JURNAL PENATAAN RUANG
Volume 21 Number 1, May, 2026
P-ISSN 1907-4972 | E-ISSN 2716-179X
DOI: https://doi.org/10.12962/j2716179X.v21i1.9198

GIS-Based Mapping of the Palm Sugar Industry and Cluster Component Identification Using Porter's Diamond Framework for Local Economic Development

Sri Apriani Puji Lestari[✉ 1], Jafar Mukhlis[1], Mahfuzur Rahman Syatar[1], Hasanul Yaomi[1], Andimas Mukhadam[1], Indra[1]

[1]Program Studi Perencanaan Wilayah dan Kota Universitas Sulawesi Barat, Majene, Indonesia

Received: 03/02/2026 | Reviewed: 02/03/2026 | Accepted: 19/05/2026

✉ sriaprianipuji@gmail.com

Abstract: Polewali Mandar Regency has substantial sugar palm resources, yet the development of the palm sugar home industry is constrained by the absence of a distribution map and a weak competitive position. This study maps the spatial distribution of palm sugar processing units using Geographic Information Systems (GIS) and assesses clustering with the Average Nearest Neighbor (ANN) statistic and then identifies cluster-forming components using Porter's Diamond to support local economic development. Coordinates of processing units were collected through field surveys and interviews and analyzed within the administrative boundary of Polewali Mandar Regency. The ANN results indicate a statistically significant clustered pattern, with the highest concentrations in the northern and northeastern uplands, where sugar palm trees are abundant, suggesting agglomeration economies. Porter's Diamond analysis further suggests that the palm sugar industry exhibits characteristics of an emerging functional cluster structure consisting of core processors, related food-and-beverage MSMEs, and supporting services such as packaging, machinery/equipment, and logistics. The cluster is reinforced by Triple Helix collaboration, where government provides enabling facilities and promotion programs, academia contributes knowledge and technology transfer, and financial institutions help address financing constraints. The findings provide a spatial basis for agro-industrial zoning, infrastructure prioritization, and value-chain upgrading strategies to strengthen cluster competitiveness and support sustainable local economic development in Polewali Mandar Regency.

Keywords: Geographic Information Systems; Porter's Diamond; industrial cluster; local economic development; palm sugar.

1. Introduction

Regional development in Indonesia has long relied on top-down and sectoral approaches (e.g., development from above, agropolitan programs, and selective spatial closure). In many places these approaches have been difficult to implement consistently and have not always produced the expected outcomes. Local economic development endeavors to integrate these concepts by enhancing the role of endogenous development elements within local socio-economic dynamics and by examining their functional and spatial interconnections and integrating them with broader regions (Sanjaya, 2024).

LED encourages communities and local governments to mobilize local resources to strengthen value chains, create jobs, improve competitiveness, and support poverty reduction and inclusion (Baker et al., 2023)(OECD, 2024). A practical instrument to operationalize these aims is industrial cluster development, particularly for micro, small, and medium enterprises (MSMEs), because clustering can consolidate local capabilities, improve market access, and reinforce regional economic empowerment (Fadillah et al., 2025)(Hasanah et al., 2023). Cluster-based strategies are frequently promoted because they facilitate coordination and collective action, improve efficiency through shared services and complementarities, and strengthen learning and knowledge exchange among firms and supporting institutions (Galaso & Rodríguez Miranda, 2021)(Ganske & Carbon, 2023a)(Zhao et al., 2023)(Wudu et al., 2024).

A cluster refers to a geographical concentration of interconnected firms and institutions in a particular field, including specialized suppliers, service providers, and supporting organizations such as universities, associations, and government agencies (Porter, 2000). Clusters can generate collective advantages through proximity, repeated interactions, knowledge transfer, and joint problem-solving, which enhance productivity and innovation within regions. Recent studies further underline that factors such as stakeholder synergy, innovation capability, entrepreneurship, infrastructure, market access, business development services, competition–collaboration dynamics, leadership, and government support strongly influence cluster performance (Akpinar, 2024)(Coman et al., 2024)(Ganske & Carbon, 2023b)(Galaso & Rodríguez Miranda, 2021)(OECD, 2021)(Lestari et al., 2019).

Polewali Mandar Regency has the largest area of sugar palm plantations in West Sulawesi, with an estimated potential of 876 hectares, of which 490 hectares are productive and yield around 404 tons of sap . Sap is traditionally processed into palm sugar and has become a flagship home-industry product. At the same time, regional economic growth is reported to be moderate (Wali et al., 2025), suggesting that strengthening local agroindustry could contribute to welfare improvements.

However, palm sugar development still faces constraints, notably the absence of a comprehensive distribution/cluster map and a relatively weak competitive position (Nurmiati, 2022). GIS-based MSME mapping is useful for visualizing business locations, diagnosing spatial patterns, and supporting targeted planning and competitiveness programs (Maesaroh, 2020)(Prasetya et al., 2025). More broadly, MSME competitiveness challenges include limited technology infrastructure, skill constraints, and uneven digital adoption (Anwar et al., 2023), as well as weak branding and market capabilities (Laurina et al., 2024)(Wijaya & Lathifah, 2024).

Previous studies on MSMEs and agroindustry development have generally focused either on GIS-based spatial distribution analysis (Maesaroh, 2020)(Prasetya et al., 2025) or on competitiveness analysis separately using cluster approaches (Pratiwi et al., 2024)(Yasin et al., 2024). GIS-based studies mainly emphasize business mapping and spatial visualization, while industrial cluster studies commonly focus on competitiveness factors without explicitly integrating spatial concentration and geographical interaction. Consequently, limited attention has been given to understanding how spatial agglomeration patterns interact with industrial cluster dynamics and local economic development processes, particularly in rural agroindustrial sectors.

