A Comparative Assessment of the Poverty Incidence Situation in Mindanao, Philippines with Quantitative Evaluation of the Impact of Road Density

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Abstract

This study investigates poverty incidence changes in Mindanao, Philippines, using the Small Area Estimation of poverty incidence data for 2018 and 2021. The General G analysis revealed clustering of hot and cold spots of poverty incidence in both periods. With sufficient evidence supporting the potential of the clustering of hot spots and cold spots clustering of poverty incidence, the Getis-Ord G_i^* was applied which generated valuable maps that may be used for planning and policy development. A significant decrease in poverty incidence was observed in some areas in the Bangsamoro Autonomous Region in Muslim Mindanao, a significant increase occurred in several areas in Zamboanga Peninsula, while Davao Region seems to have consistent economic stability in terms of having relatively lower poverty incidence, for 2021. The impact of road expansions on poverty incidence is also examined. Geographical Weighted Regression shows that a higher road density could reduce the poverty incidence. However, the study cautions against solely relying on road infrastructure development as a solution given the varying coefficients in different locations as well as a low r-squared value. The study highlights the need for concerted efforts to address poverty in Mindanao, including expanding national and rural roads, promoting economic development through MSMEs and tourism, and addressing ongoing peace and order issues and anticipative efforts for natural disasters.

Keywords: Hot Spots and Cold Spots, Mindanao, Poverty Incidence, Road Density, Small Area Estimation

1. Introduction

Road interventions have long been favored by governments and major donors to combat rural poverty. Based on the Rural Access Index provided by the World Bank, the overall level of road accessibility for rural communities in developing nations stands at a mere 57%. In Sub-Saharan Africa, this figure drops even further, with just 30% The majority of the population has access to a road [1]. Various literature suggests that overall, roads are effective in reducing poverty as well as improving education and enhancing health. Additionally, there is a substantial amount of census data available that provides information on road length, conditions, and the populations that have access to them [1]. Empirical research indicates that road enhancements positively impact farmer transport costs, income, and market access. Several studies showed that road interventions had a significant positive impact on farmer earnings [1]. Additionally, significant decreases in transport costs are observed [1]. We also demonstrated statistically significant improvements in market access [1].

Farmers benefited in the short term from the improvement in market accessibility. Reduced transportation costs resulted in increased availability of inputs at lower prices, as merchants were able to access markets at a lower cost. These advantages allowed farmers to enhance their yield in the intermediate period. Improved road infrastructure not only resulted in greater agricultural production but also attracted external investment to the communities that benefited from it. This, in turn, created employment possibilities, ultimately leading to higher household income and consumption levels and a reduction in poverty over time. Studies have generally shown that enhancements in transportation infrastructure, such as the expansion of road networks, air transport, trains, ports, and logistics, have also led to a rise in trade volumes as well [2].

The road and transportation infrastructure are crucial in fostering sustainable development and economic prosperity in specific areas. Roads and transportation benefit local communities and sustainable growth, according to literature [3]. The presence of roads and transportation systems enhances the well-being and quality of life of the local community as well. In addition, investments in local roads contribute to economic growth and alleviate poverty in local communities [3] and [4]. A recommendatory discussion from the Philippines emphasizes the significance of allocating funds toward local roads [3]. It draws attention to the crucial role of local government units (LGUs) in enhancing the local road network. Moreover, the valuation report of the International Labour Organization (ILO) on the potential socio-economic benefits of improving rural roads highlighted three key points. Firstly, it emphasized the correlation between the level of (a) isolation and (b) remoteness to poverty. Secondly, it underscored the potential for enhanced economic productivity in the surrounding areas, as the use of such roads encourages people to be more productive in their respective industries. Lastly, it stressed the importance of considering the level of social services, such as access to transportation, hospitals, health facilities, and secondary schools [4] and [5]. However, securing additional funding to support local road infrastructure is only partially effective as a solution [3] and [4].

