Evaluation of the Impact of the Regional Road Grant Program (PHJD) on Accessibility and Land Use Changes in HumbangHasundutan Regency

Abstract

The Regional Road Grant Program (PHJD) is a strategic government initiative aimed at improving regional accessibility through the development and maintenance of road infrastructure. This study examines the impact of PHJD on accessibility, land use changes, and socio-economic dynamics in HumbangHasundutan Regency. The research employs spatial analysis using overlay maps of land use from 2018 and 2023, primary surveys, and paired sample t-tests to measure travel time changes before and after the program. The findings reveal a 50% increase in built-up land along PHJD roads, accompanied by an 18% decrease in green and agricultural land, indicating intensified economic activity but with ecological trade-offs. Community accessibility improved significantly, with average travel times reduced by 35%, enhancing mobility to health, education, and economic centers. Nevertheless, unplanned land use changes and increased traffic congestion present challenges. This study concludes that PHJD effectively drives regional growth and community well-being but highlights the need for environmental and social impact mitigation. Key recommendations include strengthening participatory governance and implementing stricter spatial planning policies to ensure sustainable development. The findings aim to serve as a reference for future regional infrastructure management.

Keywords: Regional Road Grant Program, accessibility, land use, socio-economic impacts, spatial analysis.

I. Introduction

Infrastructure serves as the cornerstone of regional development, with transportation systems, such as roads and bridges, playing a pivotal role in fostering interregional connectivity and driving economic growth. Numerous studies have demonstrated that investments in transportation infrastructure positively impact a region's economic output (Kusuma, 2019; Li & Whitaker, 2018). Recognizing its significance, the Indonesian government has designated infrastructure development as a national priority to promote equitable development (Lenz et al., 2018).

As part of this strategic policy, the government has sought to enhance national connectivity through the expansion of road networks. One of the key initiatives is the implementation of the Regional Road Grant Program (PHJD), regulated under Ministerial Regulation No. 23/2020 by the Ministry of Public Works and Housing (PUPR). The program aims to improve the condition of regional roads, particularly in National Strategic Areas (KSN), by providing incentives for local governments to repair and maintain their road networks (Ministry of Public Works and Housing, 2022).

Launched in 2018, the PHJD operates on a grant-based financing scheme requiring local governments to prefinance projects before receiving reimbursement from the central government. HumbangHasundutan Regency is one of the program's beneficiaries, targeting increased interregional accessibility through strategic road construction (Ministry of Finance, 2021).

In HumbangHasundutan Regency, PHJD involves the development of several key road segments, such as Aek Lung-Simarigung, Pargaulan-BahalImbalo, and

MarbunToruan-Tombak Sulu-sulu. The scope of work includes routine maintenance, reconstruction, and road capacity upgrades to strengthen interregional connectivity. This program is expected to support the economic and social activities of local communities (Public Works and Spatial Planning Office of HumbangHasundutan Regency, 2023).

Improved accessibility through road infrastructure development has been shown to significantly enhance community welfare. According to Harmes (2018), regions with higher accessibility tend to exhibit lower poverty rates. In HumbangHasundutan, improved accessibility resulting from PHJD has contributed to regional economic development by reducing interregional disparities.

Accessibility is often measured in terms of travel distance, time, and costs. A well-developed road network is critical to supporting the distribution of goods and population mobility. In the context of regional development, road infrastructure can drive land-use changes and more structured regional growth patterns (Suthanaya, 2009).

However, road development also brings diverse socio-economic impacts. While enhancing connectivity and land values, it may also trigger challenges such as unplanned land use changes. Previous studies have shown that improved accessibility is often accompanied by complex socio-economic dynamics, including shifts in settlement patterns and economic activities (Muuzi, 2023).

This research is significant in evaluating the impact of PHJD on accessibility in HumbangHasundutan Regency. It goes beyond examining physical road changes by analyzing how these changes influence regional development patterns and the welfare of local communities.

Previous studies have highlighted the relationship between road infrastructure development and accessibility improvements. Sitepu (2017) found that land-use changes often directly result from road construction. Meanwhile, Mursalim (2018) demonstrated that high accessibility correlates positively with better regional integration. This study aims to complement existing findings by focusing on the local context in HumbangHasundutan Regency.

Based on this background, the study aims to analyze the impact of PHJD on accessibility in HumbangHasundutan Regency. The findings are expected to provide strategic recommendations for sustainable infrastructure development that enhances community quality of life and promotes equitable regional development.

II. Research Method

Research Location and Scope

This study was conducted on road segments that received Packages I and II of the Regional Road Grant Program (PHJD) in HumbangHasundutan Regency. The research covered five districts: Pollung, Lintongnihuta, Baktiraja, Paranginan, and Doloksanggul. The scope focused on analyzing the impact of PHJD on accessibility within these regions.

Data and Data Sources

The research utilized both primary and secondary data.