This study positions itself at the intersection of spatial analysis and industrial cluster competitiveness studies by integrating Geographic Information Systems (GIS), Average Nearest Neighbor (ANN) analysis, and Porter's Diamond Framework within a single analytical framework. Rather than merely applying GIS and cluster methodologies as technical tools, this research seeks to explain how spatial concentration patterns contribute

to the emergence of industrial clusters and how institutional interactions, supporting industries, and market conditions influence the competitiveness of the palm sugar industry in Polewali Mandar Regency.

Accordingly, this study addresses the following research questions: (1) How is the spatial distribution pattern of the palm sugar industry in Polewali Mandar Regency? (2) How do supporting institutions, related industries, and market interactions contribute to cluster competitiveness? (3) What are the implications of the identified cluster structure for spatial planning and local economic development strategies?

Based on these questions, this study aims to (1) analyze the spatial distribution and clustering characteristics of the palm sugar industry using GIS and Average Nearest Neighbor analysis (2) examine the structural and institutional components that shape cluster competitiveness using Porter's Diamond Framework and (3) formulate spatial planning and local economic development strategies based on the interaction between spatial agglomeration and cluster dynamics.

GIS-based mapping provides a visual representation of palm sugar industry locations and facilitates analysis of spatial distribution patterns. Meanwhile, Porter's Diamond analysis identifies cluster-forming components, including core, supporting, and related sectors; suppliers; markets; and the roles of supporting institutions/agencies. The integration of spatial and competitiveness analyses is expected to provide a stronger basis for regional planning, cluster-based policy formulation, infrastructure prioritization, and sustainable local economic development in Polewali Mandar Regency.

The study contributes theoretically by integrating spatial clustering analysis with industrial cluster competitiveness analysis within the context of local economic development. Practically, the findings provide evidence-based recommendations for cluster-oriented spatial planning, infrastructure prioritization, and agroindustrial development policy in Polewali Mandar Regency.

2. Method

2.1. Research Design

This study uses a mixed-method design to examine palm sugar MSME development from a spatial and cluster perspective. Quantitatively, GIS is used to compile location data and to test the overall distribution pattern of processing units. Qualitatively, interviews and documentation are analyzed to identify cluster components (core, related, and supporting industries; suppliers; buyers/markets; and supporting institutions) and interpret them using Porter's Diamond.

The analytical framework of this study integrates spatial analysis and cluster competitiveness analysis in a sequential manner. First, GIS-based mapping and Average Nearest Neighbor (ANN) analyzis are used to identify the spatial concentration and clustering characteristics of palm sugar industries. Second, the identified clusters are analysed using Porter's Diamond Framework to examine factor conditions, supporting industries, demand conditions, institutional roles, and inter-firm interactions. Finally, the findings from both analyses are synthesized to formulate spatial planning and local economic development strategies.

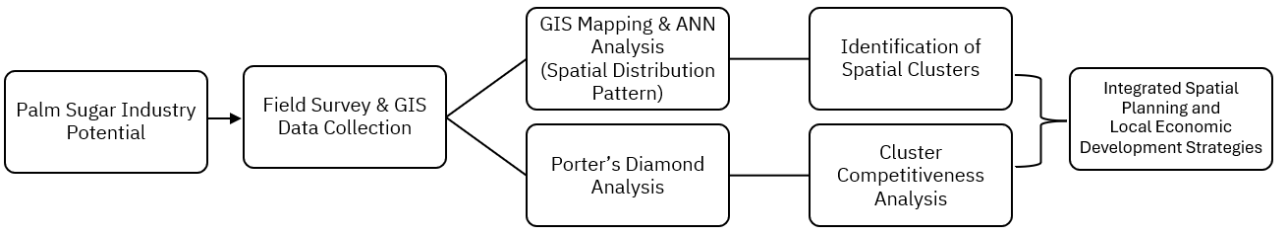

Figure 1. Research Framework

2.2. Data Collection

The data sources used are primary and secondary. Primary data were collected through field surveys and semi-structured interviews with the Department of Industry, Cooperatives, and Small and Medium Enterprises of

Polewali Mandar Regency; and palm sugar business owners in the study districts. Stakeholders were identified using purposive stakeholder mapping based on their direct involvement in the palm sugar value chain and cluster development process (Galaso & Rodríguez Miranda, 2021) (Ganske & Carbon, 2023c);

The interviews involved one representative from the Department of Industry, Cooperatives, and Small and Medium Enterprises of Polewali Mandar Regency as the primary institutional informant and 25 palm sugar business owners representing the major producing and clustered districts. Respondents were selected purposively based on the concentration of business units, spatial clustering characteristics, and their involvement in production and marketing activities. Districts with larger numbers of enterprises and stronger clustering tendencies, such as Tapango, Balanipa, Campalagian, and Luyo, were represented by a larger number of respondents to capture cluster dynamics more comprehensively.

These informants were selected because they possess direct knowledge regarding production activities, institutional support, and cluster dynamics. Supporting actors such as packaging providers, equipment services, transportation actors, and other related institutions were not interviewed directly; however, their roles and interactions within the cluster system were identified through stakeholder tracing based on interviews, field observations, and supporting documentation. This approach is consistent with qualitative cluster studies that rely on key informants and purposive sampling to explain inter-organizational relationships and cluster structures (Creswell & Creswell, 2018)(Guest et al., 2006).

The survey recorded the coordinates of palm sugar processing units using Avenza Maps and documented basic supporting-infrastructure conditions. Secondary data were obtained from agency records, documents, and relevant literature.

2.3. Data Analysis

A geospatial database was created by compiling the coordinates of palm sugar processing units from field surveys and interviews and cross-checking them with secondary records from local agencies. Each processing unit was represented as a point feature; therefore, the unit of analysis is the individual household/enterprise location rather than an administrative centroid. The study boundary follows the administrative boundary of Polewali Mandar Regency and was used consistently for map visualization and spatial statistical analysis. All coordinates were projected into a metric coordinate system to ensure accurate Euclidean distance calculations.