The success of the national and local government units will largely hinge on the quality and effectiveness of governance, as well as the commitment to sound planning, budgeting, and procurement processes [3] and [4]. The Duterte administration launched the *Build, Build, Build* (BBB) *program* as an initiative to boost the economic growth of the Philippines. It aimed at propelling the country into a period of significant infrastructure development known as the *Golden Age of Infrastructure* [5]. Its purpose was to address the considerable disparity in the country's infrastructure, which had been recognized as a significant contributor to the high expenses associated with conducting business in the country. The program's objectives were to promote investments, streamline job creation, enhance economic growth, and enhance the standard of living in urban and rural areas. The initial projection for BBB was approximately 9 trillion Philippine pesos (around USD 175.3 billion with the August 2023 conversion) from 2016 to 2022. It was anticipated that by 2022, BBB would represent 7.0 percent of the gross domestic product (GDP) of the country [5].

A study published in 2023, it was recommended that some future research related to the impacts of road networks on the poverty situation in other parts of the Philippines may be done [4], especially when the updated datasets become available. This is because of the effects of Coronavirus Disease 2019 (COVID-19) and how they might get better, the recent building projects by the Department of Public Works and Highways (DPWH) that are in line with the Better Business Bureau (BBB) Program of the previous national administration, and the chance of uncontrollable events like natural disasters [4]. We can view this study as a valuable contribution toward achieving these recommendations. It can also help reach the Sustainable Development Goals, which are to end poverty (Goal 1), lower death rates from non-communicable diseases by preventing and treating them and improving mental health and well-being, and increase access to high-quality health care services (Goal 3). Other goals include promoting decent work and economic growth (Goal 8), advancing industry, innovation, and infrastructure (Goal 9), and lowering inequality (Goal 10). Collaborations and initiatives at the local, national, and international levels can facilitate these efforts.

2. Methods

2.1 Study Setting

This paper focuses on the Mindanao Group of Islands, or simply *Mindanao*, which is situated in the southern part of the Philippines. According to the Mindanao Development Authority, Mindanao is characterized as a picturesque region with harmonious and thriving towns, abundant natural resources, and vibrant cultures. The region experiences significant advantages from extensive plantations, companies, and resource-dependent economic activities [6] and [7].

Nevertheless, it is renowned for its areas characterized by extreme poverty, glaring disparity, deliberate devastation and exhaustion of natural resources, and incidences of violence. The disparities in the characteristics of Mindanao are noticeable, and the prospects of finding a solution to these extremes are challenging, making any attempt to carry out further study and planning challenging due to a track record of inconsistent outcomes [6] and [7]. Figure 1 shows the map of Mindanao by Administrative Region (AR) and its location in the Philippines.

Although critically hampered by the COVID-19 pandemic, the BBB, as part of the Updated Philippine Development Plan 2017-2022 (PDP), aimed to create a nationwide supply chain network system that was both efficient and resilient [8]. Transport authorities in the country were encouraged to continue to develop collaborative initiatives with relevant agencies to guarantee that economic sectors received sufficient assistance and services for transport infrastructure. Plans for the provision of farm-to-market and farm-to-mill roads that would continue to help agricultural communities, adhering to the established requirements for design and construction, were envisioned [8]. The development of transportation infrastructure that supports tourist sites will continue to enhance tourism activities that were impacted by the COVID-19 epidemic were laid out as well [8]. Furthermore, the PDP pictures the implementation of the Mindanao Logistics Infrastructure Network to facilitate development in Mindanao [8]. This would involve the construction of road projects, in addition to the implementation of the Improving National Roads for Inclusive Growth in Mindanao Projects in Western Mindanao. Additionally, to enhance the quality of service provided by the national road network, local roads will undergo ongoing improvements through upgrades, expansions, and sufficient maintenance. The road network should be developed to maximize road capacity while also optimizing the design speed. Novel designs of crossroads and interchanges will be implemented, and temporary bridges will be converted into permanent structures. It is important to emphasize that the road network must remain operational for humanitarian logistics purposes as well [8]. The Philippines is divided into 17 administrative regions (AR). Six Ars are found in Mindanao. The Ars situated in Mindanao are the Autonomous Region of Muslim Mindanao (ARMM), Caraga Region, Zamboanga Peninsula, the provinces of South Cotabato, Cotabato, Sultan Kudarat, Sarangani and General Santos (SOCCSKSARGEN), Northern Mindanao, and Davao Region. Note that ARMM is now renamed as Bangsamoro Autonomous Region of Muslim Mindanao or BARMM and hence, ARMM and BARMM are used in this study interchangeably. Figure 2 shows the map of Mindanao by AR with overlain national road networks. The shapefile of the road networks was provided by the Department of Public Works and Highways.