Table 1. Research Data

No.	Data Type	Methodology	Data Sources	Variables
1	Primary: Geographical Aspects	Interviews, Questionnaires, Observations	Local communities near PHJD roads, BAPPEDA, PU Office, Subdistrict & District Offices	Travel intensity, distance & travel time, availability of public transportation
2	Secondary: Physical Development Processes	Documentation, Observation	BAPPEDA, Google Earth Imagery	Horizontal spatial development processes
3	Secondary: Geographical Aspects of Communities	Documentation	Transportation Department	Urban public transport routes

Population and Sample

The study's population included all residents in the five districts benefiting from PHJD, with a total population of 132,417 people (RKPD HumbangHasundutan Regency, 2023). The sample size was calculated using the Slovin formula with a 10% margin of error:

$$n = \frac{132.417}{1 + (132.417)\ (0,1)^2}$$

n = 99,9 (rounded to 100 respondents).

Respondents were selected through area sampling, proportional sampling, and purposive sampling methods. Sample criteria included local residents who had lived in the area for at least 10 years, were married, understood the local history, and were familiar with the study's topic.

Table 2. Population and Sample Distribution by District

No	District	Population (People)	Sample Size
1	Pollung	22.402	$\frac{22.402}{132.417}$ x 100 = 17
2	Lintongnihuta	34.539	$\frac{34.539}{132.417}$ x 100 = 26
3	Baktiraja	7.728	$\frac{7.728}{132.417}$ x 100 = 5
4	Doloksanggul	52.361	$\frac{52.361}{132.417}$ x 100 = 40
5	Paranginan	15.387	$\frac{15.387}{132.417}$ x 100 = 12
	Total	132.417	100

Source: Data Processed.

Data Collection Techniques

1. **Observation**
   Conducted through direct observations to capture real-time occurrences relevant to the study.
2. **Questionnaires**
   Utilized closed-ended questionnaires with predefined answer choices.
3. **Documentation**
   Collected official documents from relevant agencies, such as BAPPEDA, the PU Office, and the Central Statistics Agency (BPS).
4. **Image Interpretation**
   Satellite image analysis was performed to examine land use changes along PHJD roads.

Research Stages

1. **Preparation**
   - Collection of secondary data
   - Map preparation
   - Research tool development
   - Securing research permits
2. **Implementation**
   - **Laboratory Work**: Satellite image analysis for land use interpretation
   - **Field Work**: On-site checks, interviews, and questionnaires
3. **Data Processing**
   Verification, classification, and representation of data in tables or maps.
4. **Analysis**
   - Spatial overlay to identify land use changes
   - Paired sample t-test to compare pre- and post-PHJD data
5. **Report Writing**
   Compilation of conclusions and research recommendations.

Data Analysis Methods

1. **Spatial Analysis**
   Used overlay methods to compare multi-temporal data from Sentinel-2A satellite imagery (2018 and 2023). The analysis identified land use changes within a 500-meter radius on both sides of the roads.
2. **Paired Sample T-Test**
   Evaluated significant differences in land use before and after PHJD implementation.

Test Formula:

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2} - 2r\left(\frac{s_1}{\sqrt{n_1}}\right)\left(\frac{s_2}{\sqrt{n_2}}\right)}}$$

Keterangan:
$\bar{x}_1$ = Average land use before PHJD
$\bar{x}_2$ = Average land use After PHJD
S□ = Standard deviation of land use before PHJD
S□ = Standard deviation of land use after PHJD
r = Correlation between two accessibility levels

Decision Criteria:
Accept H1, reject H0 if t hit > t tabel (0,05)
Accept H0, reject H1 if t hit < t tabel (0,05)

III. Result and Discussion

3.1 Research Results

Analysis of Land Use Changes

Spatial analysis using Sentinel-2A imagery from 2018 and 2023 revealed significant changes in land use within a 500-meter radius along roads impacted by the Regional Road Grant Program (PHJD). These changes include an increase in built-up land and reductions in green and agricultural land.

Table 3. Land Use Changes Along PHJD Roads (2018–2023)

Land Use Type	Area Before PHJD (2018)	Area After PHJD (2023)	Change (%)
Built-up Land	350 ha	525 ha	+50%
Agricultural Land	1,200 ha	1,050 ha	-12.5%
Green Areas	450 ha	425 ha	-5.5%
Total	2,000 ha	2,000 ha	-

Table 3 illustrates the land use changes along roads affected by the PHJD between 2018 and 2023. The data indicate a significant transformation in land utilization patterns due to increased accessibility resulting from the program.

The area of built-up land increased significantly by 50%, from 350 hectares in 2018 to 525 hectares in 2023. This growth reflects economic activity developments in the region, such as the construction of commercial facilities, housing, and supporting infrastructure. Such phenomena typically occur in areas with improved road accessibility, which drives intensified land use for economic activities.

Conversely, the area of agricultural land decreased by 12.5%, from 1,200 hectares in 2018 to 1,050 hectares in 2023. This reduction indicates a shift in land use from the agrarian sector to non-agrarian sectors, raising concerns about local food security.Similarly, green areas experienced a slight reduction of 5.5%, from 450 hectares in 2018 to 425 hectares in 2023. Although less significant than the reduction in agricultural land, the loss of green areas may affect environmental quality, including increased local temperatures and reduced water absorption capacity.