2.3.1. Nearest Neighbor Analysis

The Average Nearest Neighbor (ANN) method was selected because it provides a statistically robust global indicator for determining whether industrial locations tend to cluster, disperse, or distribute randomly within a study area (Widayanti & Yulita, 2024)(Zhang et al., 2023). Compared with descriptive mapping alone, ANN enables the spatial concentration pattern to be quantified through the Nearest Neighbor Ratio (R), z-score, and p-value.

Alternative methods such as Kernel Density Estimation (KDE) and Moran's I were considered; however, KDE primarily visualizes density concentration without directly testing statistical randomness, while Moran's I is generally more suitable for areal or attribute-based spatial autocorrelation. Since this study uses point-location data of palm sugar processing units, ANN was considered the most appropriate method for identifying the overall clustering tendency of the industry.

Spatial clustering was tested using the Average Nearest Neighbor (ANN) tool in ArcGIS. ANN compares the observed mean distance between each point and its nearest neighbor to the expected mean distance under complete spatial randomness within the study boundary.

For each processing unit, the nearest neighbor distance (d_i) was calculated. The observed mean distance is $d_o = (\Sigma d_i)/n$. The expected mean distance under randomness is $d_e = 0.5/\sqrt{(n/A)}$, where n is the number of points and A is the study area. The nearest neighbor ratio is $R = d_o/d_e$.

Interpretation follows: $R < 1$ indicates clustering, $R \approx 1$ indicates randomness, and $R > 1$ indicates dispersion. Statistical significance was assessed using the z-score and p-value produced by the ANN tool at a 95%

confidence level ($p < 0.05$). Distances were computed as Euclidean distances in the projected coordinate system.

Because ANN is a global spatial statistic, the method only identifies the overall clustering tendency and does not reveal local hotspots or multi-scale clustering variations (Tang & Tang, 2024)(Zhang et al., 2023). Therefore, future studies are recommended to complement ANN with Kernel Density Estimation (KDE), Local Moran's I, or Getis-Ord Gi* analysis to identify local concentration patterns more comprehensively.

2.3.2. Porter's Diamond Analysis

Porter's Diamond Framework was employed because industrial cluster development is not solely determined by spatial proximity but also by interactions among factor conditions, supporting industries, market demand, institutional support, and firm strategy (Porter, 1990)(Porter, 2000). Therefore, combining ANN and Porter's Diamond enables this study to connect spatial agglomeration patterns with competitiveness dynamics and local economic development processes.

Qualitative descriptive analysis was used to identify and interpret cluster-forming components, including core industries, related and supporting industries, suppliers, markets and buyers, and supporting institutions/agencies.

Stakeholders were identified using purposive stakeholder mapping based on their direct involvement in the palm sugar value chain and cluster development process. The selected stakeholders include government institutions, palm sugar producers, supporting business actors, and academic institutions. The importance of institutional interaction and stakeholder collaboration in cluster development has been emphasized in previous cluster studies (Galaso & Rodríguez Miranda, 2021)(Ganske & Carbon, 2023b).

Interview and documentation data were analyzed through data reduction, data display, and conclusion verification to identify relationships among cluster actors and competitiveness determinants.

3. Results and Discussion

3.1. Mapping the Spatial Distribution Pattern of the Palm Sugar Industry

Polewali Mandar Regency consists of 16 districts with a total area of 1,775.65 km². Based on surveys and interviews, palm sugar processing units were identified in nine districts: Anreapi, Alu, Tapango, Luyo, Limboro, Campalagian, Binuang, Bulo, and Balanipa (Table 1).

The Average Nearest Neighbor (ANN) results in Table 1 provide a district-level diagnosis of the spatial organization of the palm sugar industry. The ANN approach produces a Nearest Neighbor Ratio (R) by comparing the observed mean distance between each enterprise and its closest neighbor with the expected mean distance under a random (Poisson) distribution. Under this convention, $R < 1$ indicates clustering, $R \approx 1$ indicates randomness, and $R > 1$ indicates dispersion.

Table 1 indicates that clustering is the dominant configuration across the regency. Seven of the nine districts are classified as clustered, with R values substantially below one. The strongest clustering is observed in Campalagian (n = 28; R = 0.215009) and Luyo (n = 26; R = 0.283963), followed by Balanipa (n = 44; R = 0.347752). Clustering is also evident in Limboro (n = 6; R = 0.424454), Bulo (n = 14; R = 0.595786), Tapango (n = 84; R = 0.618213), and Anreapi (n = 8; R = 0.650329). Collectively, these values indicate that most enterprises are located closer to one another than would be expected under a random process, implying the presence of distinct production nodes within districts rather than a uniform spatial spread.

These quantitative patterns align with the manuscript's description that the main concentrations occur in the northern and northeastern parts of the regency (Figure 2), particularly in upland districts where sugar palm trees are abundant. This supports a resource-based location logic: processing activities are drawn toward areas where inputs are dense and reliable. The manuscript's interpretation that raw material availability shapes enterprise location decisions and that proximity reduces transport costs from plantations to processing sites is consistent with the direction and magnitude of the R values in the clustered districts (Heizer et al., 2020)(Porter, 2000). In

practical terms, proximity reduces the time and cost of sap collection, lowers the risk of quality deterioration during handling, and improves the reliability of production schedules, which is especially important for small and medium processors operating with limited storage and working capital.

Differences in clustering intensity among the clustered districts likely reflect how resource endowment interacts with accessibility and settlement structure. The exceptionally low R values in Campalagian and Luyo suggest localized "hotspots" where multiple enterprises concentrate near the same plantation belts or village nodes. Such co-location can also support informal knowledge exchange, easier access to labor, and more frequent interactions with traders and supporting services. Tapango displays clustering even with the largest number of enterprises (n = 84), indicating that sector growth has occurred through densification within favorable areas rather than through dispersion across the district. By contrast, Anreapi's higher clustered ratio (R = 0.650329) still indicates concentration but suggests a comparatively wider spacing of enterprises within clustered zones, which may be consistent with more fragmented plantation distribution or greater travel friction within upland terrain. Although the R-value suggests clustering tendency, the p-value slightly exceeds the 0.05 threshold, indicating that clustering in Anreapi is not statistically significant at the 95% confidence level.