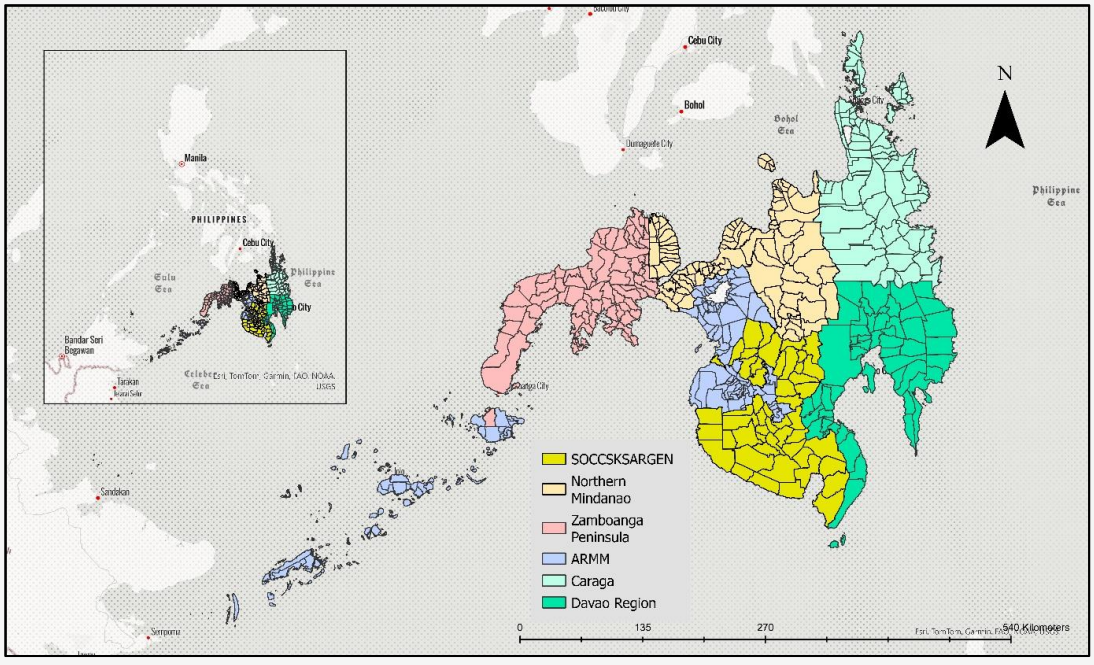

Figure 1: Map of Mindanao by administrative regions (AR)

