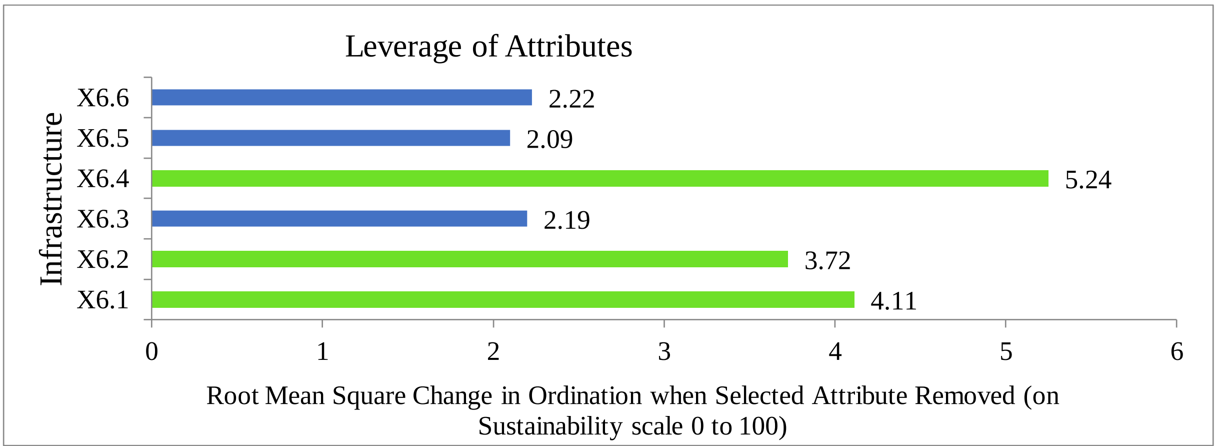

Figure 7. Leverage Analysis of Attributes in the Infrastructural Dimension

The analysis indicates that the availability of irrigation for maize farming-such as rivers, reservoirs, ponds, and bore wells-has the most substantial influence on sustainability. This aligns with the condition in West Muna Regency, where most agricultural land still relies on rainfall and lacks permanent irrigation facilities, making it unsuitable for farming during the dry season. This finding supports Gwambene, (2025) and Jamalimoghaddam et al., (2019), who emphasized that water is a fundamental resource for ensuring sustainable agricultural production in developing countries. Subsequently, storage warehouses for produce are highly sensitive, as most maize farmers face losses due to declining post-harvest quality from inadequate storage facilities, often forcing immediate sale to middlemen without proper quality assessment. Consistent with the findings of Matusse et al., (2025) and Adams et al.,

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

(2025), storing maize in woven polypropylene bags leads to significant grain damage (60–80%), underscoring the need for temperature and moisture-controlled warehouse storage. Furthermore, farm road infrastructure poses a significant constraint. Several farming areas remain difficult to access due to poor road conditions, slowing down the distribution of produce to markets and incurring additional costs for farmers.

Efficient and accessible transportation infrastructure is crucial for agricultural growth, particularly in production areas where food security and rural livelihoods depend on effective supply chain operations, necessitating adequate road infrastructure (Abbas Khan et al., 2025; Ramadhani et al., 2025). Thus, the low sustainability index of the infrastructural dimension is driven by inadequate support for storage facilities, road access, and transportation. Prioritizing the improvement of farm road quality, construction of storage warehouses, and provision of adequate transportation facilities is essential to strengthen the sustainability of maize agriculture in the region

4. Limitations and Future Directions

This study has several limitations that should be acknowledged. First, the analysis relies on cross-sectional data collected from a specific geographical context, namely West Muna Regency, which may limit the generalizability of the findings to other tropical regions with different agroecological and institutional characteristics. Second, the use of the MDS approach, although robust for rapid sustainability assessment, inherently depends on subjective attribute scoring based on respondents' perceptions and expert judgment. Despite efforts to minimize bias through standardized Likert-scale measurements and Monte Carlo simulations, potential biases may still persist. Third, the study focuses on six predefined dimensions and 40 attributes which, although comprehensive, may not fully capture emerging factors such as climate variability dynamics, digital agriculture adoption, and increasing global market integration that influence agricultural sustainability.