The western and southern parts of the regency, represented most clearly by Alu and Binuang, show a sparser and more weakly concentrated distribution. Alu is dispersed (n = 9; R = 1.351888), suggesting enterprises are more evenly spaced than expected under randomness, while Binuang is near-random (n = 11; R = 1.002).

Field observations described in the manuscript attribute this contrast to different land-use characteristics (more urban areas and non–sugar palm agriculture) and lower sugar palm resource potential compared with the northern uplands. In such settings, limited resource availability can constrain the emergence of dense production nodes, while competing land uses may restrict where processing can feasibly occur, producing either scattered spacing (dispersion) or a pattern that lacks strong spatial structure (randomness).

Overall, Table 1 and the mapped pattern in Figure 2 converge on a clear inference: the regency's palm sugar industry is organized around resource-driven clusters in the northern and northeastern uplands, while the west and south exhibit comparatively sparse, random, or dispersed distributions.

This structure has practical implications for development strategy. In clustered districts, cluster-oriented interventions—such as shared processing facilities, collective quality-control and packaging services, targeted logistics improvements, and local training—are likely to be more efficient because they can serve many enterprises within a compact area. Upgrading feeder roads and providing collection points can reinforce efficiency in northern clusters. Business-development services, certification support, and cooperative marketing are more cost-effective when enterprises are concentrated. Conversely, in the west and south, cluster programs may deliver lower returns; strategies may need to focus on improving resource potential, managing competing land uses, or supporting alternative value chains where sugar palm is scarce.

Table 1. Spatial distribution pattern based on nearest neighbor analysis using GIS (2025)

District	Number	Nearest Neighbor Ratio	Z score	P-value	Distribution Pattern
Alu	9	1.351888	2.019557	0.043429	Dispersed
Anreapi	8	0.650329	-1.892064	0.05482	Clustered
Balanipa	44	0.347752	-8.276942	0.0000	Clustered
Binuang	11	1.002	1.440375	0.149761	Random
Bulo	14	0.595786	-2.893383	0.003811	Clustered
Campalagian	28	0.215009	-8.087128	0.0000	Clustered
Limboro	6	0.424454	-2.697035	0.006996	Clustered
Luyo	26	0.283963	-3.724254	0.000196	Clustered
Tapango	84	0.618213	-12.554698	0.0000	Clustered

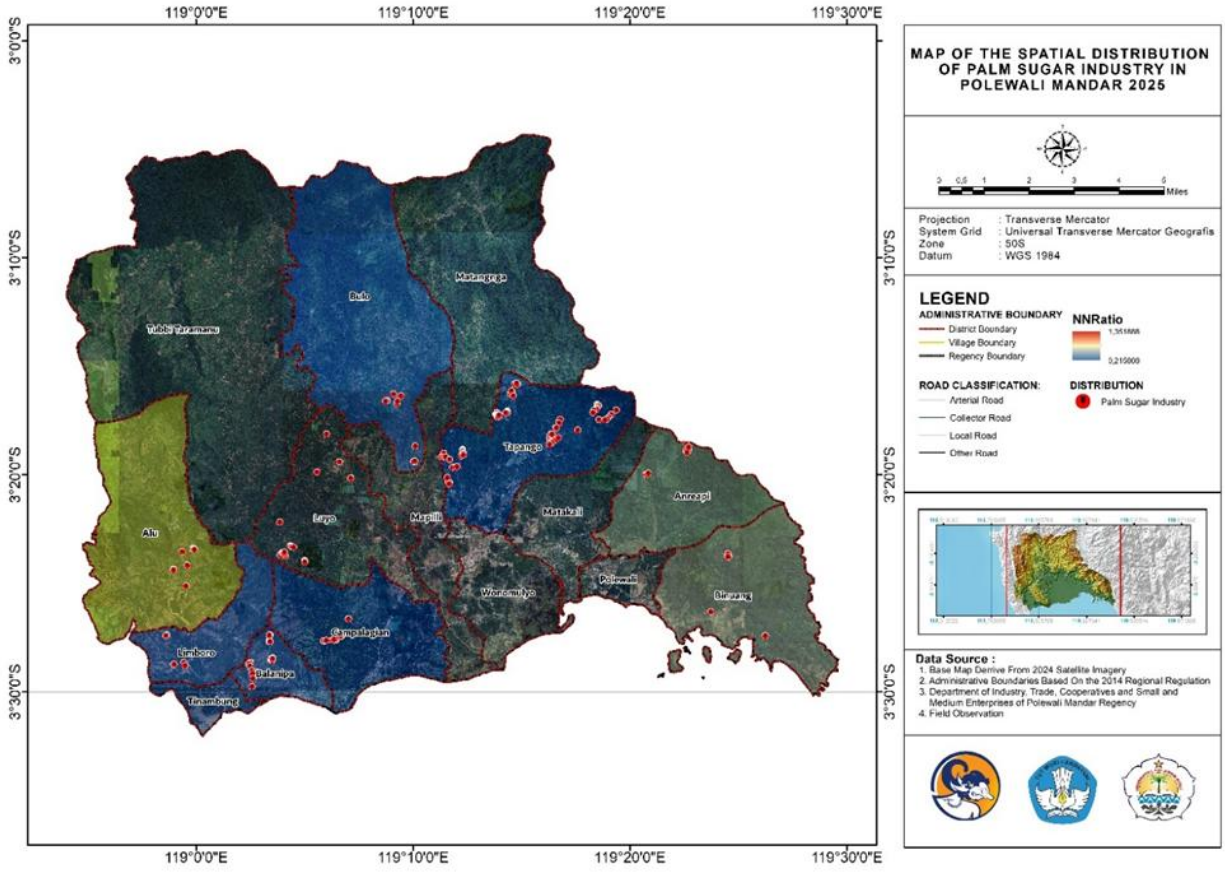

Figure 2. GIS-based map of the spatial distribution pattern of the palm sugar industry

The clustered pattern can indicate agglomeration economies: firms co-locate to benefit from shared access to inputs, labor, knowledge, and more efficient supply chains. Such spatial agglomeration can support knowledge accumulation and adaptive learning, which are important for cluster upgrading (Kakerissa & Hahury, 2022).