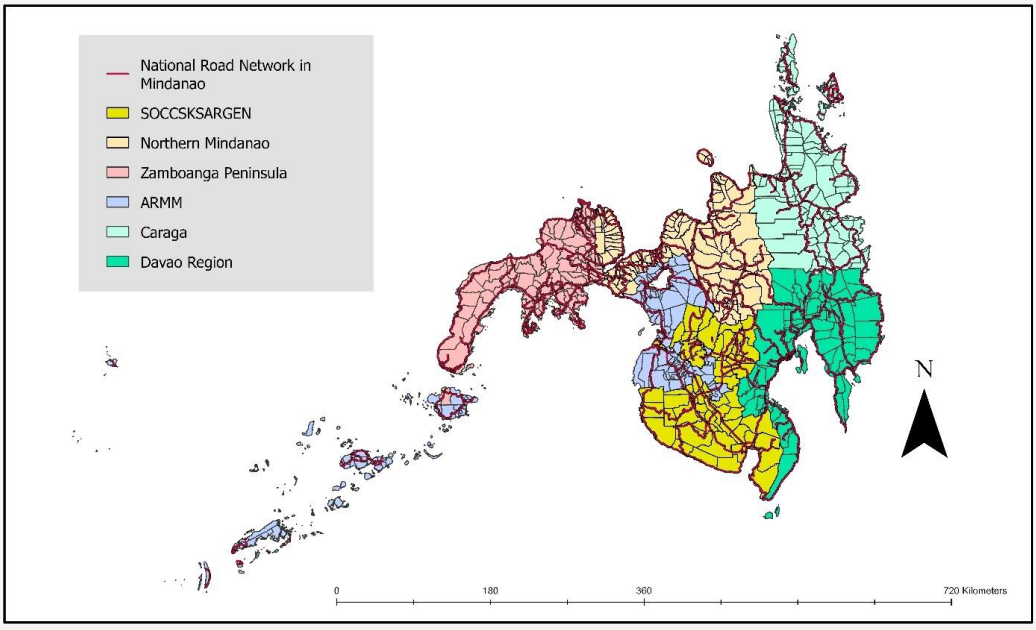

Figure 2: Map of Mindanao by AR overlain with national road networks

2.2 Sources of Data

The term *poverty incidence*, as defined by the Philippine Statistics Authority (PSA), refers to the estimated percentage of individuals or households whose income or spending capability falls below a specific poverty criterion [4] and [9]. The PSA estimates that on national level, 18.1% of Filipinos are below the poverty threshold in 2021 which is approximately 20 million individuals. The SAE of poverty incidence data, which is *official statistics*, is open for access to everyone on the website of the PSA [10]. Moreover, the poverty incidence in the Philippines, like in other countries, is determined using the Small Area Estimation (SAE) methodologies of the PSA [11]. The most popular SAE Method is the Elbers, Lanjouw, and Lanjouw (ELL) technique [11]. Although several methods are already proposed to further calibrate the poverty estimates, the ELL is still the method applied by the PSA. In addition, SAE techniques, as defined by the World Bank, are statistical tools that can be utilized to produce more accurate statistics for small geographical regions, such as cities and municipalities, compared to data acquired by a sample survey [4] and [12]. A comprehensive discussion about the ELL method and SAE in general can be accessed freely online from the Asian Development Bank [12].

Additionally, poverty maps, based on SAE, are modern tools that provide estimates of poverty rates in small geographic areas. These maps are very detailed and provide a disaggregated view of poverty incidence [4] and [13]. A poverty map visually displays the prevalence of poverty in different areas while also indicating the spatial distribution of poverty and inequality [4] and [12]. SAE can be used in producing maps that offer effective communicative instruments and aggregate easily visualizable detailed information of poverty estimates for numerous cities and villages. The maps provide a concise amount of information that maintains the spatial relationships between geographical units, something that cannot be achieved with tabular data. Poverty maps can also be used to identify the factors that contribute to poverty in smaller geographic areas [4] and [12]. The SAE of poverty incidence in all the AR in Mindanao for 2018 and 2021 are visualized in Figure 3 and Figure 4, respectively, through choropleth maps, with Table 1 showing the ranges of each symbology colors. The 20.00 percent ranges follow the customary practice of the PSA in their thematic maps [14]. The 2018 municipal and city-level poverty estimates were generated using the SAE methodology [14], which combined the 2015 Census of Population with the merged 2018 Family Income and Expenditure Survey (FIES) and the January 2019 round of the Labor Force Survey (LFS). This approach ensured the production of accurate poverty estimates at smaller geographic levels. On the other hand, the SAE methodology for 2021 [15] utilized the data from the 2020 Census of Population and Housing (CPH), the combined datasets of the 2021 Family Income and Expenditure Survey and the January 2022 round of the LFS, and the 2021 Updating of the List of Establishments.

Table 1: Ranges of small area estimates of poverty incidence

Symbology	Range in Percent
	0.00 to 20.00
	Over 20.00 to 40.00
	Over 40.00 to 60.00
	Over 60.00 to 80.00
	Over 80.00 to 100.00