Future research should aim to address these limitations by incorporating longitudinal data to better capture temporal dynamics and causal relationships in agricultural sustainability. Expanding the study area to include multi-regional or cross-country comparative analyses would enhance external validity and provide broader policy insights. Methodologically, integrating MDS with other quantitative approaches, such as Structural Equation Modeling (SEM) or system dynamics, could improve analytical depth and reduce subjectivity. Furthermore, future studies should incorporate additional dimensions, particularly climate resilience, digital transformation, and value chain integration, to reflect the evolving challenges in the agricultural sector.

5. Conclusion

This study reveals that the sustainability of maize farming in the tropical region of West Muna Regency is classified as moderately sustainable, with an index value of 52.59%. However, considerable disparities exist across dimensions, where the economic, socio-cultural, and ecological dimensions perform relatively better than the institutional, technological, and infrastructural dimensions, which remain comparatively weak. The findings highlight that sustainability is not solely determined by technical production factors but is also strongly influenced by market access, farmers' capacity, resource availability, and the effectiveness of institutional systems. Key sensitive attributes-including market access, price stability, cropping patterns, water availability, participation in extension services, institutional collaboration, and post-harvest technology-serve as critical leverage points for enhancing the overall sustainability of maize farming systems.

Based on these findings, several policy implications can be proposed. These include strengthening farmer institutions through formal partnerships and more farmer-

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

oriented pricing regulations, improving agricultural infrastructure such as irrigation systems, farm access roads, and storage facilities, and accelerating technology adoption through more intensive and locally tailored extension programs. In addition, cross-sectoral policy integration is essential to strengthen agricultural value chains and improve farmers' access to financial resources. Future research should also incorporate emerging dimensions such as climate resilience, agricultural digitalization, and global market integration to better capture the increasingly complex dynamics of agricultural sustainability.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

I hereby declare that in the preparation of this work, I have used artificial intelligence (AI) tools in a limited manner for language editing, idea development, and structural improvement. All content, analysis, and conclusions are entirely the result of my own thinking and have been prepared in accordance with academic ethics and principles of scholarly integrity.

Authorship Contribution Statement

Name of Author 1st: Composed the research context, identified problems, and formulated research objectives. Coordinated the overall writing process; Name of Author 2st: Collected relevant theories and previous studies, and developed the conceptual framework; Name of Author 3st: Designed the field research methods, data collection techniques, instruments, and analysis procedures; Name of Author 4st: Processed and analyzed field data, and discussed findings in relation to theories and research objectives; Name of Author 5st: Drew conclusions, provided recommendations, and conducted final editing for language and format consistency.

Declaration of Competing Interest

The authors declare that there are no interests or personal relationships that could have influenced the results, analysis, or conclusions presented in this article. All research and writing processes were carried out independently, objectively, and free from any form of conflict of interest.

References

Abbas Khan, M., Ni, G., Man, T., & Saud, S. (2025). Impacts of transport infrastructure on agricultural total factor productivity in Asian countries. Transport Policy, 171, 18–27. https://doi.org/10.1016/j.tranpol.2025.05.022

Abdul Halim, N. R., Hashim, H., Mutalib, S., & Abd Ghani, M. (2024). Food safety regulations implementation and their impact on food security level in Malaysia: A review. International Food Research Journal, 31(1), 20–31. https://doi.org/10.47836/ifrj.31.1.02

Abdulai, I. A., Kuusaana, E. D., & Ahmed, A. (2025). Toward sustainable urbanization: Understanding the dynamics of urban sprawl and food (in)security of indigenous households in peri-urban Wa, Ghana. Journal of Urban Affairs, 47(4), 1371–1396. https://doi.org/10.1080/07352166.2023.2224023

Abdulrahman, R. R., Salih, A. M., Hussein, H. H. S., Aivas, S. A., Ahamd, K. H., Fatah, N. A., Karem, L. E., Yaqub, K. Q., & Bayz, H. A. (2025). The Role of Agriculture Sector in Eradicating Poverty: Challenges, Policies, and Pathways for Economic Growth in Less Developed Countries. International Journal of Social Science And Education Research Studies, 05(02), 208–213. https://doi.org/10.55677/ijssers/V05I02Y2025-11