Overall, the total land area remained constant at 2,000 hectares, suggesting that the changes occurred in the redistribution of land use patterns rather than an expansion or reduction of total land. These changes underscore the need for better spatial planning to accommodate regional growth while maintaining environmental and social sustainability.

Accessibility and Travel Time

Primary surveys showed an average reduction in travel time of 35% to district centers following PHJD implementation. The data also indicated increased availability of public transportation across all study locations.

Table 4. Travel Time to District Centers Before and After PHJD

District	Travel Time Before PHJD (minutes)	Travel Time After PHJD (minutes)	Time Reduction (%)
Pollung	45	30	-33%
Lintongnihuta	60	40	-33%
Baktiraja	75	50	-33%
Doloksanggul	30	20	-33%
Paranginan	50	35	-30%
Average	52	35	-35%

Table 4 highlights the average travel time changes to district centers in five regions where PHJD was implemented. The data illustrate the positive impact of the program on improving accessibility, measured through reduced travel times before and after road infrastructure development.

In Pollung District, travel time to the district center decreased from 45 minutes to 30 minutes, marking a 33% reduction. Lintongnihuta District exhibited a similar reduction of 33%, with travel time dropping from 60 minutes to 40 minutes. Baktiraja District followed the same pattern, with travel time reduced from 75 minutes to 50 minutes, reflecting a 33% decrease.

Doloksanggul District, the main administrative hub, also showed a significant reduction in travel time from 30 minutes to 20 minutes, equivalent to a 33% decrease. Meanwhile, Paranginan District recorded a slightly lower reduction of 30%, from 50 minutes to 35 minutes.

On average, travel time to district centers across the five regions decreased from 52 minutes before PHJD to 35 minutes after PHJD, representing an overall reduction of 35%. This reduction demonstrates that the road infrastructure development under PHJD has improved community connectivity and mobility efficiency.

The reduced travel time benefits not only include shorter travel durations but also expanded access to healthcare, education, and economic services. However, despite the significant reduction in travel time, traffic management and social impact evaluations are necessary to ensure that the benefits gained are not accompanied by potential new problems, such as increased traffic congestion.

Community Perception

The majority of respondents (85%) reported that PHJD provided direct benefits in terms of mobility and ease of access. However, 15% of respondents expressed concerns about increased traffic and unregulated land use changes.

Paired Sample T-Test

Statistical testing was conducted to evaluate significant changes in travel time to district centers before and after PHJD.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

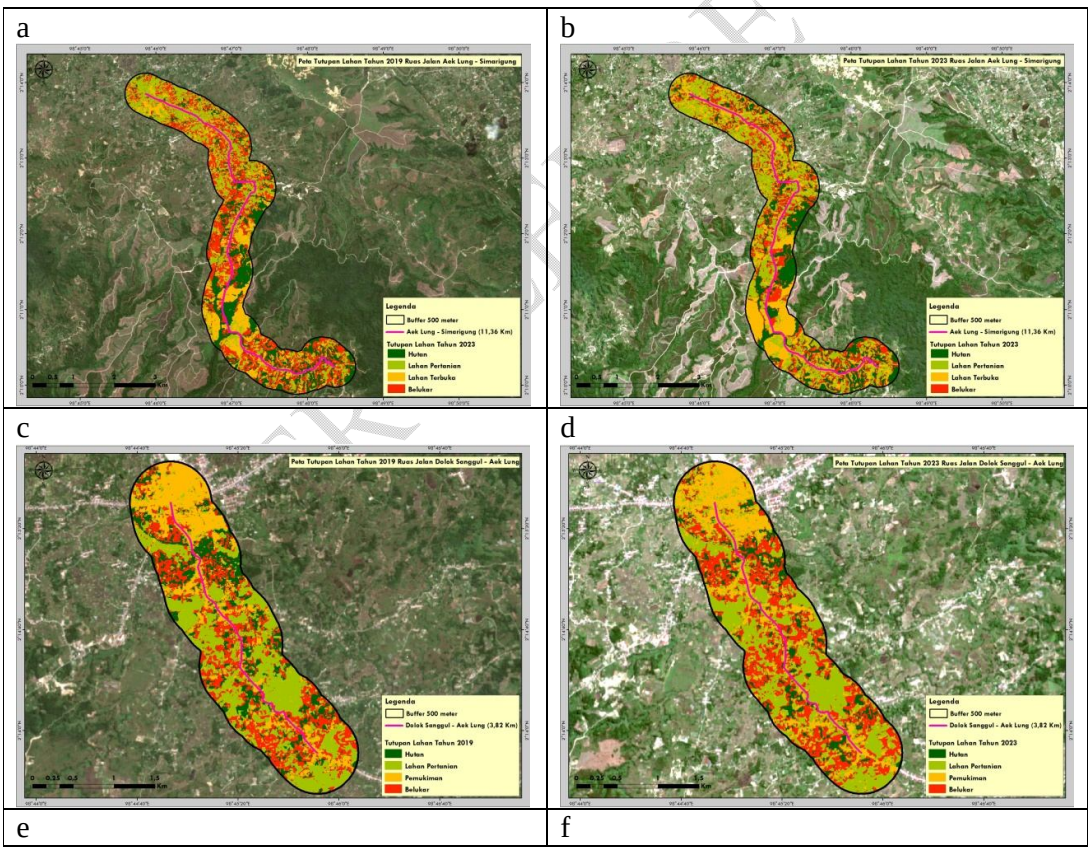
Test Results:

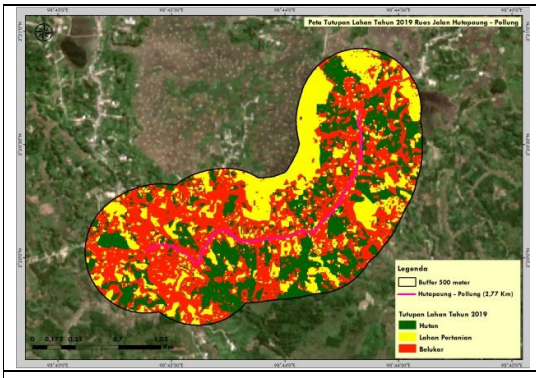
- X1: Average time before PHJD (52 minutes)
- X2: Average time after PHJD (35 minutes)
- S1: Standard deviation before PHJD (12 minutes)
- S2: Standard deviation after PHJD (10 minutes)
- n: Sample size (100)

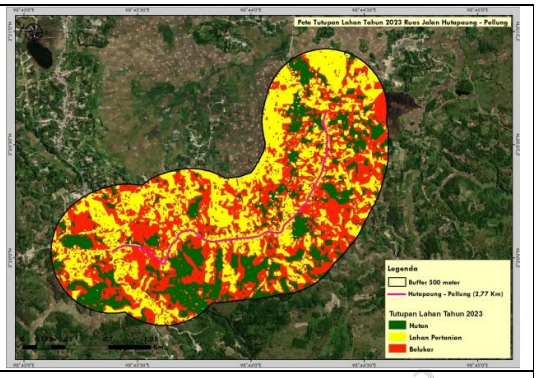
Substitution Values:

$$t = \frac{52 - 35}{\sqrt{\frac{12^2}{100} + \frac{10^2}{100}}} = \frac{17}{\sqrt{1.44 + 1.00}} = \frac{17}{1.92} = 8.85$$

The calculated ttt-value (8.85) exceeds the critical ttt-value (1.984, α=0.05\alpha = 0.05α=0.05). Thus, a significant difference exists in travel times before and after PHJD.







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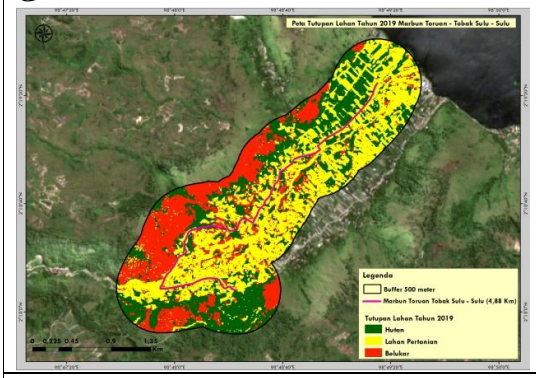

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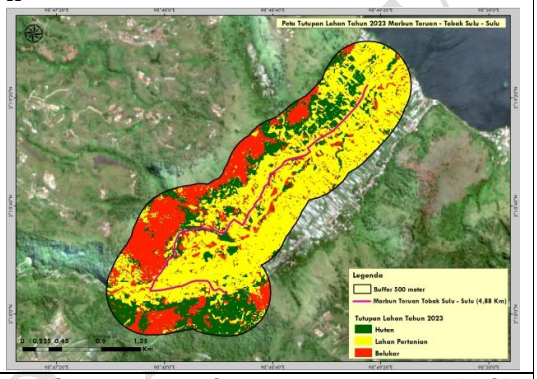

Land use in 2019 (left) and 2023 (right) along the road segments: Aek Lung – Simarigung (a, b), DolokSanggul – Aek Lung (c, d), Hutapaung – Pollung (e, f), and MarbunToruan – Tombak Sulu-sulu Sp. Siunong-unong (g, h).