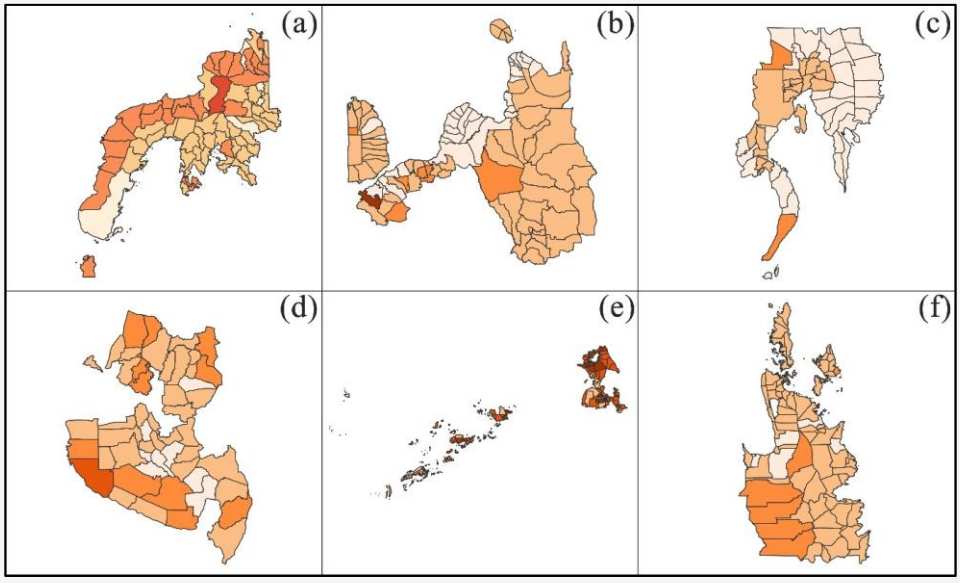

Figure 3: Choropleth map of the SAE of poverty incidence for 2018 for all ARs
(a) Zamboanga Peninsula, (b) Northern Mindanao, (c) Davao Region, (d) SOCCSKSARGEN, (e) ARMM, and (f) Caraga Region

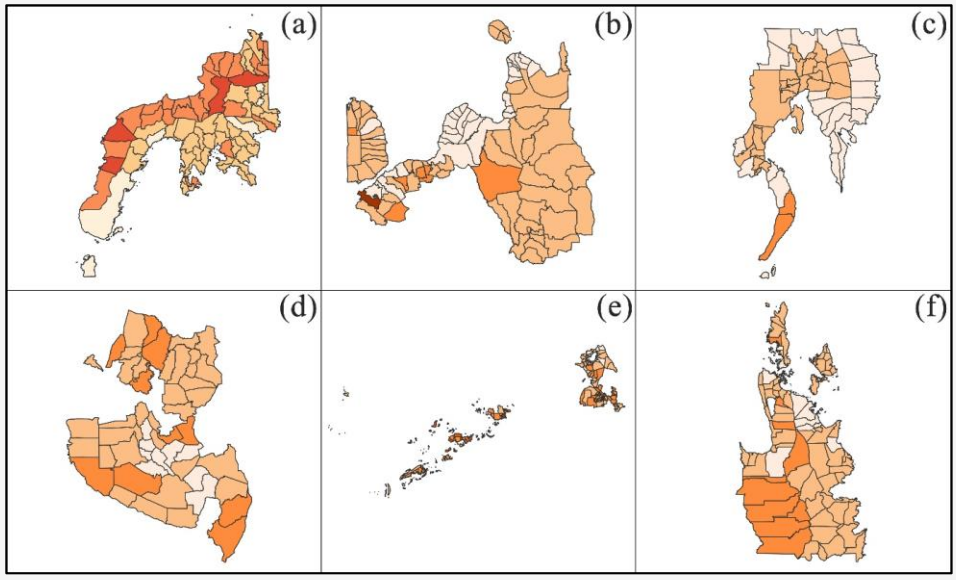

Figure 4: Choropleth map of the SAE of poverty incidence for 2021 for all ARs
(a) Zamboanga Peninsula, (b) Northern Mindanao, (c) Davao Region, (d) SOCCSKSARGEN, (e) ARMM, and (f) Caraga Region

Their analysis also included the examination of the 2021 Nighttime Lights Data. The data originates from the Earth Observation Group at the Colorado School of Mines. Figure 3 shows the visualization of SAE for 2018 in Mindanao. As seen, some municipalities have a poverty incidence of 60% to less than 80% in ARMM. Some areas have poverty incidence exceeding 80% as well. In addition, the northern coastal areas of Zamboanga Peninsula, at a glance, show contiguous areas with higher levels of poverty incidence, although mostly ranging from 40.01% to 60.00% only. Moreover, some western parts of the SOCCSKSARGEN areas have 40% to less than 60.00% poverty incidence. Some northern and southern parts of Mindanao have lower poverty incidence, while the central and eastern parts have around 60.00% or lower poverty incidence, too.

Figure 4 shows the visualization of SAE for 2021 of the ARs in Mindanao. Remarkably, all areas from ARMM have poverty incidence in the 40.01 to 60.00% range only. Only four areas, all of which belong to the Zamboanga Peninsula, have poverty incidence slightly exceeding 60.00%.