3.2. Mapping Cluster Components Using Porter's Diamond

This section summarizes the palm sugar cluster structure in Polewali Mandar from an industrial-cluster perspective. In regional planning, a cluster is not only a concentration of firms but also a system of interactions among core firms, suppliers, service providers, and institutions that generates collective competitive advantages (Porter, 2000).

Interviews indicate that the cluster's core activity is palm sugar processing (value-added production) rather than raw-material trade. The large number of processing units (230 business units) suggests active local competition and incentives for product and process improvements (e.g., packaging and derivative products). Related industries include processed food-and-beverage MSMEs and palm flour/sago businesses, indicating movement beyond basic commodity production toward downstream development that can strengthen demand conditions for quality and standardization (Porter, 1990).

Supporting industries span upstream and downstream services, including seedling suppliers; machinery/equipment services; packaging and label/printing services; and transportation/logistics. Co-location of core, related, and supporting activities can reduce transaction costs and improve efficiency (Porter, 2000), consistent with evidence that agglomeration/clustering can reduce transaction and operating costs, generate employment opportunities, and strengthen competitiveness gains (Cai et al., 2025)(Xiao et al., 2025).

Government support plays a key role in shaping the enabling environment. Documentation and interviews show that the regency government established an SME gallery (2018) for product promotion and a packaging house facility (2021) to improve packaging quality. Training, equipment support, and exhibitions are also provided by relevant agencies at regency and provincial levels. Such interventions align with contemporary cluster and innovation-ecosystem policy perspectives that prioritize building enabling framework conditions and network connectivity for collective innovation and shared goals, recognizing that complex challenges are not solved by actors in isolation (Ganske & Carbon, 2023b)(Thornton, 2023).

Academia is involved through research and community-service activities that support knowledge and technology transfer (e.g., improved processing hygiene, packaging, and marketing), which can enhance competitiveness (Cheng et al., 2024). However, financing remains a constraint: many MSMEs rely on personal capital or informal loans, while access to formal finance is limited by administrative requirements. This can restrict scaling and upgrading, highlighting the importance of strengthening the financial node within the cluster (International Monetary Fund. Asia and Pacific Dept, 2024).

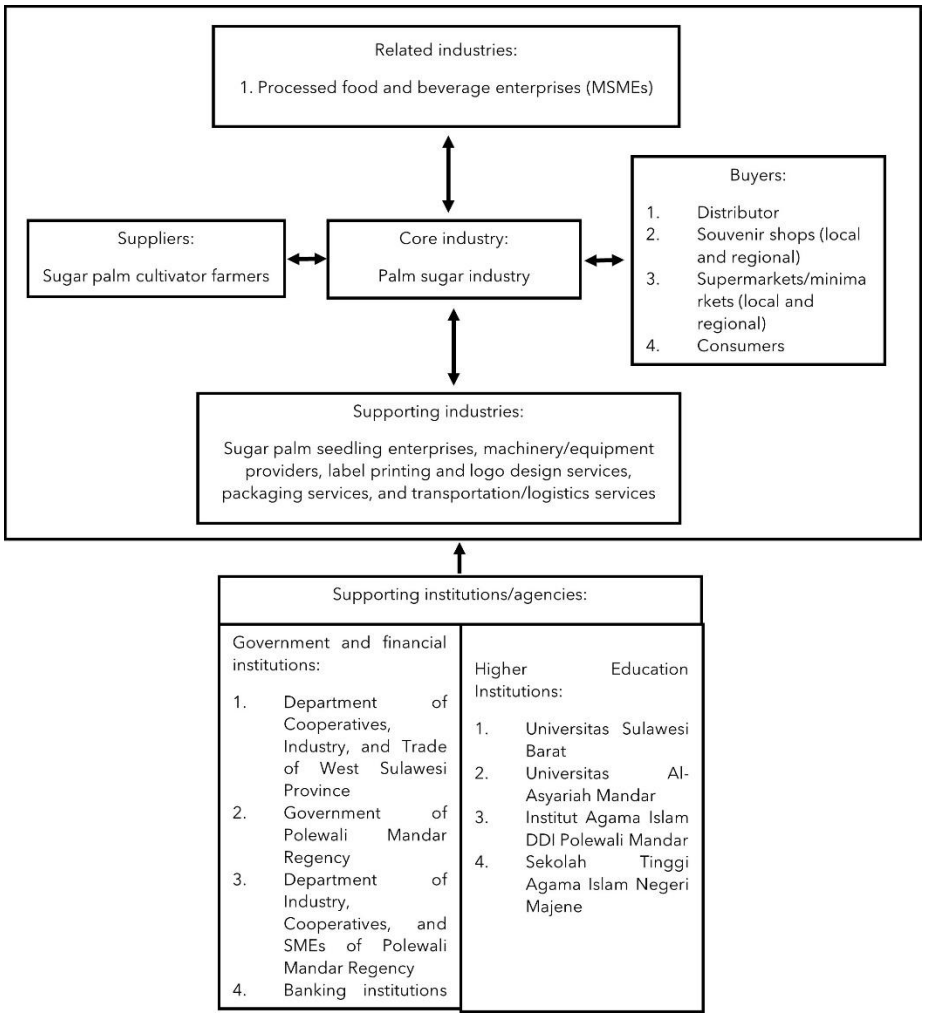

Figure 3. Components of the palm sugar industry cluster in Polewali Mandar (2025)

The findings suggest that the palm sugar concentration exhibits characteristics of a functional cluster in which interactions among core, related, and supporting actors create collective advantages. The presence of downstream-related activities and packaging/design support indicates potential for value-chain upgrading and higher value capture.

