JPPIPA 12(10) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Integrating Leading Commodities and Agricultural Infrastructure Hierarchy for Agricultural Regional Development in North Tapanuli Regency, Indonesia

Hotsetia Uli Gultom[1*], Andrea Emma Pravitasari [2,3], Rilus A. Kinseng [4]

[1]Master's Program in Regional Planning Science, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Bogor, Indonesia.
[2]Regional Development Planning Division, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Bogor, Indonesia.
[3] Center for Regional Systems Analysis, Planning and Development (CRESTPENT/P4W), IPB University, Bogor, Indonesia.
[4] Department of Communication and Community Development Sciences, Faculty of Human Ecology, IPB University, Bogor, Indonesia

Received: June 12, 2026
Revised: September 25, 2026
Accepted: October 23, 2026
Published: October 31, 2026

Corresponding Author:
Hotsetia Uli Gultom[1]
gultomhotsetia@apps.ipb.ac.id

DOI: 10.29303/jppipa.v12i10.15674

Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)

Abstract: The agricultural sector is the main driver of the economy in North Tapanuli Regency; however, its contribution and growth rate have shown a stagnant trend in recent years. This study aimed to identify leading commodities, analyze the agricultural infrastructure hierarchy, and formulate agricultural regional development recommendations in North Tapanuli Regency. A quantitative descriptive approach was employed using Location Quotient (LQ), Shift Share Analysis (SSA), and scalogram analysis. The results indicate that all sub-districts in North Tapanuli Regency possess leading commodities, including food crops, horticultural crops, and plantation crops, with upland rice emerging as the most dominant commodity. However, agricultural infrastructure remains unevenly distributed and is predominantly classified as low (Hierarchy III). The integration analysis shows that most sub-districts already possess considerable leading commodity potential but continue to face limitations in agricultural infrastructure support. Furthermore, commodity superiority does not always correspond to infrastructure capacity, as reflected by Garoga Sub-district, which recorded the highest commodity superiority level despite being classified in the lowest infrastructure hierarchy, whereas Tarutung Sub-district exhibited the opposite condition. These findings indicate that commodity superiority does not always correspond to infrastructure capacity, highlighting the need for integrated and place-based agricultural development strategies tailored to the characteristics of each sub-district.

Keywords: Agricultural infrastructure; Location quotient; Regional development; Shift share analysis

Introduction

Regional development is a planned process aimed at improving community welfare through the utilization of local potential. The optimal and sustainable utilization of natural resources, human resources, technology, and infrastructure serves as a key driver of regional development, as it determines a region's capacity to sustain economic growth, maintain environmental quality, and enhance community welfare (Medeu et al., 2025; Mensah, 2019; Wibiseno, 2023).

According to Statistics Indonesia of North Tapanuli Regency (2024), the agriculture, forestry, and fisheries sector has been the primary contributor to the local economy. During the period 2020–2024, this sector contributed 43.31%, 43.91%, 44.91%, 45.16%, and 44.85%

How to Cite:
Gultom, H. U., Pravitasari, A. E., & Kinseng, R. A. (2026). Integrating Leading Commodities and Agricultural Infrastructure Hierarchy for Agricultural Regional Development in North Tapanuli Regency, Indonesia. *Jurnal Penelitian Pendidikan IPA*, *12*(10), 306–220. https://doi.org/10.29303/jppipa.v12i10.15674

to the Gross Regional Domestic Product (GRDP) of North Tapanuli Regency, respectively. Despite its dominant role, the sector's contribution has shown a stagnant trend, even declining by 0.31 percentage points in 2024 compared with the previous year. Furthermore, the sector's growth rate exhibited a downward trend, decreasing from 3.99% in 2023 to 2.95% in 2024 (Statistics Indonesia of North Tapanuli Regency, 2024). These conditions indicate structural challenges in the agricultural development system.

The development of the agricultural sector in North Tapanuli Regency is not only an economic necessity but also a regional development strategy based on sustainable local potential. According to the 2023 National Labor Force Survey (Sakernas), approximately 57.69% of the population aged 15 years and above in North Tapanuli Regency was employed in the agriculture, plantation, forestry, hunting, and fisheries sectors. This condition indicates that the agricultural sector plays a strategic role in both the regional economy and employment absorption in North Tapanuli Regency. From a regulatory perspective, the importance of agricultural development is also emphasized in the Regional Regulation of North Tapanuli Regency Number 3 of 2017 concerning the Regional Spatial Plan (RTRW) of North Tapanuli Regency for 2017–2037, which stipulates that spatial development should be based on agriculture and agro-industry. This regulation legally establishes agricultural regional development as a long-term development priority for the regency.

In the context of regional development, internal factors such as natural resource potential and the availability of agricultural infrastructure are crucial to determining the success of agricultural development. Natural resource potential is reflected in the development of leading agricultural commodities, while technological and infrastructural support is represented by the availability of agricultural facilities and infrastructure. These two aspects are closely interconnected, as leading commodities require adequate infrastructure support to maximize agricultural productivity, facilitate distribution, and improve market access for agricultural products.

Weak infrastructure and inefficient goods distribution systems can constrain economic growth, particularly in developing countries (Ringga et al., 2022). In addition, disparities in the availability and quality of infrastructure, as well as public service facilities, may limit a region's capacity to develop optimally (Arnawa & Arisena, 2013). In the agricultural sector, inadequate infrastructure not only affects agricultural productivity and the distribution of agricultural products but also increases production and transaction costs borne by farmers, thereby affecting their welfare (Chairuddin & Abdullah, 2023). More broadly, infrastructure deficiencies may contribute to higher poverty levels within a region (Anaman & Shaibu, 2024). Therefore, agricultural development requires not only the identification of leading commodities but also consideration of the availability of infrastructure as a key supporting factor in promoting regional development. Given these conditions, a study integrating leading agricultural commodities and the availability of agricultural infrastructure is needed to formulate recommendations for agricultural regional development in North Tapanuli Regency.

Several previous studies in North Tapanuli Regency have identified leading agricultural commodities using the Location Quotient (LQ) method (Sinabutar et al., 2023; L. Tobing, 2011). These studies have contributed to understanding the comparative advantages of agricultural commodities across sub-districts. However, they have primarily focused on identifying leading commodities without examining whether areas with comparative and competitive commodity advantages are supported by adequate agricultural infrastructure capacity. Consequently, it remains unclear whether commodity superiority and agricultural infrastructure capacity develop in a corresponding manner across sub-districts. Furthermore, the commodity superiority level has not been integrated with the agricultural infrastructure hierarchy and spatial characteristics to formulate differentiated agricultural regional development recommendations. Addressing this gap is important because strong commodity potential may not necessarily be accompanied by adequate infrastructure support, while areas with relatively well-developed infrastructure may not necessarily possess strong commodity advantages.

Based on the aforementioned background, this study aims to identify leading agricultural commodities, analyze the agricultural infrastructure hierarchy, and formulate agricultural regional development recommendations for North Tapanuli Regency by integrating commodity superiority and agricultural infrastructure capacity from a spatial perspective. The findings are expected to provide insights into the spatial correspondence between commodity potential and infrastructure capacity and support the formulation of place-based agricultural development strategies according to the characteristics of each sub-district.

Method

This study was conducted in North Tapanuli Regency, North Sumatra Province, Indonesia, comprising 15 sub-districts, from December 2025 to March 2026. A quantitative descriptive approach was

employed using secondary data sources. The data consisted of agricultural production data for 2020 and 2024, Village Potential Statistics (PODES) data for 2024 obtained from Statistics Indonesia (BPS) of North Tapanuli Regency, and agricultural infrastructure data obtained from the North Tapanuli Regency Agricultural Office.