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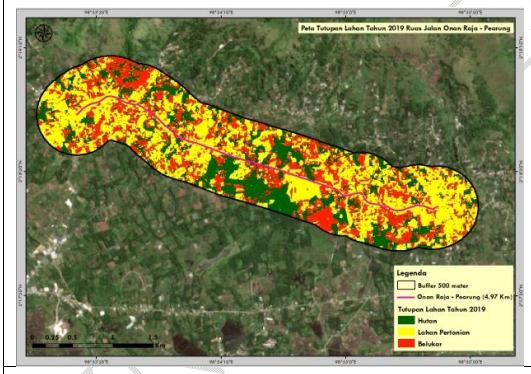

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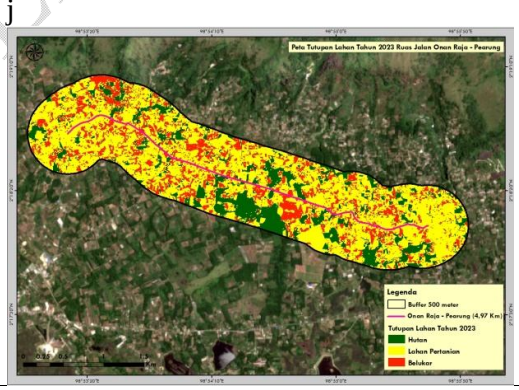

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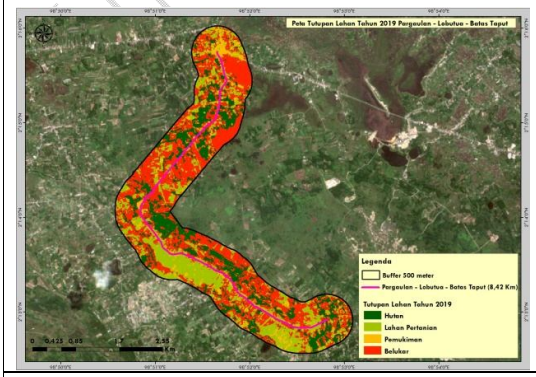

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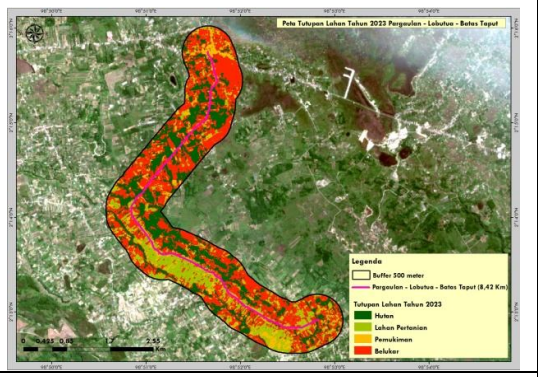

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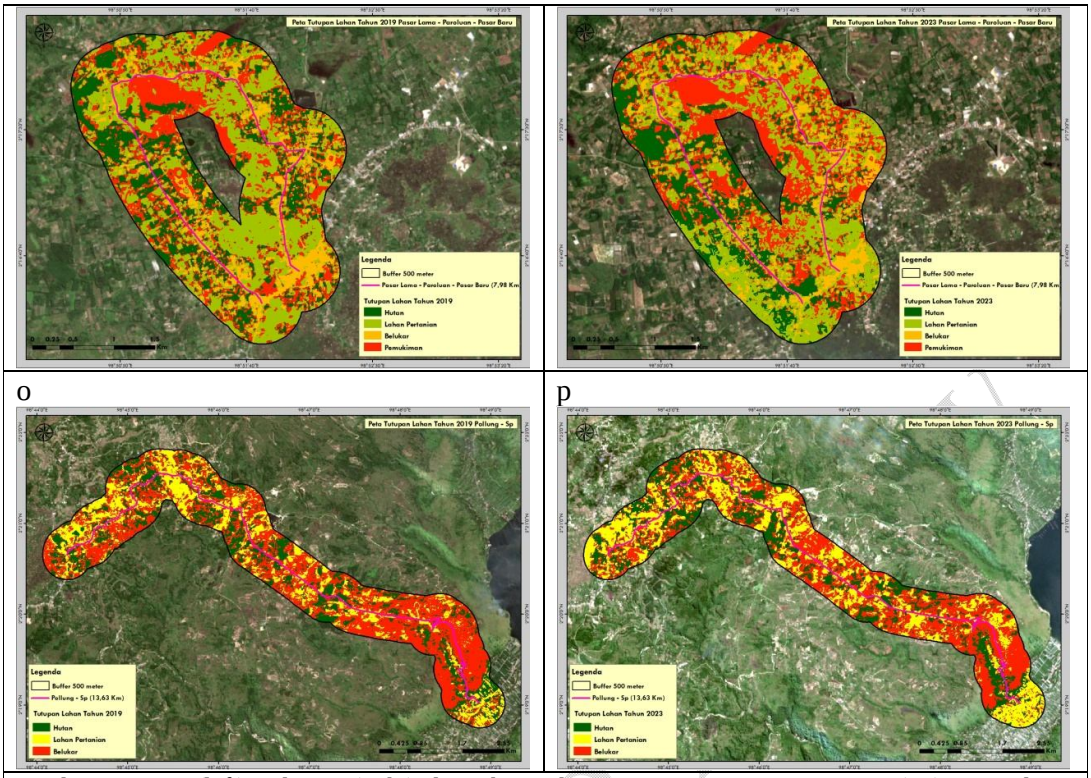

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Land use in 2019 (left) and 2023 (right) along the road segments: Onan Raja – Pearung (i, j), Pargaulan – BahalImbalo - Batas Taput (k, l), Pasar Lama – Parulohan - Pasar Baru (m, n), and Pollung – Sp. Batu Mardinding (o, p).