Adams, A. A., Akrofi, M. N. A., & Sarpong, D. B. (2025). The choice of maize (Zea mays L.) storage facility among farmers in the Sissala East District in northern Ghana: What are the determinants? Journal of Stored Products Research, 111, 102571. https://doi.org/10.1016/j.jspr.2025.102571

Althani, N. A., Elzaki, R. M., & Alzahrani, F. (2025). Food Security–Renewable Energy Nexus: Innovations and Shocks in Saudi Arabia. Foods, 14(10), 1797. https://doi.org/10.3390/foods14101797

Antwi-Agyei, P., & Stringer, L. C. (2021). Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. Climate Risk Management, 32, 100304. https://doi.org/10.1016/j.crm.2021.100304

Ariningsih, E., Rachman, B., Sudaryanto, T., Ariani, M., Septanti, K. S., & Adawiyah, C. R. (2021). Strategies for sustainable corn production: a case of South Lampung District, Lampung Province, Indonesia. IOP Conference Series: Earth and Environmental Science, 892(1), 012075. https://doi.org/10.1088/1755-1315/892/1/012075

BPS. (2025). Statistik tanaman pangan. Badan Pusat Statistik Kabupaten Muna Barat.

Caparas, M., Zobel, Z., Castanho, A. D. A., & Schwalm, C. R. (2021). Increasing risks of crop failure and water scarcity in global breadbaskets by 2030. Environmental Research Letters, 16(10), 104013. https://doi.org/10.1088/1748-9326/ac22c1

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

Cinner, J. E., Caldwell, I. R., Thiault, L., Ben, J., Blanchard, J. L., Coll, M., Diedrich, A., Eddy, T. D., Everett, J. D., Folberth, C., Gascuel, D., Guiet, J., Gurney, G. G., Heneghan, R. F., Jägermeyr, J., Jiddawi, N., Lahari, R., Kuange, J., Liu, W., Pollnac, R. (2022). Potential impacts of climate change on agriculture and fisheries production in 72 tropical coastal communities. Nature Communications, 13(1), 3530. https://doi.org/10.1038/s41467-022-30991-4

Colombo, R., Ferron, L., & Papetti, A. (2021). Colored Corn: An Up-Date on Metabolites Extraction, Health Implication, and Potential Use. Molecules, 26(1), 199. https://doi.org/10.3390/molecules26010199

Daniel, A. I., Fadaka, A. O., Gokul, A., Bakare, O. O., Aina, O., Fisher, S., Burt, A. F., Mavumengwana, V., Keyster, M., & Klein, A. (2022). Biofertilizer: The Future of Food Security and Food Safety. Microorganisms, 10(6), 1220. https://doi.org/10.3390/microorganisms10061220

DeBoe, G. (2020). Impacts of agricultural policies on productivity and sustainability performance in agriculture: A literature review. OECD Food, Agriculture and Fisheries Papers, No. 141(141), 1–78.

Efrina, L. (2022). Efforts to Improve Community Welfare Through Farming Group Empowerment from an Islamic Economic Perspective. Indonesian Journal of Islamic Economics and Finance, 2(2), 95–109. https://doi.org/10.37680/ijief.v2i2.1799

Ehlers, M.-H., Huber, R., & Finger, R. (2021). Agricultural policy in the era of digitalisation. Food Policy, 100, 102019. https://doi.org/10.1016/j.foodpol.2020.102019

Esubalew, A. A., & Adebisi, S. A. (2024). Sustainable Entrepreneurship as a Solution to Urbanization and Food Security Challenges: A Developing Countries Perspective. Indonesian Journal of Multidiciplinary Research, 4(2), 363–376. https://doi.org/10.17509/ijomr.v4i2.78272

FAO. (2020). The State of Agricultural Commodity Markets 2020. FAO. https://doi.org/10.4060/cb0665en

Farrance, I., & Frenkel, R. (2014). Uncertainty in measurement: a review of monte carlo simulation using microsoft excel for the calculation of uncertainties through functional relationships, including uncertainties in empirically derived constants. The Clinical Biochemist. Reviews, 35(1), 37–61. http://www.ncbi.nlm.nih.gov/pubmed/24659835