Leading agricultural commodities were identified using the Location Quotient (LQ) method. LQ analysis has been widely applied to determine the degree of concentration and to identify whether a commodity, economic sector, or region functions as a basic or non-basic component within a regional economy (Bayramoğlu et al., 2025; Brosnan, 2017; Harinta et al., 2018; Hidayatullah et al., 2024; Klau & Hidayah, 2023; Sebayang et al., 2026). The method measures the relative specialization of a commodity in a particular region compared with a larger reference region. According to Blakely (1994), as cited in Panuju and Rustiadi (2013), the LQ value is calculated using Formula 1.

$$LQ_{ij} = \frac{X_{ij}/X_{i.}}{X_{.j}/X_{..}} \quad (1)$$

Where $LQij$ represents the Location Quotient value of commodity j in sub-district i, Xij the production of commodity j in sub-district i, $Xi.$ is the total production of all agricultural commodities in sub-district i, $X.j$ the total production of commodity j in North Tapanuli Regency, and $X..$ is the total production of all agricultural commodities in North Tapanuli Regency.

An LQ value greater than 1 ($LQ > 1$) indicates a basic commodity, meaning that commodity i possesses a comparative advantage. In this case, the proportional contribution of the commodity's production within a sub-district is greater than its average contribution at the regency level (Nurlaela & Abdullah, 2025). An LQ value equal to 1 ($LQ = 1$) indicates that commodity i does not exhibit a comparative advantage, as its production is only sufficient to meet local demand. Meanwhile, an LQ value less than 1 ($LQ < 1$) indicates a non-basic commodity, implying that commodity i lacks a comparative advantage. The production level is insufficient to satisfy local demand, thereby requiring supplies from other regions.

Shift Share Analysis (SSA) was employed to identify changes in the regional economic structure relative to a reference region, thereby enabling the assessment of the competitive advantage of agricultural commodities. This method has been widely applied in various fields of study, including ecological footprint analysis (Dembinska et al., 2022), labor market analysis (Bandara, 2024), and the identification of leading economic sectors (Harjanti et al., 2021). SSA consists of three components: Regional Share (RS), Proportional Shift (PS), and Differential Shift (DS).

This study focuses on the Differential Shift (DS) component to identify commodities that exhibit competitive advantages within the study area. A positive Differential Shift value (DS > 0) indicates that a commodity possesses a competitive advantage and grows faster than the same commodity in the reference region. According to Rustiadi et al. (2011), the SSA indicator reflects the competitiveness of a commodity relative to the overall growth rate of the same commodity in a reference region. Furthermore, SSA can be used to identify commodities with sustainable growth prospects (Novandaya et al., 2022). The Differential Shift component is calculated using Formula 2.

$$DS = \left(\frac{X_{ij(t1)}}{X_{ij(t0)}} - \frac{X_{j(t1)}}{X_{j(t0)}}\right) \quad (2)$$

Where $X.j$ is total production of commodity j in North Tapanuli Regency, Xij is production of commodity j in sub-district i, t1 is final year of observation (2024), t0 is initial year of observation (2020). The SSA analysis used 2020 and 2024 as the initial and final observation years to assess changes in agricultural commodity production over the study period. The two observation points provide a comparison between the initial and final conditions.

The identification of leading commodities in each sub-district was conducted by integrating the results of the Location Quotient (LQ) and Differential Shift (DS) analyses. A commodity was classified as a leading commodity when it satisfied both criteria, namely (LQ > 1) and (DS > 0), indicating that the commodity possesses both comparative and competitive advantages (Rustiadi et al., 2011). The integration of LQ and DS has been widely applied in previous studies to identify leading commodities (Haditia et al., 2024; Helmi et al., 2025; Hendriany et al., 2023; Klau et al., 2019; Salimi et al., 2025; Wazhari et al., 2023; Zamhari et al., 2017;) as well as leading economic sectors (Wahyuni et al., 2024). Only commodities satisfying both criteria (LQ > 1 and DS > 0) were included in the subsequent index calculation. This restriction was applied because the index was intended to measure the relative strength of commodities that had already been identified as leading commodities, rather than to reclassify commodities that did not meet the leading-commodity criteria.

The LQ and DS values were normalized using a proportional approach by dividing each value by the respective total LQ and DS values of all commodities included in the analysis. This transformation converted the two indicators into relative index values while preserving the proportional contribution of each

commodity. Following normalization, the sum of the LQ Index values and the sum of the DS Index values were each equal to 1, ensuring that the two dimensions contributed equally in aggregate to the composite index. The normalized LQ and DS indices were combined using an additive approach to construct the Commodity-Level Superiority Index (CLSI). LQ represents the comparative advantage dimension, whereas DS represents the competitive advantage dimension. Equal contribution of the two dimensions was adopted because no empirical or theoretical basis was established in this study for assigning differential importance to comparative and competitive advantage. The LQ Index and DS Index were calculated using the following equations (Formula 4,5 and 6):

$$ILQ_{ij} = \frac{LQ_{ij}}{\sum_{j=1}^{n} LQ_j} \quad (3) \qquad IDS_{ij} = \frac{DS_{ij}}{\sum_{j=1}^{n} DS_j} \quad (4)$$

Commodity Level Superiority Index (CLSI):

$$CLSIij = ILQ_{(ij)} + IDS_{(ij)} \quad (5)$$

Sub-district Commodity Superiority Index (SCSI) :

$$SCSIi = \sum_{(j=1)}^{n} CLSIij \quad (6)$$

Where ILQij represents LQ Index of commodity *j* in sub-district i, LQij is Location Quotient value of commodity *j* in sub-district *i*, ΣLQj is total LQ value of all leading commodities, IDSij represents DS Index of commodity *j* in sub-district *i*, DSij is Differential Shift value of commodity *j* in sub-district *i*, ΣDSj is total DS value of all leading commodities.

The Commodity-Level Superiority Index (CLSI) represents the superiority level of an individual leading commodity within a sub-district based on its comparative and competitive advantages. The Sub-district Commodity Superiority Index (SCSI) was calculated by summing the CLSI values of all leading commodities within each sub-district. Therefore, SCSI represents the aggregate level of commodity superiority within a sub-district, whereas CLSI represents the superiority level of an individual commodity.

The primary leading commodity was determined based on the highest CLSI value among the leading commodities within each sub-district. Other commodities that met the leading-commodity criteria were classified as supporting commodities. SCSI values were subsequently classified into four categories, namely very high, high, moderate, and low, using the Natural Breaks (Jenks) method, which groups data according to the natural distribution patterns of index values.

The level of agricultural infrastructure development in North Tapanuli Regency was assessed using the Scalogram Analysis method, which is derived from the Guttman scale approach. The analysis results were used to classify sub-districts into three hierarchical categories: Hierarchy I, Hierarchy II, and Hierarchy III. According to Panuju and Rustiadi (2013), scalogram analysis can be utilized to determine the level of development of regions, institutions, and settlements based on the availability of service facilities. Consistent with Ilhami et al. (2024), infrastructure is a key factor supporting sustainable regional development. The infrastructure variables were selected to represent the main dimensions of agricultural infrastructure relevant to agricultural production, farmer services, economic support, and water resource availability at the sub-district level. A total of 31 variables were therefore included in the scalogram analysis, covering agricultural machinery and equipment, farmer institutions, agricultural support services, economic facilities, and water resource infrastructure.

Equal weighting was applied to the infrastructure variables because the scalogram analysis was intended to assess the breadth of agricultural infrastructure availability across sub-districts rather than to assign different levels of importance to individual facility types. Each facility was therefore treated as one component of the agricultural infrastructure service system. This approach also avoids introducing subjective differences in weights among facility types for which no empirical weighting basis was established in this study.