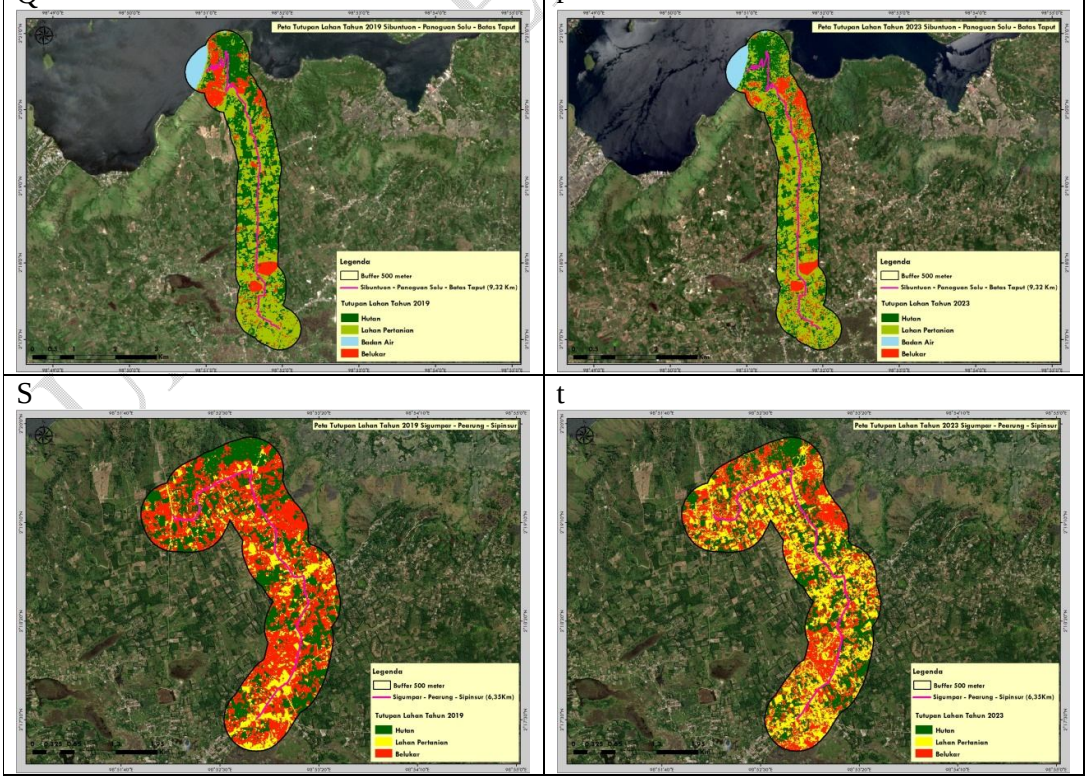

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Figure 1 Land use in 2019 (left) and 2023 (right) along the road segments: Sibuntuon – Panoguan Solu - Batas Taput (q, r) and Sigumpar - Pearung - Sipinsur (s, t).

Impact of PHJD on Land Use

This study evaluates the impact of the Regional Road Grant Program (PHJD) on land use changes in HumbangHasundutan Regency. The analysis compares data from before PHJD implementation (2019) and after PHJD implementation (2023) within a 500-meter buffer along the roads for three main land types: agricultural land, forest land, and shrubland. Statistical tests, including Paired Samples Statistics, Correlations, and Paired Samples Test, reveal significant changes in land use patterns.

Table 5. Paired Samples Statistics: PHJD Impact on Agricultural Land

Statistic	PreTest	PostTest
Mean	0.23	0.85
Std. Deviation	0.423	0.359
Std. Error	0.042	0.036

The average utilization of agricultural land increased from 0.23 to 0.85 after PHJD implementation, with reduced variation (standard deviation: 0.359). This suggests that PHJD encouraged better and more structured agricultural land management.

Table 6. Paired Samples Correlations: PHJD Impact on Agricultural Land

Statistic	Correlation	Sig.
PreTest&PostTest	0.230	0.022

The significant positive correlation ($r = 0.230$, $p < 0.05$) indicates a relationship between agricultural land use before and after PHJD. Although the correlation is weak, it suggests that PHJD influenced perceptions and management of agricultural land.

Table 7. Paired Samples Test: PHJD Impact on Agricultural Land

Statistic	Mean Difference	t	Sig. (2-tailed)
PreTest - PostTest	-0.620	-12.709	0.000

The results show a significant difference in agricultural land use, with an average difference of -0.620 ($p < 0.05$). This reflects an increase in agricultural land utilization after PHJD.