3.3. Integration of ANN and Porter's Diamond Analysis

The ANN results and Porter's Diamond analysis collectively indicate that the palm sugar industry exhibits characteristics of an emerging functional cluster. The statistically significant clustered pattern identified through ANN reflects geographical proximity among producers, which creates opportunities for interaction, resource sharing, collective efficiency, and knowledge exchange (Porter, 2000)(Xiao et al., 2025).

In clustered districts such as Campalagian, Luyo, and Balanipa, the proximity among enterprises facilitates easier access to suppliers, labor, transportation networks, and market information. Such conditions strengthen factor conditions and related supporting industries, which are central components of Porter's Diamond Framework. Similar findings have been reported in previous studies emphasizing the role of institutional support and industrial interaction in strengthening cluster competitiveness (Galaso & Rodríguez Miranda, 2021)(Zhao et al., 2023).

The findings demonstrate that spatial agglomeration and cluster competitiveness are interconnected processes. Spatial concentration creates the physical basis for interaction and efficiency, while institutional support, supporting industries, and market linkages determine whether agglomeration demonstrates the characteristics of a sustainable industrial cluster.

3.4. Spatial Planning and Local Economic Development Implications

The identified clustering pattern has important implications for spatial planning and local economic development policy. Districts with strong clustering characteristics such as Campalagian, Luyo, Tapango, and Balanipa can be prioritized as agroindustrial cluster zones within regional spatial planning instruments (RTRW and RDTR). Spatial planning studies indicate that accessibility, land-use designation, and infrastructure networks strongly influence the concentration and development of small business activities (Widita & Lechner, 2024)(Tang & Tang, 2024).

Infrastructure development should therefore prioritize farm-to-market roads, logistics accessibility, clean water and energy provision, digital connectivity, waste management facilities, and shared processing and packaging facilities.

Cluster strengthening strategies should also focus on value-chain upgrading through product diversification, standardized hygienic processing, branding improvement, certification, and cooperative marketing systems. Previous agroindustrial studies have emphasized that value-chain governance and downstream upgrading are important for improving competitiveness and increasing local value capture (Nurohmah et al., 2024)(Astuti et al., 2025).

Furthermore, Triple Helix collaboration among government, academia, and business actors can support innovation diffusion, entrepreneurship development, and technology transfer (Commission, 2025)(Cheng et al., 2024). However, strengthening institutional coordination and improving access to formal finance remain necessary to support sustainable cluster development. Sustainable cluster development should also consider environmental carrying capacity, waste management, and inclusive participation of small-scale producers to ensure that economic benefits are distributed more equitably and do not generate new environmental pressures.

3.5. Discussion in Relation to Recent Studies (2021–2025)

Recent GIS-based point-pattern studies often combine ANN/NNA with complementary techniques (e.g., kernel density estimation, spatial autocorrelation, and multi-distance clustering) to capture both global and local concentration. This study uses ANN as an initial diagnostic; future work can strengthen policy targeting by adding multi-scale and local analyses for hotspot identification (Zhang et al., 2023)(Tang & Tang, 2024).

Indonesian evidence shows that MSMEs tend to concentrate in areas with supportive commercial land uses and good accessibility and that land-use and built-environment policy can enable or constrain agglomeration (Widita & Lechner, 2024). The clustered pattern in Polewali Mandar is therefore not only a market outcome but also a spatial planning issue, where service infrastructure, road connectivity, and compatible zoning may reinforce cluster evolution.

From a competitiveness perspective, recent palm sugar studies emphasize governance and upgrading as key levers for improving value capture (Nurohmah et al., 2024)(Astuti et al., 2025). International evidence further suggests that well-supported agro-industrial clusters can enhance productivity and create spillovers to neighboring areas (Xu et al., 2025), supporting the integration of cluster-based LED with spatial plans that provide enabling infrastructure and clear land-use direction.

4. Conclusion

The palm sugar industry in Polewali Mandar Regency demonstrates a statistically significant clustered spatial distribution pattern. The Average Nearest Neighbor (ANN) analysis shows that more districts have Nearest Neighbor Ratio (R) values below one, particularly Campalagian (R = 0.215009), Luyo (R = 0.283963), and Balanipa (R = 0.347752), indicating strong spatial clustering tendencies. Several clustered districts produced statistically significant z-scores and p-values below 0.05, confirming that the observed clustering pattern is unlikely to occur randomly. These findings indicate that raw-material availability, accessibility, and transportation efficiency strongly influence the spatial concentration of palm sugar processing activities in the northern and northeastern upland areas of Polewali Mandar Regency.

The integration of ANN and Porter's Diamond analysis suggests that the palm sugar industry exhibits characteristics of an emerging functional cluster structure rather than merely a simple spatial agglomeration. The cluster is characterized by interactions among core industries, supporting industries, suppliers, markets, and institutional actors. The presence of Triple Helix collaboration among government, academia, and financial institutions strengthens cluster competitiveness through training, technology transfer, packaging support, promotion programs, and financial facilitation. These interactions create opportunities for collective efficiency, value-chain upgrading, and downstream agroindustrial development.

The findings imply that cluster-based spatial planning strategies should prioritize agroindustrial zoning, infrastructure improvement, logistics connectivity, and institutional strengthening in high-concentration districts such as Campalagian, Luyo, Tapango, and Balanipa. Strengthening downstream industries, packaging quality, certification systems, digital marketing, and cooperative marketing mechanisms can improve local value capture and support sustainable local economic development. Therefore, the integration of spatial planning and industrial cluster development is important for enhancing regional competitiveness and promoting inclusive economic growth in Polewali Mandar Regency.