The analysis was based on Village Potential Statistics (PODES) 2024 data of North Tapanuli Regency and agricultural infrastructure data obtained from the North Tapanuli Regency Agricultural Office. The variables used in this study were adapted from previous studies and modified to align with the objectives of the research. The selection of variables was based on their relevance in representing the availability and capacity of agricultural infrastructure within each sub-district. The equations used in the scalogram analysis are presented as follows:

$$K_{ij} = \frac{X_{ij} - (MinX_j)}{S_j} \quad (7)$$

Where Kij represents standardized hierarchy index value of facility *j* in sub-district *i*, Xij agricultural infrastructure index value of facility *j* in sub-district *i*, Min (Xj) is minimum index value of facility *j*, Sj is standard deviation of facility *j*. The classification of sub-district development levels was determined based on the hierarchy index values presented in Table 1. The resulting hierarchy reflects the relative level of agricultural infrastructure development among sub-districts rather than the absolute adequacy of infrastructure provision.

Table 1. Determination of Class Intervals for Scalogram Analysis.

Hierarchy	Sub-district Development Index (SDI)	Hierarchy Level
I	SDI ≥ Mean SDI + Standard Deviation (SDI)	High
II	(Mean SDI) ≤ SDI < (Mean SDI + Standard Deviation (SDI))	Moderate
III	SDI < Mean SDI	Low

Source: Rustiadi et al. (2011)

A total of 31 variables were therefore included in the scalogram analysis, covering agricultural machinery and equipment, farmer institutions, agricultural support services, economic facilities, and water resource infrastructure. Agricultural machinery and equipment included four-wheel tractors, two-wheel tractors, water pumps, cultivators, hand sprayers, mini tractors, hand tractors, corn shellers, compost shredding machines, corn planters, power sprayers, pH meters, Dry Soil Test Kits (PUTK), and Wet Soil Test Kits (PUTS). Farmer institutions consisted of farmer groups (Poktan), farmer group associations (Gapoktan), and seed producer groups. Agricultural support services included Agricultural Extension Office or Balai Penyuluhan Pertanian (BPP) and agricultural extension workers. Economic facilities comprised trade facilities, agricultural input kiosks, shops and markets, banks, cooperatives, credit facilities, and other economic support facilities. Water resource infrastructure included rivers, irrigation canals, lakes/reservoirs/dams, farm ponds, and springs. In addition, the number of farmers in each sub-district was used as supporting data for index calculation and standardization.

Agricultural regional development recommendations were formulated based on the integration of the commodity superiority level and the agricultural infrastructure hierarchy. The integration of these two indicators was used to identify the characteristics and development capacity of each sub-district, thereby providing a basis for the formulation of agricultural development recommendations. Strengthening strategies were assigned to areas with high capacity, enhancement strategies to areas with moderate capacity, and development strategies to areas with low capacity. The complete classification framework is presented in Table 2.

Table 2. Agricultural Regional Development Recommendation Matrix.

Commodity Superiority Level	Agricultural Infrastructure Hierarchy	Development Recommendation
Very High / High	I	Strengthening of Leading Agricultural Areas
Very High / High	II/III	Strengthening of Agricultural Infrastructure
Moderate	I	Enhancement of Leading Commodity
Moderate	II/III	Enhancement of Leading Commodity and Agricultural Infrastructure
Low	I	Optimization of Agricultural Infrastructure Utilization
Low	II/III	Development of Leading Commodity and Agricultural Infrastructure

Result and Discussion

Leading Commodity

The results of the Location Quotient (LQ) and Shift Share Analysis (SSA) indicate that agricultural superiority in North Tapanuli Regency is not concentrated in a single commodity or commodity group but rather consists of a combination of food crops, horticultural crops, and plantation crops (Table 3). All sub-districts in North Tapanuli Regency possess leading commodities. Adiankoting Sub-district recorded the highest number of leading commodities, with nine commodities, whereas Purbatua and Tarutung Sub-districts each had only one leading commodity and no supporting leading commodities. The large number of leading commodities in Adiankoting indicates that more commodities satisfy the criteria of comparative and competitive advantages compared with other sub-districts. Of the 15 sub-districts, 13 possess both primary and supporting leading commodities. This diversity indicates that agricultural activities in North Tapanuli Regency are not dependent on a single commodity but are supported by multiple agricultural subsectors, reflecting local resource characteristics and agricultural development patterns. Commodity diversity may also promote agricultural diversification and reduce dependence on a particular commodity, thereby lowering income-related risks (Grilli et al., 2024; Mihrete & Mihretu, 2025). On the other hand, several leading commodities were found only in specific sub-districts. Galangal was identified exclusively in Garoga Sub-district, mango in Muara Sub-district, and banana in Simangumban Sub-district. These findings indicate the presence of location-specific commodities that reflect the

unique characteristics of local resources and agricultural production systems.

Table 3. Leading Agricultural Commodities in North Tapanuli Regency.

Sub-district	Primary Leading Commodity	Supporting Leading Commodities
Adiankoting	Durian	Upland Rice, Groundnut, Cassava, Sweet Potato, Chili Pepper, Papaya, Salak, Rubber
Pagaran	Siam Orange	Lowland Rice, Groundnut, Cabbage, Spring Onion, Chinese Cabbage, Coffee
Sipahutar	Maize	Cassava, Chili Pepper, Tomato, Siam Orange, Turmeric, Coffee
Sipoholon	Sweet Potato	Upland Rice, Groundnut, Cassava, Spring Onion, Papaya
Siborongborong	Siam Orange	Lowland Rice, Cassava, Potato, Cabbage, Coffee
Garoga	Galangal	Upland Rice, Maize, Durian, Turmeric
Pangaribuan	Turmeric	Upland Rice, Chili Pepper, Tomato, Siam Orange
Parmonangan	Chinese Cabbage	Upland Rice, Maize, Peanut, Siam Orange
Siatas Barita	Salak	Upland Rice, Siam Orange, Coffee
Muara	Mango	Lowland Rice, Sweet Potato, Potato
Pahae Julu	Cocoa	Lowland Rice, Papaya, Rubber
Simangumban	Cocoa	Banana, Coconut
Pahae Jae	Durian	Cocoa
Purbatua	Coconut	–
Tarutung	Upland Rice	–

Source: Data Processing Results, 2026

Based on the spatial distribution of leading commodities (Figure 1), upland rice exhibited the widest distribution, occurring in seven sub-districts, followed by Siam orange, which was identified in six sub-districts. Lowland rice, peanut, cassava, and coffee were each found in four sub-districts. The widespread occurrence of upland rice is likely due to its adaptability to diverse land conditions, including dryland areas and regions with limited irrigation. This finding is consistent with Mustikarini et al. (2025), who reported that upland rice can grow well under dryland conditions and serves as a suitable alternative for rice cultivation in areas with limited water availability.

The dominance of upland rice and Siam orange indicates that these commodities satisfy the criteria of leading commodities in many sub-districts. Their broad distribution suggests that they play important and strategic roles in the agricultural structure of North Tapanuli Regency and have the potential to drive regional agricultural development. Furthermore, the diversity and distribution of leading commodities indicate that the development of food, horticultural, and plantation crops is not concentrated in a single area but is distributed across several sub-districts with suitable agroecological conditions. Previous studies have emphasized that agroecological zoning and land-use characteristics are important tools for identifying land suitability and determining optimal areas for commodity cultivation (Nabati et al., 2020). These findings also suggest that not all sub-districts exhibit similar patterns of agricultural superiority; therefore, agricultural development strategies should be tailored to local conditions rather than uniformly applied across the region (Balland et al., 2019).