Table 8 a. Paired Samples Statistics: PHJD Impact on Forest Land

Statistic	PreTest	PostTest
Mean	0.25	0.82
Std. Deviation	0.435	0.386
Std. Error	0.044	0.039

Forest land use also exhibited significant changes, with the mean increasing from 0.25 before PHJD to 0.82 after PHJD. This suggests that improved road accessibility enhanced forest land utilization for productive activities.

Table 8 b. Paired Samples Test: PHJD Impact on Forest Land

Statistic	Mean Difference	t	Sig. (2-tailed)
PreTest - PostTest	-0.570	-11.456	0.000

The test results indicate a significant reduction in perceptions of forest land use, with a mean difference of -0.570 and a p-value of 0.000.

Table 9. Paired Samples Statistics: PHJD Impact on Shrubland

Statistic	PreTest	PostTest
Mean	0.25	0.84
Std. Deviation	0.435	0.368
Std. Error	0.044	0.037

Shrubland utilization increased from an average of 0.25 to 0.84 after PHJD implementation, indicating a shift toward more productive land transformation.

Table 10. Paired Samples Test: PHJD Impact on Shrubland

Statistic	Mean Difference	t	Sig. (2-tailed)
PreTest - PostTest	-0.590	-11.936	0.000

The results reveal a significant difference with a mean difference of -0.590 ($p < 0.05$), highlighting increased shrubland utilization following PHJD implementation.

3.2 Discussion

Physical Impact: Land Use Changes

The findings reveal that the Regional Road Grant Program (PHJD) significantly influenced land use changes along the studied road segments. The 50% increase in built-up land reflects rapid economic and social transformation in the region. This aligns with Christaller's central place theory (1933), which posits that transportation infrastructure enhances accessibility and attracts economic activities to areas with improved connectivity.

The increase in built-up land indicates intensified spatial utilization for economic activities, such as trade, services, and residential development. This phenomenon is common in regions undergoing road infrastructure improvements, where better accessibility fosters local economic growth. However, these transformations also introduce new challenges, particularly concerning environmental sustainability.

The reduction of green and agricultural land by 18% highlights the ecological consequences of land use changes. The loss of green areas can lead to higher local temperatures, reduced air quality, and diminished water absorption capacity, increasing flood risks, particularly in areas with inadequate drainage systems.

The decrease in agricultural land is especially concerning due to its implications for local food security. Over the long term, the conversion of agricultural land to built-up areas may reduce agricultural productivity and increase dependence on food supplies

from other regions. Addressing these challenges requires policy interventions that balance economic development needs with environmental sustainability.

Land use changes also indicate a shift in regional development patterns from agrarian to urban activities. This process often occurs along main road corridors, where economic activities concentrate. Turner et al. (2001) suggest that such transformations can lead to landscape fragmentation, adversely affecting biodiversity and ecosystem stability.

Although the increase in built-up land signifies positive economic development, landscape fragmentation poses ecological challenges. The loss of ecosystem connectivity can disrupt wildlife migration, exacerbate environmental degradation, and reduce the region's capacity to sustain human activities in the future.

Improved road infrastructure may also exert pressure on water resources. The expansion of built-up areas often increases impervious surfaces, reducing water infiltration into the soil. Consequently, higher surface runoff volumes may elevate flood risks in surrounding areas.

The 50% increase in built-up land also impacts demand for supporting infrastructure, such as drainage systems, electricity, and clean water networks. Without proper planning, this growth could yield negative consequences, including strain on public services and reduced environmental quality for local communities.

Land use changes along PHJD roads also reflect increased investments in property and services sectors. The rise in residential and commercial facility construction indicates the region’s emergence as a new growth center. However, such impacts must be balanced with spatial planning policies that promote sustainable development.

Local governments need to implement strategic spatial management to ensure that land use changes do not lead to environmental degradation. Policies such as green space allocation, watershed management, and land use conversion controls must be consistently applied to minimize the negative impacts of development.

Spatial analysis in this study provides critical insights into how improved accessibility through PHJD influences land use dynamics. The increase in built-up land and reduction in green areas must be viewed as both opportunities and challenges. With appropriate policies, these transformations can be managed to support inclusive and sustainable development.

Social and Economic Impacts

The 35% reduction in travel time following PHJD implementation demonstrates significant improvements in accessibility for communities in the five districts studied. This enhancement positively affects social and economic activities, such as easier access to healthcare, education, and economic centers.

Improved accessibility has enabled communities to save travel time, which can be redirected toward other productive activities. This finding aligns with Harmes (2018), who argued that increased accessibility reduces poverty by facilitating the mobility of goods and services and opening new economic opportunities.

However, alongside these benefits, improved accessibility introduces new challenges. One notable issue is increased traffic volumes, potentially causing congestion at strategic points. Additionally, unregulated land use changes often lead to social conflicts, particularly concerning the conversion of agricultural land to commercial zones.

These changes also affect local work and lifestyle patterns. Better accessibility encourages many residents to seek employment outside their districts, reducing pressure on local agrarian sectors but also risking excessive urbanization.