Nevertheless, this study has several limitations. First, the ANN method only provides a global clustering indicator and does not identify local hotspot variations or multi-scale clustering dynamics. Second, the study boundary follows the administrative boundary of Polewali Mandar Regency, which may produce edge effects and overlook cross-boundary interactions. Third, the analysis relies primarily on field surveys and interview-based data collection, which may introduce reporting bias or omit unregistered household-scale enterprises. Fourth, the study is based on cross-sectional data and therefore does not capture temporal changes in cluster evolution. Future studies are recommended to incorporate kernel density estimation, local spatial autocorrelation analysis, remote sensing data, and longitudinal approaches to better understand the dynamics of agroindustrial clustering.

Acknowledgement

The authors express their sincere gratitude for financial support from the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia (Bima-PDP). This support enabled the research implementation and the preparation of this article.

References

Akpinar, M. (2024). *A stakeholder-oriented approach to managing cluster relationships. In M. Kiese, R. C. Beck, D. Fornahl, & C. Ketels*

(Eds.) Beyond innovation hotspots: Clusters for competitiveness and transformation in real regions (pp. 145–164). Edward Elgar Publishing.

Anwar, H., Sya'rawi, H., & Pratiwi, E. L. (2023). Faktor Penghambat Daya Saing Usaha Mikro Kecil Menengah Kota Banjarmasin Dalam Menghadapi Era Industri 5.0. *Jurnal Intekna*, *23*(2), 179–183. https://ejurnal.poliban.ac.id/index.php/intekna/article/view/14407

Astuti, N., Dewi, N., & Maharani, E. (2025). Analisis Rantai Nilai Agroindustri Gula Aren Murni dan Campuran di Kecamatan Rambah, Kabupaten Rokan Hulu, Indonesia. *Journal of Integrated Agribusiness*, *7*(1), 110–124. https://doi.org/10.33019/jia.v7i1.5435

Baker, J., Choi, N., Gonzalez-Schuler, M., & Sivaev, D. (2023). Cities, Jobs, and Local Economic Development: A Guidance Note for Task Teams. *Cities, Jobs, and Local Economic Development: A Guidance Note for Task Teams*, (May). https://doi.org/10.1596/41519

Cai, Y., Zhang, Y., Gong, Y., Li, W., & Li, F. (2025). The Impact of Logistics Industry Clustering on Green Total Factor Productivity: Evidence from China. *Sustainability (Switzerland)*, *17*(17), 1–27. https://doi.org/10.3390/su17177978

Cheng, C. H., Li, M. H., Tang, B. J., & Cheng, Y. R. (2024). The Impact of Knowledge Management and Organizational Learning Promotion in Small and Medium Enterprises on the Implementation of Industry 4.0 and Competitiveness. *Administrative Sciences*, *14*(8). https://doi.org/10.3390/admsci14080161

Coman, C.-I., Alexoaei, A.-P., & Cojanu, V. (2024). The Role of Clusters in Managing Technological Challenges and Achieving Resilient Agri-Food Systems at the Global Level. *Proceedings of the International Conference on Business Excellence*, *18*(1), 1495–1505. https://doi.org/10.2478/picbe-2024-0123

Commission, E. (2025). *Horizon Europe Work Programme 2025 10 . European Innovation Ecosystems (EIE) (European Commission Decision C (2025) 2779 of 14 May 2025)* (Number May).

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.)*. SAGE Publications.

Fadillah, T. D., Khairina, Ikhsan, A., & Amin, N. A. (2025). *Local Economic Development Strategy Through Human*. *7*(2), 286–304. https://journal.uinsgd.ac.id/index.php/aksy/index

Galaso, P., & Rodríguez Miranda, A. (2021). The leading role of support organisations in cluster networks of developing countries. *Industry and Innovation*, *28*, 902–931. https://doi.org/10.1080/13662716.2020.1856046

Ganske, P., & Carbon, C.-C. (2023a). Re-thinking cluster policies: the role of shared vision and Place Leadership on the development of resilient clusters. *Leadership, Education, Personality: An Interdisciplinary Journal*, *4*(1–2), 1–6. https://doi.org/10.1365/s42681-023-00032-9

Ganske, P., & Carbon, C. C. (2023b). Successful clusters through successful communication: why clusters should be managed by Place Leaders. *Frontiers in Communication*, *8*. https://doi.org/10.3389/fcomm.2023.1194103

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field Methods*, *18*(1), 59–82. https://doi.org/10.1177/1525822X05279903

Hasanah, Q., Pratiwi, I. Y. R., & Amalia, Z. (2023). Analysis distribution and segmentation of micro, small, and medium enterprises (MSMEs) in Kediri Residency Area: implications for local economic development. *MATRIX : Jurnal Manajemen Teknologi Dan Informatika*, *13*(3), 130–141. https://doi.org/10.31940/matrix.v13i3.130-141

Heizer, J., Render, B., & Munson, C. (2020). *Operations management: Sustainability and supply chain management (13th ed.).* Pearson Education.

International Monetary Fund. Asia and Pacific Dept. (2024). Financing Barriers and Performance of Micro, Small, and Medium Enterprises (MSMES). In *IMF Staff Country Reports* (Vol. 2024, Number 271). https://www.elibrary.imf.org/view/journals/002/2024/271/article-A002-en.xml

Kakerissa, A. L., & Hahury, H. D. (2022). Identifikasi Potensi Klaster Industri Pembekuan Ikan Di Pulau Ambon. In *Arika* (Vol. 16, Number 1, pp. 27–35). https://doi.org/10.30598/arika.2022.16.1.27

Laurina, N. A., Swastuti, E., Nurchayati, N., & Yunita, L. E. (2024). Meningkatkan Daya Saing UMKM Melalui Branding dan Inovasi Digital. In *Dst* (Vol. 4, Number 1, pp. 7–15). https://doi.org/10.47709/dst.v4i1.3636

Lestari, S. A. P., Kurniawan, A., & Ridha, R. (2019). Sinergitas Jejaring Klaster MEP Sekarbela dalam Kerangka Sistem Inovasi Daerah. In *Journal of Regional and Rural Development Planning* (Vol. 3, Number 1, p. 85). https://doi.org/10.29244/jp2wd.2019.3.1.85-94

Maesaroh, S. S. (2020). Upaya Peningkatan Daya Saing Usaha Mikro, Kecil, dan Menengah (UMKM) Kota Tasikmalaya melalui Pemanfaatan System Informasi Geografis (SIG). *Jurnal Ilmu Manajemen Dan Bisnis*, *11*(1), 61–74. https://doi.org/10.17509/jimb.v11i1.21148

Nurmiati. (2022). *Desa Ongko , Kecamatan Campalagian , Nurmiati a 0117305 Program Studi Agribisnis*.