Although upland rice and Siam orange exhibited the widest spatial distribution across North Tapanuli Regency, the primary leading commodities differed among sub-districts. Based on the highest Commodity-Level Superiority Index (CLSI) value, galangal was identified as the primary leading commodity in Garoga Sub-district, while upland rice functioned only as a supporting leading commodity. This finding indicates that the most dominant commodity within a sub-district is not necessarily the commodity with the widest distribution at the regency level. Rather, it reflects the commodity that contributes the most to the commodity superiority level within a particular sub-district. Therefore, the structure of leading commodities in North Tapanuli Regency comprises both widely distributed commodities and location-specific commodities, reflecting the diversity of local resources and agricultural development patterns across sub-districts.

Based on the sub-district commodity superiority level (Table 4), Garoga Sub-district recorded the highest Sub-district Commodity Superiority Index (SCSI) value of 0.505. This result indicates that Garoga possesses a greater accumulation of comparative and competitive commodity advantages than other sub-districts. Consequently, the area demonstrates strong potential for agricultural development based on leading commodities (Kim et al., 2019). Adiankoting Sub-district

ranked second with an SCSI value of 0.202. Interestingly, Adiankoting possesses a larger number of leading commodities than Garoga (Table 3), yet its SCSI value is considerably lower. This finding suggests that the commodity superiority level within a sub-district is determined not only by the number of leading commodities but also by the relative contribution of each commodity to the overall superiority index. While a greater number of leading commodities may provide broader opportunities for agricultural development, the commodity superiority level ultimately depends on the strength and contribution of individual commodities within the sub-district.

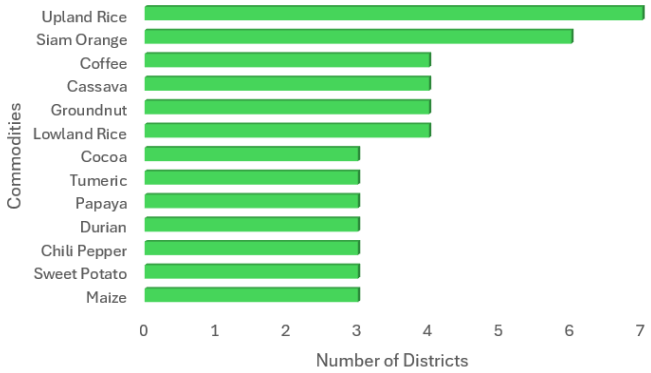


Figure 1. Distribution of Leading Commodities by Number of Sub-districts in North Tapanuli Regency

The contrast between the number of leading commodities and the SCSI value indicates that commodity superiority should not be interpreted simply in terms of commodity diversity. A sub-district with fewer leading commodities may achieve a higher overall superiority level when its leading commodities exhibit stronger comparative and competitive advantages. This distinction is important for regional agricultural planning because diversification and specialization represent different dimensions of agricultural potential. Therefore, areas with many leading commodities may require strategies that maintain diversification, whereas areas with fewer but stronger commodities may benefit from more focused commodity development.

The distribution of sub-district commodity superiority levels exhibits considerable variation across North Tapanuli Regency. Six sub-districts were classified as Very High and High, indicating a relatively strong concentration of comparative and competitive commodity advantages. These areas exhibit relatively stronger commodity potential based on the identified leading commodities. The Moderate category was the most dominant, encompassing seven sub-districts. This finding suggests that most sub-districts have developed leading commodities but have not yet achieved a high level of commodity specialization. Meanwhile, only two sub-districts, namely Tarutung and Purbatua, were classified in the Low category, indicating relatively limited commodity superiority compared with other sub-districts.

Table 4. Sub-district Commodity Superiority Levels in North Tapanuli Regency.

Sub-district	SCSI	Category
Garoga	0.505	Very High
Adiankoting	0.202	High
Siatas Barita	0.188	High
Pangaribuan	0.187	High
Sipoholon	0.177	High
Pagaran	0.140	High
Parmonangan	0.102	Moderate
Sipahutar	0.089	Moderate
Muara	0.086	Moderate
Simangumban	0.085	Moderate
Siborongborong	0.072	Moderate
Pahae Jae	0.070	Moderate
Pahae Julu	0.062	Moderate
Purbatua	0.028	Low
Tarutung	0.007	Low

Source: Data Processing Results, 2026

The low index value for Purbatua indicates a limited number of leading commodities and their contribution compared with other sub-districts. Meanwhile, the low superiority level observed in Tarutung suggests that agriculture plays a less dominant role in the local economic structure. This condition may be associated with Tarutung's function as the administrative and service center of North Tapanuli Regency, where economic activities are likely to be more diversified than in other sub-districts. Although the analysis identified upland rice as a leading commodity in Tarutung, commodity dominance is inherently relative to a region's overall production structure.

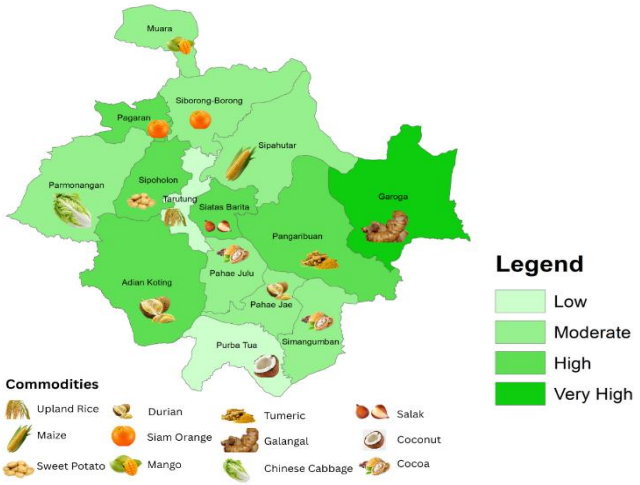


Figure 2. Spatial Distribution of Sub-district Commodity Superiority Levels and Primary Leading Commodities in North Tapanuli Regency

From a spatial perspective (Figure 2), sub-districts classified as Very High and High tend to be geographically clustered rather than evenly distributed across the regency. A similar pattern is observed for sub-districts in the Moderate category. The eastern and western parts of North Tapanuli Regency are generally characterized by High and Very High levels of commodity superiority, whereas the northern and southern parts are predominantly classified as Moderate. The concentration of commodity superiority in particular areas suggests that the development of agricultural potential is not spatially uniform across the regency.

Agricultural Infrastructure

The scalogram analysis revealed disparities in the availability of agricultural infrastructure across sub-districts, as reflected in three hierarchical levels (Table 5). North Tapanuli Regency is predominantly characterized by Hierarchy III, which includes nine sub-districts, indicating that agricultural infrastructure availability remains relatively low in most areas. Previous studies have highlighted the important role of infrastructure in improving agricultural productivity and supporting the modernization of agricultural production systems in rural areas (Kusumastuti, 2025). Market, irrigation, and road infrastructure have been shown to positively influence agricultural development (Purwansyah, 2013), while inadequate infrastructure has been identified as a major constraint to agricultural sector development (Llanto, 2012).

The findings also indicate that the hierarchy index is not determined solely by the number of facilities available but also by their availability relative to the farming population and the diversity of facilities provided. For example, Pahae Jae and Sipahutar each possess 27 agricultural infrastructure facilities; however, Pahae Jae is classified in Hierarchy I, whereas Sipahutar belongs to Hierarchy III. A similar pattern is observed in Adiankoting and Siborongborong. This difference is associated with variations in the number of farmers across sub-districts. Consequently, even when the number of facilities is similar, service availability becomes relatively lower in sub-districts with larger farming populations, resulting in lower hierarchy index values. This finding is consistent with the concept of regional service hierarchy, which emphasizes that the function and service capacity of facilities are important determinants of regional development levels (Rustiadi et al., 2011). This finding indicates that infrastructure provision should be interpreted in relation to the population or user base it serves. An identical number of facilities does not necessarily represent an identical level of service capacity when the number of agricultural users differs. Therefore, infrastructure planning based solely on facility counts may overestimate service capacity in areas with larger farming populations.