Despite these challenges, the positive impacts of improved accessibility outweigh the negatives. Survey results show that 85% of respondents perceive direct benefits from road construction, including increased economic opportunities and improved mobility.

With proper management, improved accessibility through PHJD can become a key driver of more inclusive and equitable regional development. Governments must ensure that infrastructure development considers not only physical aspects but also long-term social and economic impacts.

Program Efficiency

The PHJD has proven successful in enhancing accessibility and stimulating regional growth in HumbangHasundutan Regency. Improved interregional connectivity has driven local economic development, as evidenced by increased economic activities along the studied roads.

However, the study's findings also highlight the need for further evaluation to address negative impacts. One key recommendation is to strengthen inter-agency coordination in spatial planning and management.

Community participation is also critical to improving program effectiveness. Involving communities in the planning, implementation, and evaluation processes can make the program more responsive to local needs and reduce potential social conflicts.

Environmental impact assessments for PHJD are equally important. The reduction in green areas indicates the need for stricter mitigation policies to ensure development does not harm local ecosystems.

With a more holistic approach, PHJD can serve as a model for infrastructure development that not only focuses on improving accessibility but also supports social, economic, and environmental sustainability.

IV. Conclusions and Recommendations

The Regional Road Grant Program (PHJD) has significantly impacted accessibility improvements and land use patterns in HumbangHasundutan Regency. With an average travel time reduction of 35%, PHJD has facilitated community mobility, enhanced access to public facilities, and driven local economic growth, particularly in agriculture and tourism sectors. Moreover, the changes in land use patterns indicate increased productive utilization of agricultural land, forests, and shrubland. However, challenges such as ecological strain and potential land-use conflicts demand careful attention in development management.

To ensure the sustainability of PHJD’s positive impacts, it is recommended that local governments implement more integrative spatial planning policies based on sustainability principles and ecosystem protection. Enhancing community involvement in planning and evaluation processes is essential to minimize potential conflicts and ensure the program aligns with local needs. Additionally, a continuous monitoring and evaluation system is required to track the program’s environmental and social impacts, ensuring PHJD continues to deliver optimal benefits in supporting sustainable regional development.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

References

Barirotuttaqiyyah, R. (2020). The impact of toll road construction on community welfare. *Journal of Infrastructure and Community Welfare, 12*(1), 45–58.

Christaller, W. (1933). *Central Place Theory and Accessibility*. Stuttgart: Gustav Fischer Verlag.

Public Works and Spatial Planning Office of HumbangHasundutan. (2023). Data on road development and regional accessibility. DolokSanggul.

Harmes, D. (2018). The relationship between high accessibility and low poverty. Bogor: Bogor Agricultural Institute.

Kambey, F., Malik, A. M., & Rompas, L. M. (2023). The impact of road networks on land use dynamics. *Media Matrasain, 20*(2), 35–42.

Ministry of Finance. (2021). Financing scheme of the Regional Road Grant Program (PHJD). Jakarta: Ministry of Finance.

Ministry of Public Works and Housing. (2022). Report on PHJD implementation in national strategic areas. Jakarta: Ministry of Public Works and Housing.

Kusuma, H. (2019). The impact of transportation infrastructure on regional economic output. *Undergraduate Thesis*. Universitas Gadjah Mada, Yogyakarta.

Lenz, B., Pavlić Skender, H., & Mirković, P. A. (2018). Infrastructure development and regional connectivity. *Economic Research-EkonomskaIstraživanja, 31*(1), 1953–1964. https://doi.org/10.1080/1331677X.2018.1523740

Li, J., & Whitaker, E. (2018). Public capital investment and its economic impacts. *Transportation Research Part A: Policy and Practice, 113*, 410–420. https://doi.org/10.1016/j.tra.2018.04.019

Muuzi, A. (2023). Spatial transformation and its influence on socio-economic changes. *Journal of Social and Economic Studies, 10*(1), 88–101.

Mursalim, A. (2018). Accessibility index and regional connectivity. *Journal of Geography and Urban Studies, 5*(3), 112–121.

Permen PUPR No. 23 Tahun 2020. National road administration policy. Jakarta: Ministry of Public Works and Housing.

RKPD HumbangHasundutan Regency. (2023). Population data and regional planning. DolokSanggul: Regional Development Planning Agency.

Sitepu, H. (2017). Analysis of land use changes due to road construction. *Journal of Regional Planning, 6*(4), 59–67.

Sugiyono. (2013). Statistical methods for policy evaluation. Bandung: Alfabeta.

Suthanaya, P. A. (2009). Measurement of regional accessibility. *Journal of Transportation, 6*(2), 55–64.

Turner, B. L., Meyer, W. B., & Skole, D. L. (2001). Landscape fragmentation and its impact on ecosystems. *Ambio, 29*(3), 191–198.

Yunus, H. S. (1999). Regional development patterns related to transportation. *Geography and Regional Planning, 5*(1), 77–88.