Nurohmah, N. N., Kusnadi, N., & Kilat Adhi, A. (2024). Tata Kelola Rantai Nilai Gula Aren di Kabupaten Tasikmalaya. In *Jurnal Agribisnis Indonesia* (Vol. 12, Number 1, pp. 106–119). https://doi.org/10.29244/jai.2024.12.1.106-119

OECD. (2021). *Entrepreneurship in Regional Innovation Clusters*. https://www.oecd.org/en/publications/entrepreneurship-in-regional-innovation-clusters_2a24a552-en.html

OECD. (2024). *Job Creation and Local Economic Development 2024: The Geography of Generative AI*. OECD Publishing. https://doi.org/10.1787/2f5b8bf5-ja

Porter, M. E. (1990). *The Competitive Advantage of Nations*. Free Press.

Porter, M. E. (2000). Location, competition, and economic development: Local clusters in a global economy. *Economic Development Quarterly*, *14*(1), 15–34. https://doi.org/10.1177/089124240001400105

Prasetya, B. D., Sari, P. D. K., Ma'rouf, F., Kamilatutsaniya, N., Islami, B. M., Alviyanti, S. H., Ramadhan, A. T., Bujana, A. T., Tribuanawati, O., & Zulkarnain, E. Z. (2025). Pemetaan UMKM Unggulan Berbasis Geographic Information System (GIS) di Kelurahan Sukorame Kota Kediri. *Proceedings of The National Conference on Community Engagement*, *2*(1), 286–295.

Pratiwi, A. A., Wessiani, N. A., Suwignjo, P., & Fadli, R. (2024). Industrial Cluster Design using Value Chain Analysis and Diamond Porter's Model (Case Study in Batik Trusmi Cirebon Center). *E3S Web of Conferences*, *517*. https://doi.org/10.1051/e3sconf/202451705005

Sanjaya, A. R. A. (2024). The Concept of Local Economic Development Based on Circular Economic Specialization and Integrated Governance. *Serunai*, *2*(2), 73–81. https://doi.org/10.63019/serunai.v2i2.47

Tang, Y., & Tang, Y. (2024). Analysis of the spatial characteristics and driving forces of underground consumer service space in Chinese megacities based on multi-source data. *Sustainable Cities and Society*, *116*(October). https://doi.org/10.1016/j.scs.2024.105924

Thornton, G. (2023). *Development of an Evidence Base to Support the Development of a National Clustering Policy and Framework* (Number January).

Wali, A. H., Situmorang, R., & Taki, H. M. (2025). Kajian Perkembangan Wilayah Provinsi Sulawesi Barat. *Jurnal Bhuwana*, *5*(1), 32–40. https://doi.org/10.25105/bhuwana.v5i1.22043

Widayanti, T., & Yulita, T. (2024). Settlement Patterns of the Population Use the Average Nearest Neighbor Method. *International Journal of Scientific Research in Science, Engineering and Technology*, *11*(5), 128–132. https://doi.org/10.32628/ijsrset2411587

Widita, A. A., & Lechner, A. M. (2024). Spatial Interactions between Planned Settlements and Small Businesses: Evidence from the Jakarta Metropolitan Area, Indonesia. *Land*, *13*(2). https://doi.org/10.3390/land13020203

Wijaya, M. B., & Lathifah, N. (2024). Strategi Peningkatan Daya Saing UMKM Pengolahan Bandeng di Desa Jarangan, Kecamatan Rejoso (Menggunakan Analisis SWOT). *Inisiatif: Jurnal Ekonomi, Akuntansi Dan Manajemen*, *4*(1), 372–391. https://doi.org/10.30640/inisiatif.v4i1.3563

Wudu, A., Singh, K., & Kassahun, S. (2024). Industry clusters and firm performance: Evidence from the leather product industry in Addis Ababa. *Heliyon*, *10*(20). https://doi.org/10.1016/j.heliyon.2024.e39486

Xiao, W., Ji, C., Shao, Q., & Zhang, S. (2025). Does population agglomeration of urban clusters boost total factor productivity of enterprises? Evidence from listed companies in China. *Plos One*, *20*(6 June). https://doi.org/10.1371/journal.pone.0325703

Xu, W., Zhou, S., & Lei, H. (2025). Agro-industrial clusters, spatial effects and agricultural total factor productivity ——an empirical analysis based on county-level panel data from China. *International Review of Economics and Finance*, *102*(July). https://doi.org/10.1016/j.iref.2025.104395

Yasin, M., Fitriani, A., & Baihaqi, M. I. (2024). Analisis Struktur Klaster Industri Pada Sektor Publik. *Jurnal Ekonomi Bisnis Dan Kewirausahaan*, *1*(4), 44–47. https://doi.org/10.69714/16wezw60

Zhang, T., Hu, Y., Lei, T., & Hu, H. (2023). A GIS-based study on the spatial distribution and influencing factors of monastic gardens in Jiangxi Province, China. *Frontiers in Environmental Science*, *11*(November), 1–15. https://doi.org/10.3389/fenvs.2023.1252231

Zhao, L., Liang, Y., & Tu, H. (2023). How Do Clusters Drive Firm Performance in the Regional Innovation System? A Causal Complexity Analysis in Chinese Strategic Emerging Industries. *Systems*, *11*(5). https://doi.org/10.3390/systems11050229