Table 5. Agricultural infrastructure hierarchy of Sub-districts in North Tapanuli Regency

Hierarchy	Sub-district	Sub-district Agricultural Development Index (SDI)	Number of Facilities
Hierarchy I	Tarutung	58.46	29
	Sipoholon	55.20	29
	Pahae Jae	53.38	27
Hierarchy II	Adiankoting	47.06	26
	Pahae Julu	46.45	22
	Purbatua	37.95	19
Hierarchy III	Parmonangan	37.82	25
	Muara	36.46	25
	Siatas Barita	36.40	21
	Simangumban	33.44	18
	Siborongborong	30.00	26
	Pagaran	28.38	21
	Sipahutar	24.55	27
	Pangaribuan	23.23	24
	Garoga	19.72	22
Mean	-	37.90	24.07
Standard Deviation	-	12.01	3.43

Note: Hierarchy I : SDI >49.91; Hierarchy II : 37.90 ≤ SDI ≤ 49.91; Hierarchy III: SDI < 37.90.
Source: Data Processing Results, 2026

From a spatial perspective (Figure 3), sub-districts classified in the highest agricultural infrastructure hierarchy (Hierarchy I) tend to be concentrated around Tarutung, the capital of North Tapanuli Regency and the main regional service center. This pattern indicates a concentration of facilities within service centers that support surrounding areas, consistent with the regional service center concept proposed by Rustiadi et al. (2011). Similar findings were reported by Wahyuni et al. (2022), who found that infrastructure connectivity development is primarily directed toward linking service centers with their surrounding regions, resulting in disparities in infrastructure accessibility across areas. The observed pattern suggests that the availability and capacity of agricultural infrastructure remain unevenly distributed among sub-districts.

Based on the analysis, Tarutung has a relatively large number and diversity of facilities while serving a smaller farming population, resulting in a higher service capacity than many other sub-districts. In contrast, most sub-districts are classified in Hierarchy III, indicating relatively low levels of agricultural infrastructure development. The dominance of the low hierarchy category suggests that strengthening agricultural infrastructure remains a key development priority in North Tapanuli Regency. Previous studies have

demonstrated that infrastructure development can contribute to poverty reduction (Suwardi, 2011), increase household income (Zheng et al., 2025), and reduce income inequality (Taena et al., 2023). Therefore, the evaluation of agricultural infrastructure should not be based solely on the number of facilities available but should also consider their service capacity and accessibility.

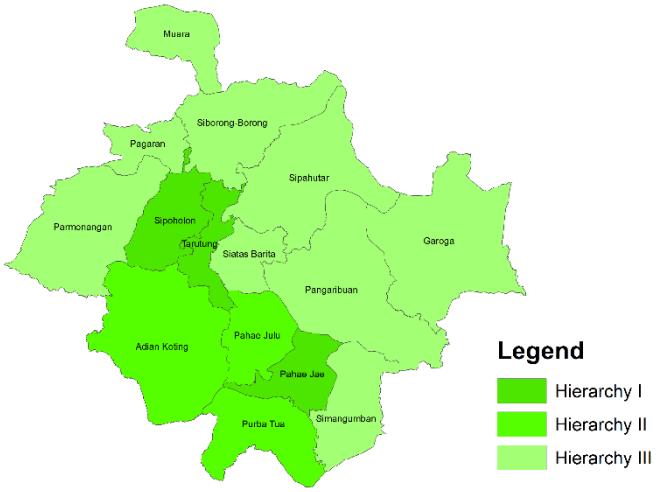


Figure 3. Agricultural infrastructure hierarchy across Sub-districts in North Tapanuli Regency

In general, sub-districts with higher levels of agricultural infrastructure are expected to have greater capacity to support agricultural development. However, the results reveal a contrasting pattern. Garoga Sub-district recorded the highest Sub-district Commodity Superiority Index (SCSI) but was classified in the lowest agricultural infrastructure hierarchy. Conversely, Tarutung Sub-district exhibited the lowest commodity superiority level while possessing the highest agricultural infrastructure hierarchy. The results indicate that commodity superiority and agricultural infrastructure capacity do not always exhibit corresponding spatial patterns. Areas with strong commodity superiority may not always be supported by relatively high agricultural infrastructure capacity, while areas with relatively high infrastructure capacity may not necessarily exhibit high levels of commodity superiority.

This discrepancy may reflect differences in the underlying factors influencing each indicator. Commodity superiority is closely related to local resource endowments and agricultural production structures, whereas agricultural infrastructure development may also reflect regional service functions and development priorities. These differences may help explain the contrasting positions of Garoga and Tarutung. Garoga's very high commodity superiority indicates strong relative commodity potential, but its Hierarchy III classification indicates a relatively lower level of supporting infrastructure capacity. In contrast, Tarutung's Hierarchy I classification indicates relatively high infrastructure capacity, but its low commodity superiority suggests that the availability of infrastructure does not necessarily translate into strong commodity superiority. Thus, the two indicators capture different dimensions of regional agricultural development: commodity superiority reflects the relative strength of agricultural potential, whereas infrastructure hierarchy reflects the relative capacity of supporting facilities and services.

This finding has an important implication for agricultural regional development analysis, as commodity potential and infrastructure capacity should not be treated as interchangeable dimensions of regional development. Considering only commodity superiority may overlook limitations in supporting infrastructure, whereas considering infrastructure hierarchy alone may overlook differences in agricultural production potential. Their integration therefore provides a broader basis for distinguishing the development conditions of individual sub-districts.

Nevertheless, the present study did not explicitly examine the determinants underlying these differences. Therefore, factors such as development policies, fiscal capacity, and institutional factors should be considered as potential explanations rather than interpreted as causal determinants based on the present analysis. Further research is needed to examine these factors empirically. From a planning perspective, the findings imply that development interventions should be differentiated according to the combination of commodity potential and infrastructure capacity. Sub-districts with strong commodity superiority but relatively low infrastructure capacity require greater attention to infrastructure that supports their existing leading commodities, whereas sub-districts with relatively high infrastructure capacity but low commodity superiority require greater emphasis on optimizing the utilization of existing infrastructure and strengthening its linkage with agricultural activities. Therefore, integrating both indicators provides a basis for formulating place-based development strategies rather than applying uniform interventions across the regency.

Agricultural Development Recommendations

Agricultural regional development recommendations were formulated by integrating commodity superiority levels and agricultural infrastructure hierarchies. The integration of these two indicators resulted in six development recommendation categories, reflecting differences in agricultural potential and infrastructure support among sub-districts (Table

6). The results demonstrate that sub-districts with different combinations of commodity superiority and infrastructure capacity require different development priorities. Therefore, agricultural development in North Tapanuli Regency should not be approached through a uniform strategy, but should consider the specific combination of commodity potential and infrastructure capacity in each sub-district.

The recommendation category of enhancement of leading commodities and agricultural infrastructure is the most dominant, covering six sub-districts, followed by agricultural infrastructure strengthening, which applies to five sub-districts. Together, these two categories cover 11 of the 15 sub-districts, indicating that most sub-districts already possess identifiable leading commodity potential while their agricultural infrastructure remains in a category requiring strengthening or improvement. This condition suggests that infrastructure development is an important planning priority for supporting the utilization of existing commodity potential. Rather than introducing new commodity development as the primary intervention, infrastructure improvement in these areas can be directed toward supporting the production, distribution, and development of commodities that have already demonstrated comparative and competitive advantages.