2.3 Inference on Hot Spots and Cold Spots

This study implemented the Getis-Ord General *G* geostatistical tool to assess the level for a *global scale* i.e. overall clustering of high or low attribute values of features within the chosen study setting [17] and [16]. For simplicity, the features consisting of cities or municipalities will be referred to as *areas*. The Getis-Ord General *G* statistic is defined in equation 1.

$$G = \frac{\sum_{p=1}^{H}\sum_{h=1}^{H} w_{p,h} G_p G_h}{\sum_{p=1}^{H}\sum_{h=1}^{H} G_p G_h}, \forall\ p \neq h.$$

Equation 1

The G_p and G_h components in Equation 1 are the values of the attributes for pairwise unique areas p and h. The spatial weight existing between any distinct areas p and h at a time is $w_{p,h}$. The statement $\forall p \neq h$ ensures that p and h are pairwise and distinctive of each other. In addition, H denotes the total areas in the dataset. Furthermore, a normalized statistic Z_G is calculated based on equation 2.

$$Z_G = \frac{G - E[G]}{\sqrt{V[G]}}$$

Equation 2

Where the expected value of G is given by equation 3.

$$E[G] = \frac{\sum_{p=1}^{H}\sum_{h=1}^{H} w_{p,h}}{H(H-1)}, \forall\ p \neq h$$

Equation 3

and the variance of G is given by equation 4:

$$V[G] = E[G^2] - E[G]^2.$$

Equation 4

The standardized calculated Z_G statistic is also accompanied by a p-value that is used for testing the statistical inference of whether or not the clustering of the features (areas for this study) are significantly clustered [16] and [17].

2.4 Visualizations of Hot Spots and Cold Spots

The study utilized the Optimized Hot Spot Analysis as well for the *local scale* i.e. whether an area is a hot spot (or cold spot) with varying confidence levels. The implementation was primarily concentrated on the Getis-Ord G_i^* Analysis. The G_i^* statistic is a method used to measure the strength of clustering of a characteristic in features (areas) if determined to be statistically significant [17] and [18]. This statistic allows for the categorization of areas as either areas with high levels of poverty incidence or areas with low levels of poverty incidence, with varying levels of significance. In the context of this study, a hot spot of a poverty incidence parameter refers to areas that exhibit significantly high values within a cluster, whereas a cold spot of poverty incidence is defined as clusters of areas with significantly low values. Moreover, a hot spot is determined through empirical evidence when the actual values exceed the predicted values, and a cold spot is recognized statistically when the observed values are lower than the expected values [17] and [18]. A statistically significant hot spot or cold spot is determined by the values of the nearby areas, upon which it is contiguous and relative. Equation 3 offers a normalized value for the statistical measure [17] and [18]. The G_i^* statistic is given by

$$G_i^* = \frac{\sum_{h=1}^{H} w_{p,h} g_p - \bar{G}\sum_{h=1}^{H} w_{p,h}}{\sigma_g \sqrt{\frac{1}{H-1}\left[\left(H\sum_{h=1}^{H} w_{p,h}^2\right) - \left(\sum_{h=1}^{H} w_{p,h}^2\right)\right]}}.$$

Equation 5

Herein, g_h denotes the value of the poverty incidence in specified distinct areas, p and h, which has a spatial weight of $w_{p,h}$ between them. The expected value of the poverty incidence is given by $\bar{G}$ and is calculated using equation 6.

$$\bar{G} = \frac{1}{H}\sum_{h=1}^{H} g_h$$

Equation 6

The standard deviation denoted by σ_g, on the other hand, is calculated using equation 7:

$$\sigma_g = \sqrt{\left(\frac{1}{H}\sum_{h=1}^{H} g_h^2\right) - \bar{G}^2}.$$

Equation 7

2.5 Impacts of Road Infrastructure

To provide a more standardized statistical modeling approach, this study opted to utilize road density as opposed to solely considering the length of the road. *Road density* refers to the proportion of the overall length of a country's road network to its land area [19]. In the same context yet on a lower scale, this study utilized the ratio of the measurement of national highways in kilometers from various provinces and HUCs, with accessible data, about their respective land area measured in square kilometers. In the Philippines, a *province* is a larger geographical area that is composed of component cities and municipalities. The measurement of road length was requested from the DPWH. According to the records of the DPWH, the total length of the national roads in Mindanao is 9,966.978 km.