Fauzi, A. (2019). Teknik Analisis Keberlanjutan. Jakarta: Gramedia Pustaka Utama

Fikri, M., Farid, M., Musa, Y., Anshori, M. F., Padjung, R., & Nur, A. (2023). Multivariate analysis in the development of technology packages for corn cultivation by adding fertilizer to compost. Chilean Journal of Agricultural Research, 83(4), 471–483. https://doi.org/10.4067/S0718-58392023000400471

Fu, B., Wang, S., Zhang, J., Hou, Z., & Li, J. (2019). Unravelling the complexity in achieving the 17 sustainable-development goals. National Science Review, 6(3), 386–388. https://doi.org/10.1093/nsr/nwz038

Garfansa, M. P., Iswahyudi, Adilla, N. A., & Kristiana, L. (2022). Perbandingan Pertumbuhan Dan Produksi Jagung Hibrida (Zea Mays L.) Pada Lahan Kering Dan Basah. Jurnal Pertanian Presisi (Journal of Precision Agriculture), 6(2), 108–121. https://doi.org/10.35760/jpp.2022.v6i2.6946

Guo, H. (2024). SDG 2, Zero Hunger (pp. 5–45). https://doi.org/10.1007/978-981-97-3278-4_2

Gwambene, B. (2025). Unveiling Innovative Solutions to Unlock Underutilized Groundwater and Rainwater Potential in Tanzania. Physics and Chemistry of the Earth, Parts A/B/C, 104072. https://doi.org/10.1016/j.pce.2025.104072

Halkos, G., & Gkampoura, E.-C. (2021). Where do we stand on the 17 Sustainable Development Goals? An overview on progress. Economic Analysis and Policy, 70, 94–122. https://doi.org/10.1016/j.eap.2021.02.001

Hasrida, Ilham, M., & Rizal. (2023). Peran Gender Dalam Keluarga Petani. 8(1), 181–189.

Hout, M. C., Papesh, M. H., & Goldinger, S. D. (2013). Multidimensional scaling. WIREs Cognitive Science, 4(1), 93–103. https://doi.org/10.1002/wcs.1203

Hurduzeu, G., Pânzaru, R. L., Medelete, D. M., Ciobanu, A., & Enea, C. (2022). The Development of Sustainable Agriculture in EU Countries and the Potential Achievement of Sustainable Development Goals Specific Targets (SDG 2). Sustainability, 14(23), 15798. https://doi.org/10.3390/su142315798

Ismail, I. J. (2022). Agriculture Supply Chain Challenges and Smallholder Maize Farmers' Market Participation Decisions in Tanzania. 21(1), 104–120.

Jamalimoghaddam, E., Yazdani, S., Salami, H., & Peykani, G. (2019). The impact of water supply on farming systems: A sustainability assessment. Sustainable Production and Consumption, 17, 269–281. https://doi.org/10.1016/j.spc.2018.11.001

Jaworska, N., & Chupetlovska-Anastasova, A. (2009). A Review of Multidimensional Scaling (MDS) and its Utility in Various Psychological Domains. Tutorials in Quantitative Methods for Psychology, 5(1), 1–10. https://doi.org/10.20982/tqmp.05.1.p001

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

Kang, M. S. (2024). Crop Improvement. CRC Press. https://doi.org/10.1201/9781003578512

Khusni, A., Suhartini, S., & Sujarwo, S. (2024). Sustainability of Corn Farming Systems on Post-Sand Mining Land in Malang, East Java, Indonesia. HABITAT, 35(1), 96–105. https://doi.org/10.21776/ub.habitat.2024.035.1.9

Koopmans, M. E., Rogge, E., Mettepenningen, E., Knickel, K., & Šūmane, S. (2018). The role of multi-actor governance in aligning farm modernization and sustainable rural development. Journal of Rural Studies, 59, 252–262. https://doi.org/10.1016/j.jrurstud.2017.03.012

Latifah, N., & Ekawati, I. (2023). Status Keberlanjutan Usaha Tani Palawija-Kencur Sistem Tumpang Sari: Kasus di Lahan Kering Madura. AgriTECH, 43(1), 47. https://doi.org/10.22146/agritech.71974

Lairez, J., Affholder, F., Scopel, E., Leudpanhane, B., & Wery, J. (2023). Sustainability assessment of cropping systems: A field-based approach on family farms. Application to maize cultivation in Southeast Asia. European Journal of Agronomy, 143, 126716. https://doi.org/10.1016/j.eja.2022.126716