The importance of infrastructure development is supported by previous studies. Leading commodities require continuous development to maintain their competitiveness and contribution to regional growth (Adyanti et al., 2025). However, agricultural development in many regions remains constrained by inadequate infrastructure, limited market access, and insufficient agricultural support services despite having substantial resource potential (Fuseini, 2024; Salsabila & Wulandari, 2025; Ulia et al., 2025). Furthermore, agricultural infrastructure plays a critical role in improving market accessibility, enhancing production efficiency, and strengthening food security (Mulyono et al., 2024; Rahmayana et al., 2025). At a broader scale, infrastructure investment has also been shown to increase agricultural productivity, create employment opportunities, and support sustainable agricultural development, as demonstrated in the Economic Community of West African States (ECOWAS) region (Edeme et al., 2020). This implies that infrastructure strengthening in North Tapanuli should not be interpreted simply as increasing the number of facilities, but as improving the supporting capacity required by existing leading commodities. In this context, the infrastructure priorities identified through the integration analysis provide a spatial basis for directing interventions toward sub-districts where commodity potential is already evident but the level of infrastructure capacity remains relatively lower.

The recommendations for Tarutung and Purbatua Sub-districts are particularly noteworthy because they represent contrasting development conditions. Tarutung was classified under the optimization of agricultural infrastructure utilization category, reflecting its low commodity superiority despite having the highest agricultural infrastructure hierarchy. This condition indicates that infrastructure availability alone does not necessarily correspond to strong commodity superiority. Therefore, the development priority in Tarutung is not primarily the addition of infrastructure, but the optimization of existing facilities and their linkage with agricultural production and leading commodity development. Strengthening the functional utilization of existing infrastructure may help ensure that its relatively high infrastructure capacity contributes more effectively to agricultural development.

Purbatua represents a different development condition. The sub-district has low commodity superiority and is classified in Hierarchy II for agricultural infrastructure, resulting in a recommendation for the development of leading commodities and agricultural infrastructure. Unlike Tarutung, Purbatua does not have a high infrastructure capacity that can readily support commodity development. Therefore, development intervention needs to address both dimensions by strengthening existing or potential leading commodities while improving the supporting infrastructure required for their development. This integrated intervention is intended to establish the basic conditions necessary for strengthening agricultural potential over time.

Garoga also illustrates the importance of differentiating infrastructure intervention according to existing commodity potential. Although Garoga has the highest SCSI and is classified as Hierarchy III, its recommendation is focused on agricultural infrastructure strengthening rather than commodity identification. This indicates that the main planning opportunity lies in supporting an already strong commodity base through improved infrastructure capacity. Such an approach can help avoid directing resources toward identifying new commodities when substantial commodity potential has already been demonstrated.

Table 6. Integration of Commodity Superiority and Agricultural Infrastructure Hierarchy in North Tapanuli Regency.

Sub-district	Commodity Superiority Level	Agricultural Infrastructure Hierarchy	Development Recommendation
Sipoholon	High	I	Strengthening of Leading Agricultural Areas
Adiankoting	High	II	Strengthening of Agricultural Infrastructure
Garoga	Very High	III	
Pagaran	High	III	
Siatas Barita	High	III	
Pangaribuan	High	III	
Pahae Jae	Moderate	I	Enhancement of Leading Commodity
Muara	Moderate	III	Enhancement of Leading Commodity and Agricultural
Parmonangan	Moderate	III	Infrastructure
Pahae Julu	Moderate	II	
Sipahutar	Moderate	III	
Simangumban	Moderate	III	
Siborongborong	Moderate	III	
Tarutung	Low	I	Optimization of Agricultural Infrastructure Utilization
Purbatua	Low	II	Development of Leading Commodity and Agricultural Infrastructure

The integration results indicate that commodity superiority does not always develop in line with agricultural infrastructure capacity. Garoga Sub-district recorded the highest commodity superiority level, yet its agricultural infrastructure was classified in the low category (Hierarchy III). In contrast, Tarutung Sub-district exhibited the lowest commodity superiority level while possessing a high level of agricultural infrastructure (Hierarchy I). These findings suggest that commodity superiority and the availability of agricultural infrastructure do not always develop in a balanced manner. Therefore, agricultural regional development cannot focus solely on improving leading commodities or agricultural infrastructure independently. Instead, it requires an integrated approach that accounts for the specific characteristics and development needs of each sub-district.

From a spatial perspective (Figure 4), the recommendations also reveal differentiated patterns across North Tapanuli Regency. Sub-districts in the western and eastern parts of the regency are predominantly assigned to agricultural infrastructure strengthening, whereas sub-districts in the northern and southern parts are primarily directed toward the enhancement of leading commodities and agricultural infrastructure. These spatial patterns indicate that areas with existing commodity potential are not uniformly supported by agricultural infrastructure capacity. Consequently, infrastructure interventions should be spatially aligned with the distribution of leading commodity potential rather than concentrated only in areas with stronger regional service functions. At the same time, areas with relatively high infrastructure capacity but low commodity superiority, such as Tarutung, require strategies focused on improving the utilization and linkage of existing facilities with agricultural activities.

Overall, the integration of commodity superiority and agricultural infrastructure hierarchy provides a basis for distinguishing development priorities according to the specific conditions of each sub-district. Areas with high commodity superiority and relatively low infrastructure capacity require infrastructure strengthening to support existing agricultural potential, whereas areas with relatively high infrastructure capacity and low commodity superiority require optimization of existing facilities and stronger linkages with agricultural activities. Areas with moderate levels of both dimensions require simultaneous enhancement of commodities and infrastructure. This differentiated approach demonstrates the practical value of integrating commodity and infrastructure perspectives in agricultural regional planning and provides a basis for more place-specific development interventions in North Tapanuli Regency.

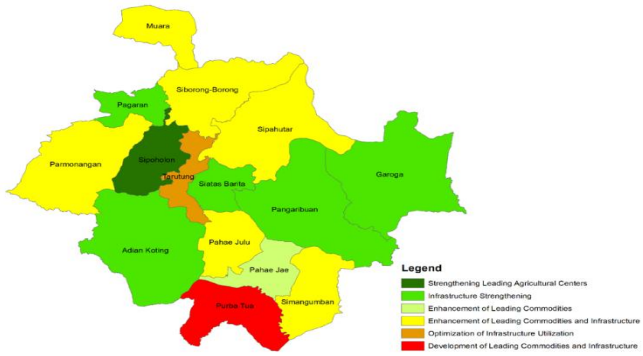


Figure 4. Spatial Distribution of Agricultural Regional Development Recommendations in North Tapanuli Regency

Conclusion

North Tapanuli Regency possesses diverse leading commodities, including food crops, horticultural crops, and plantation crops, with varying levels of commodity superiority across sub-districts. The agricultural infrastructure hierarchy is unevenly distributed, with Hierarchy III dominating most sub-districts. The results indicate that commodity superiority does not always correspond to agricultural infrastructure capacity, as reflected by Garoga, which recorded the highest commodity superiority level despite being classified as Hierarchy III, whereas Tarutung exhibited the opposite condition, with the lowest commodity superiority level but the highest agricultural infrastructure hierarchy.

The integration of commodity superiority and agricultural infrastructure hierarchy yielded six categories of agricultural regional development recommendations, reflecting the different development conditions across sub-districts. The findings demonstrate that agricultural development potential cannot be assessed solely based on commodity superiority or infrastructure capacity, as the two dimensions do not always exhibit corresponding spatial patterns. Therefore, agricultural development policies should adopt an integrated and place-based approach that considers the specific combination of commodity potential and infrastructure capacity in each sub-district.