Lestari, E. (2024). Eskalasi Tata Kelola Kebijakan Pemerintah Daerah Terhadap Pertanian Berkelanjutan: Upaya Mewujudkan Kedaulatan Pangan Berbasis Kearifan Lokal. Jurnal Hukum Mimbar Justitia, 10(1), 141. https://doi.org/10.35194/jhmj.v10i1.4154

Marcos-Garcia, P., Carmona-Moreno, C., & Pastori, M. (2024). Intra-growing season dry–wet spell pattern is a pivotal driver of maize yield variability in sub-Saharan Africa. Nature Food, 5(9), 775–786. https://doi.org/10.1038/s43016-024-01040-8

Matusse, C., Bila, J., Macuamule, C., Sampaio, A., Venâncio, A., & Rodrigues, P. (2025). Evaluation of corn drying and storage techniques to mitigate damage and total aflatoxin contamination in Mozambique. Journal of Stored Products Research, 114, 102794. https://doi.org/10.1016/j.jspr.2025.102794

Mrope, F., & Kigodi, O. (2024). Modeling the Transmission Dynamics of Maize Foliar Disease in Maize Plants. Journal of Mathematical Analysis and Modeling, 5(2), 114–135. https://doi.org/10.48185/jmam.v5i2.1198

Nations, U. (2022). Focus on governance for more effective policy and technical support. Framework paper. In Focus on governance for more effective policy and technical support. Framework paper. FAO. https://doi.org/10.4060/cc0240en

Nations, U., & Development, A. (2025). International Fund for Food Security and Nutrition.

Norman, G. (2010). Likert scales, levels of measurement and the “laws” of statistics. Advances in Health Sciences Education, 15(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y

Ortez, O. A., Lindsey, A. J., Thomison, P. R., Coulter, J. A., Singh, M. P., Carrijo, D. R., Quinn, D. J., Licht, M. A., & Bastos, L. (2023). Corn response to long-term seasonal weather stressors: A review. Crop Science, 63(6), 3210–3235. https://doi.org/10.1002/csc2.21101

Padrilah, S. N., Samsudin, N. I. P., Shukor, M. Y. A., & Masdor, N. A. (2024). Nanoemulsion strategies in controlling fungal contamination and toxin production on grain corn using essential oils. Green Chemistry Letters and Reviews, 17(1). https://doi.org/10.1080/17518253.2024.2315138

Pitcher, T. J., & Preikshot, D. (2001). Rapfish: a rapid appraisal technique to evaluate the sustainability status of fisheries. Fisheries Research, 49(3), 255–270. https://doi.org/10.1016/S0165-7836(00)00205-8

Pitcher, T., & Kavanagh, P. (2004). Implementing Microsoft Excel Software for RAPFISH: A Technique for The Rapid Appraisal of Fisheries Status. Fisheries Centre Research Reports, 12(2).

Prata, J. C., & Dias-Pereira, P. (2023). Microplastics in Terrestrial Domestic Animals and Human Health: Implications for Food Security and Food Safety and Their Role as Sentinels. Animals, 13(4), 661. https://doi.org/10.3390/ani13040661

Ramadhani, D., Suhartini, Nugroho, T. W., Muhaimin, A. W., & Wahyuningtyas, A. S. H. (2025). Dampak Pembangunan Infrastruktur Pertanian terhadap Kesejahteraan Rumah Tangga Petani Padi di Malang. Pangan, 34(1), 1–12. https://doi.org/10.33964/jp.v34i1.859

Rinansi, O., Suhartini, & Fahriyah. (2025). Analisis Keberlanjutan Usahatani Ubi Kayu (Manihot Esculenta) Di Kabupaten Sikka Provinsi Nusa Tenggara Timur. Jurnal Ekonomi Pertanian Dan Agribisnis, 9 (2), 715–729. https://doi.org/10.21776/ub.jepa.2025.009.02.24

Salun, S., Nikoyan, A., & Arif, L. O. K. (2024). Fungsi Kelompok Tani Dan Penggunaan Input Produksi Dalam Kegiatan Usahatani Jagung Di Desa Maperaha Kecamatan Sawerigadi Kabupaten Muna Barat. Jurnal Ilmiah Penyuluhan Dan Pengembangan Masyarakat, 4(1), 96–113. https://doi.org/10.56189/jippm.v4i1.21

Shaw, D. J. (2007). World Food Summit, 1996. In World Food Security (pp. 347–360). Palgrave Macmillan UK. https://doi.org/10.1057/9780230589780_35

Simane, B., Kapwata, T., Naidoo, N., Cissé, G., Wright, C. Y., & Berhane, K. (2025). Ensuring Africa’s Food Security by 2050: The Role of Population Growth, Climate-Resilient Strategies,

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v9i1.2666

and Putative Pathways to Resilience. Foods, 14(2), 262. https://doi.org/10.3390/foods14020262

Suh, J., Ji, S., & Nindi-Chigwe, T. C. (2025). Collective action under risk and uncertainty: assessing impacts on smallholder farmers' income and food security in Malawi. Frontiers in Sustainable Food Systems, 9. https://doi.org/10.3389/fsufs.2025.1607329

Syafaruddin Syafaruddin. (2024). Analysis Of The Role Of Local Governments In Sustainable Development In Urban Areas. Digital Innovation: International Journal of Management, 1(4), 212–226. https://doi.org/10.61132/digitalinnovation.v1i4.119

Taiwo, A. E., & Musonge, P. (2024). Valorization of Corn Steep Liquor for Improved Value-added Products: A Review. Recent Innovations in Chemical Engineering (Formerly Recent Patents on Chemical Engineering), 17(1), 26–43. https://doi.org/10.2174/0124055204282376231219095404

Thabane, V. N., Agholor, I. A., Ludidi, N. N., Morepje, M. T., Mgwenya, L. I., Msweli, N. S., & Sithole, M. Z. (2025). Irrigation Water and Security in South African Smallholder Farming: Assessing Strategies for Revitalization. World, 6(1), 32. https://doi.org/10.3390/world6010032

Viana, C. M., Freire, D., Abrantes, P., Rocha, J., & Pereira, P. (2022). Agricultural land systems importance for supporting food security and sustainable development goals: A systematic review. Science of The Total Environment, 806(Pt 3), 150718. https://doi.org/10.1016/j.scitotenv.2021.150718

Vieira, R. A., Uhdre, R., Scapim, C. A., & van Becelaere, G. (2025). Global corn area from 1960 to 2030: patterns, trends and implications. The Journal of Agricultural Science, 163(3), 295–306. https://doi.org/10.1017/S002185962500019X

Viganò, E., Maccaroni, M., & Righi, S. (2022). Finding the right price: supply chain contracts as a tool to guarantee sustainable economic viability of organic farms. International Food and Agribusiness Management Review, 25(3), 411–426. https://doi.org/10.22434/IFAMR2021.0103

Wossen, T., Abdoulaye, T., Alene, A., Haile, M. G., Feleke, S., Olanrewaju, A., & Manyong, V. (2017). Impacts of extension access and cooperative membership on technology adoption and household welfare. Journal of Rural Studies, 54, 223–233. https://www.sciencedirect.com/science/article/pii/S0743016716302790

Yuan, X., Li, S., Chen, J., Yu, H., Yang, T., Wang, C., Huang, S., Chen, H., & Ao, X. (2024). Impacts of Global Climate Change on Agricultural Production: A Comprehensive Review. Agronomy, 14(7), 1360. https://doi.org/10.3390/agronomy14071360

Yusuf, L. O. M. I., Firmansyah, M., Masyitah, M., & Syafitri, S. (2025). Evaluasi Keberlanjutan Pertanian Jagung dalam mendukung Ketahanan Pangan (Studi Kecamatan Sawerigadi Kabupaten Muna Barat Indonesia). JIA (Jurnal Ilmiah Agribisnis): Jurnal Agribisnis Dan Ilmu Sosial Ekonomi Pertanian, 10(6), 668–678. https://doi.org/10.37149/jia.v10i6.2405

Yusuf, L. O. M. I., Ismail, A., & Nuva, N. (2023). Evaluasi Status Keberlanjutan Budidaya Rumput Laut Di Kecamatan Pasikolaga Kabupaten Muna (Pendekatan Rapfish- Multidimensional Scaling). Jurnal Ilmu Lingkungan, 21(1), 150–158. https://doi.org/10.14710/jil.21.1.150-158