Acknowledgments

The authors would like to express their sincere gratitude to the Indonesia Endowment Fund for Education (LPDP), Ministry of Finance of the Republic of Indonesia, for providing financial support through the LPDP Targeted Scholarship Program. The authors also acknowledge the North Tapanuli Regency Agricultural Office and Statistics Indonesia (BPS) of North Tapanuli Regency for providing data and support during the research process.

Author Contributions

Conceptualization and methodology: H.U.G; validation: A.E.P and R.A.K; formal analysis: H.U.G; data curation: A.E.P and R.A.K; preparation of initial draft: H.U.G; writing review and editing: H.U.G, A.E.P and R.A.K.

Funding

This research was funded by the Indonesia Endowment Fund for Education (LPDP), Ministry of Finance of the Republic of Indonesia, for providing financial support through the LPDP Targeted Scholarship Program.

Conflicts of Interest

The authors declare no conflict of interest.

References

Adyanti, A. S., Murti, J., Aji, M., & Hani, E. S. (2025). Mapping and future potential of Cocoa commodity base regions in Indonesia. *Agro Ekonomi*, *36*(2), 129–147. https://doi.org/10.22146/ae.103907

Anaman, K. A., & Shaibu, A. (2024). Development of regional input-output tables for Northern Ghana : An analysis using location quotient methods. *Cogent Social Sciences*, *10*(1). https://doi.org/10.1080/23311886.2024.2340429

Arnawa, I. K., & Arisena, G. M. K. (2013). Potensi daya dukung pengembangan kawasan minapolitan di Kabupaten Gianyar, Bali. *Agriekonomika*, *2*(2), 108–116.

Balland, P. A., Boschma, R., Crespo, J., & Rigby, D. L. (2019). Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies*, *53*(9), 1252–1268. https://doi.org/10.1080/00343404.2018.1437900

Bandara, S. J. H. (2024). Regional workforce dynamics in West Virginia : Insights from Shift-Share and Location Quotient Analysis. *Economies*. https://doi.org/10.3390/ economies12110290 Academic

Bayramoğlu, Z., Ağızan, K., Ağızan, S. (2025). Determination of Location Quotient of organic agriculture in Türkiye. *Journal of Tekirdag Agricultural Faculty*, *22*(January), 58–73. https://doi.org/10.33462/jotaf.1367319

Brosnan, S. (2017). Crime concentration in Ireland in 2012 : A Location Quotient approach. *Irish Journal of Applied Social Studies*, *17*(1). https://doi.org/10.21427/D77147

Chairuddin, Z., & Abdullah, N. (2023). Analisis Skalogram: Studi kasus pengembangan Kopi Mamasa berbasis kesesuaian lahan dan sarana fasilitas penunjang di Kabupaten Mamasa. *Jurnal Ecosolum*, *12*(1), 86–104. https://doi.org/10.20956/ecosolum.v12i1.25663

Dembinska, I., Sabina, K., Agnieszka, T., Szopik-depczy, K., Marzantowicz, Ł., & Ioppolo, G. (2022). Science of the Total Environment The impact of space development structure on the level of ecological footprint - Shift share analysis for European Union countries. *Science of the Total Environment*, *851*(March). https://doi.org/10.1016/j.scitotenv.2022.157936

Edeme, R. K., Nkalu, N. C., Idenyi, J. C., & Arazu, W. O. (2020). Infrastructural development, sustainable agricultural output and employment in ECOWAS countries. *Sustainable Futures*, *2*(January), 100010. https://doi.org/10.1016/j.sftr.2020.100010

Fuseini, M. N. (2024). Rural infrastructure and livelihoods enhancement: The case of Community-Based Rural Development Program in Ghana. *Heliyon*, *10*(13), e33659. https://doi.org/10.1016/j.heliyon.2024.e33659

Government of North Tapanuli Regency. (2017). Regional regulation of North Tapanuli Regency No. 3 of 2017 concerning the regional spatial plan of North Tapanuli Regency 2017–2037. Tarutung, Indonesia: Government of North Tapanuli Regency.

Grilli, G., Pagliacci, F., & Gatto, P. (2024). Determinants of agricultural diversification : What really matters ? A review. *Journal of Rural Studies*, *110*(September 2023), 103365. https://doi.org/10.1016/j.jrurstud.2024.103365

Haditia, M., Panuju, D. R., & Kinseng, R. A. (2024). Partisipasi perempuan pada usahatani hortikultura unggulan di Kabupaten Agam. *Syntax Literate*, *9*(4). https://doi.org/10.36418/syntax-literate.v9i4

Harinta, Y. W., Basuki, J. S., & Sukaryani, S. (2018). Pemetaan dan pengembangan agribisnis komoditas unggulan sayuran di Kabupaten Karanganyar. *Agriekonomika*, *7*. https://doi.org/10.21107/agriekonomika.v7i1.3201

Harjanti, D. T., Apriliyana, M. I., & Arini, A. C. (2021). Analysis Of regional leading sector through location quotient approach , shift share analysis , and klassen typology (case study : Sanggau Regency , West Kalimantan Province). *Jurnal Geografi Gea*, *21*(2). https://ejournal.upi.edu/index.php/gea

Helmi, F., Rustiadi, E., Juanda, B., & Mulatsih, S. (2025). Determination of leading commodity for food security in the PEKANSIKAWAN metropolitan area. *Jurnal Bina Praja*. https://doi.org/10.21787/jbp.17.2025-2609

Hendriany, R., Pravitasari, A. E., & Rustiadi, E. (2023). Pengembangan wilayah Kabupaten Pangandaran berbasis komoditas unggulan tanaman pangan. *Analisis Kebijakan Pertanian*, *21*(2), 231-240.

Hidayatullah, R., Watemin, Watemin., & Fathurrohman, Y. E. (2024). Analysis sector potential and contribution of agriculture in increasing Gross Regional Domestic Product (GRDP) Of Banyumas Regency. *AGRITEPA*, *11*(2), 353–372.

Ilhami, W. T., Susilo, H., Pramudya, B., & Kosmaryandi, N. (2024). Sustainable scientific tourism development planning using Micmac-Mactor in Bogor City , Indonesia. *Journal of Natural Resources and Environmental Management*, 757–769. https://doi.org/10.29244/jpsl.14.4.757

Kim, S., Kyo, S., Kim, Y., Kim, C., & Jung, C. (2019). Quantitative evaluation on geographical indication of. *Journal of the Korean Society of Agricultural Engineers*, *61*(2), 75–83. https://doi.org/10.5389/KSAE.2019.61.2.075

Klau, A. D., & Hidayah, U. (2023). Mapping analysis of leading commodities based on food crops in Malaka Regency. *Agriekonomika*, *12*(2), 193–204. https://doi.org/10.21107/agriekonomika.v12i1.18785

Klau, A. D., Rustiadi, E., & Siregar, H. (2019). Analisis pengembangan kawasan agropolitan berbasis tanaman pangan di Kabupaten Malaka Provinsi Nusa Tenggara Timur. *Journal of Regional and Rural Development Planning (Jurnal Perencanaan Pembangunan Wilayah Dan Perdesaan)*, *3*(3), 172–179. https://doi.org/10.29244/jp2wd.2019.3.3.172-179

Kusumastuti, G. (2025). The Role of rural production systems in the transformation of rural areas in Kediri Regency. *The Indonesian Journal of Planning and Development*, *8*(2), 75–83. https://doi.org/10.14710/ijpd.8.2.75-83

Llanto, G. M. (2012). The Impact of infrastructure on agricultural productivity. *Infrastructure and Agricultural Productivity*, *12*, 469–486. http://www.scopus.com/inward/record.url?eid=2-s2.0-0028580356&partnerID=tZOtx3y1

L.Tobing, F.H. (2011). Perencanaan sektor pertanian dalam rangka pengembangan wilayah di Kabupaten Tapanuli Utara [Master's thesis, Universitas Sumatera Utara]. Repository Universitas Sumatera Utara. http://repositori.usu.ac.id/handle/123456789/40259

Medeu, A., Askarova, M., Zhakupova, A., Bauyrzhan, U., & Klug, H. (2025). Sustainable regional development : A challenge between socio-economic development and sustainable environmental management. *Sustainability*, 1–16. https://doi.org/10.3390/su17136020

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, *5*(1). https://doi.org/10.1080/23311886.2019.1653531

Mihrete, T. B., & Mihretu, F. B. (2025). Crop diversification for ensuring sustainable agriculture , risk management and food security. *Global Challenges Published by Wiley-VCH GmbHGmbH*, *2400267*, 1–13. https://doi.org/10.1002/gch2.202400267

Mulyono, M. R., Latief, Y., & Dita, A. (2024). Agricultural infrastructure funding assessment : Research opportunities and trends. *Journal of Optimization in Industrial Engineering*, *17*(1), 203–212. https://doi.org/10.22094/QJIE.2024.1116129

Mustikarini, E. D., Prayoga, G. I., Santi, R., & Aprilla, N.

N. (2025). Potensi galur Padi Gogo di lahan kering Pulau Belitung. *Agrosains : Jurnal Penelitian Agronomi*, *26*(2), 86. https://doi.org/10.20961/agsjpa.v26i2.77393

Nabati, J., Nezami, A., Neamatollahi, E., & Akbari, M. (2020). GIS-based agro-ecological zoning for crop suitability using fuzzy inference system in semi-arid regions. *Ecological Indicators*, *117*(June), 106646. https://doi.org/10.1016/j.ecolind.2020.106646

Novandaya, Z., Wijaya, H. B., Hadi, W. M. I., Azmi, H. N., & Kuriniawati, H. (2022). Pemanfaatan penilaian indeks daya saing daerah untuk optimalisasi sektor unggulan dan berkembang pada aglomerasi Wilayah Kedungsepur. *Jurnal Penataan Ruang*, *17*(2).

Panuju, D. R., & Rustiadi, E. (2013). Teknik analisis perencanaan pengembangan wilayah. Labor Pengembangan Wilayah, Departemen Ilmu Tanah Dan Sumberdaya Lahan, Institut Pertanian Bogor.

Purwansyah, F. E. (2013). Pengaruh pembangunan infrastruktur terhadap di Kabupaten Muaro Jambi. *Jurnal Perspektif Pembiayaan Dan Pembangunan Daerah*, *1*(1), 29–34.

Rahmayana, L., Rusadi, M. W., & Fajriani, K. (2025). Keterkaitan desa - kota dalam mendukung ketahanan pangan di Kabupaten Bogor. *Jurnal Pembangunan Wilayah Dan Kota*, *21*(2), 280–296. https://doi.org/10.14710/pwk.v21i2.70516

Ringga, E. S., Silvia, V., & Abrar, M. (2022). The Effect of infrastructure and labor in agricultural sector on agricultural economic growth in Aceh Province. *International Journal of Finance, Economics and Business*, *1*(2), 103–108. https://doi.org/10.56225/ijfeb.v1i2.25

Rustiadi, E., Sunsun, S., & Dyah, R. P. (2011). Perencanaan dan pengembangan wilayah. Yayasan Pustaka Obor Indonesia.

Salimi, G. K., Mulatsih, S., & Pravitasari, A. E. (2025). Regional development based on leading agricultural commodities of food crop in Cianjur Regency , West Java Province , Indonesia. *Jurnal Penelitian Pendidikan IPA*, *11*(5). https://doi.org/10.29303/jppipa.v11i5.11293

Salsabila, P., & Wulandari, W. (2025). Kajian peran sektor pertanian dalam pembangunan ekonomi daerah di Nusa Tenggara Barat. *Journal of Economics Development Research*, *1*(3), 102–112. https://doi.org/10.71094/joeder.v1i3.146

Sebayang, V. B., Karo, R., Sitepu, K., Fatah, F. A., (2026). Identifying leading commodities for regional development in Transmigration Areas: Evidence from Muaro Takung-Kamang Baru, Indonesia. *Agriekonomika*, *15*(1), 85–104. https://doi.org/10.21107/agriekonomika.v15i1.33909

Sinabutar, R., Lubis, S. N., & Harahap, H. (2023). Analysis of leading agricultural commodities and their role in regional development in North Tapanuli Regency, Indonesia. *Asian Journal of Advanced Research and Reports*, *17*(12), 116–126. https://doi.org/10.9734/ajarr/2023/v17i12591

Statistics Indonesia of North Tapanuli Regency. (2024). Kabupaten Tapanuli Utara Dalam Angka 2024. https://tapanuliutarakab.bps.go.id/id

Suwardi, A. (2011). Pengeluaran pemerintah daerah, produktivitas pertanian, dan kemiskinan di Indonesia. *Jurnal Ekonomi Dan Pembangunan Indonesia*, *12*(1), 39–55. https://doi.org/10.21002/jepi.v12i1.04

Taena, W., Sipayung, B. P., Blegur, F. M. A., & Klau, A. D. (2023).The impact of agricultural infrastructure development on inequality and optimization equality of farmer's income in Indonesia-Timor Leste Border Area. *Asian Journal of Agriculture and Rural Development*, *13*(4), 269–276. https://doi.org/10.55493/5005.v13i4.4933

Ulia, R., Arafah, Y., & Hanifah, W. (2025). Persepsi petani terhadap infrastruktur pendukung kawasan agropolitan di Kecamatan Tangse, Kabupaten Pidie. *JPPE (Jurnal Perencanaan Dan Pengembangan Ekonomi)*, *8*(2), 111–122.

Wahyuni, R. N. T., Ikhsan, M., Damayanti, A., & Khoirunurrofik, K. (2022). Inter-District road infrastructure and spatial inequality in Rural Indonesia. *Economies*. https://doi.org/10.3390/economies10090229

Wahyuni, S., Siregar, H., Rustiadi, E., & Pravitasari, A. E. (2024). Analysis of the leading sector for regional development : A case study of Batam , Bintan , and Karimun (BBK), Riau Islands Province , Indonesia. *Jurnal Agraria Dan Pertanahan*, *10*(1). https://doi.org/10.31292/bhumi.v10i1.792

Wazhari, M., Pravitasari, A. E., & Sarma, M. M. (2023). Analisis pengembangan industri prioritas daerah berbasis komoditas pertanian unggulan di Kabupaten Bogor. *Jurnal Agro Ekonomi*, *41*(2), 83-100.

Wibiseno, T. (2023). Pengukuran kemampuan kabupaten / kota untuk pencapaian target indikator pembangunan pada rencana pembangunan jangka menengah daerah Provinsi Jawa Tengah. *Bappenas Working Papers*, *VI*(3). https://doi.org/10.47266/bwp.v6i3.193 |

Zamhari, A., Sitorus, S. R. P., & Pravitasari, A. E. (2017). Analisis komoditas unggulan dan arahan rencana pengembangannya di Kota Pagar Alam, Provinsi Sumatera Selatan. *Tata Loka*, *19*, 218–229. https://doi.org/10.14710/tataloka.19.3.218-229

Zheng, Z. (2025). How does transport infrastructure development impact rural livelihoods in the Global

South? A systematic review of the English language academic literature. *Environmental Science and Policy*, *173* (January), 104231. https://doi.org/10.1016/j.envsci.2025.104231