2.6 Geographically Weighted Regression

Recall that the multiple linear regression model is given by equation 8:

$$Y_i = \beta_0 + \sum_{i=1}^{k} \beta_i x_{ij} + \varepsilon_i,\ i = 1, 2, \ldots, n$$

Equation 8

With n is the number of observations, Y_i values in the response variable which is the SAE of poverty incidence of the of a location for this study, x_{ij} values of the regressors at point i, k number of regressors, β_0 as the constant, β_i coefficient of a specific regressor, and ε_i residuals. Extending Equation 8 to the spatial regression field, the Geographically Weighted Regression (GWR) is a local spatial regression model where the coefficient of each regressor varies depending on the spatial location [20] and [21]. The GWR Model is given by:

$$Y_i = \beta_0(p_i, h_i) + \sum_{i=1}^{k} \beta_i(p_i, h_i) x_{ij} + \varepsilon_i,\ i = 1, 2, \ldots, n$$

Equation 9

Where (p_i, h_i) are the spatial coordinates at point i, $\beta_0(p_i,h_i)$ is the constant of the model at (p_i, h_i), $\beta_i(p_i,h_i)$ are the coefficient that spatially varies for the j^{th} variable, and lastly, ε_i denotes the residuals [21]. Note that Equation 9 is a general and closed form, yet this paper follows a bivariate modeling procedure. The response variable is the SAE of poverty incidence of the locations in 2021 with available data with the corresponding road density as the regressor. The road density as the regressor, on a *localized scale* for Mindanao, is the ratio of the number of kilometers of road in the location against its total land area in kilometers as well.

2.7 Procedures

The distribution of SAE of poverty incidence was visualized for the covered AR per area for 2018 and 2021 through choropleth maps. To determine if there is sufficient evidence to claim that hot spots and cold spots of poverty exist on a *global* scale, the Getis-Ord General *G* analysis was applied. If the significance of spots is proven, maps for both 2018 and 2021 shall be generated using the Getis-Ord G_i^* Analysis. The comparison of spots follows next if both analyses for 2018 and 2021 are significant. Thereafter, the GWR Model will be implemented for 2021 with the corresponding model evaluations. Figure 5 presents the workflow of the study.

3. Results and Discussion

3.1 Poverty Comparison by Region

Figure 6 shows the box plots of the SAE of poverty incidence for both 2018 and 2021 per AR. As seen, the SAE for 2018 in ARMM has several outliers below the whisker of the box plot. This indicates that there were areas with low poverty incidence levels. In addition, all ARs for 2018 have no positive outlier except for the Caraga Region which has one. For 2021, both the Davao Region and Northern Mindanao have two outliers, whereas Caraga Region has 1. The remaining box plots of ARs shows no outliers. Table 2 displays the mean and standard deviation (SD) of the SAE of poverty incidence for the years 2018 and 2021 of the ARs in Mindanao. Excluded from consideration is each Highly Urbanized City (HUC), which is normally known for having low levels of poverty incidence. This was done to mitigate the potential biases in the estimated values. Excluding the HUCs that may include low-valued outliers could improve the reliability of the hypothesis testing approach described in Table 1. Consistent with Section 2.4 of the Methods, the areas denote aggregated cities or municipalities.

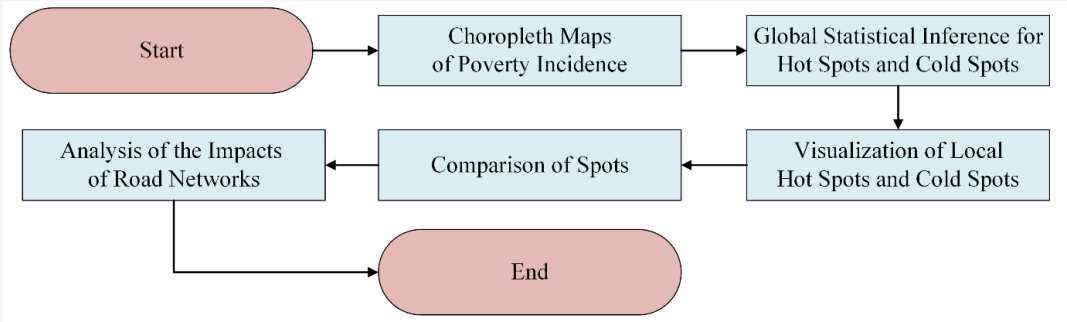

Figure 5: Impact of road networks on the poverty incidence situation in Mindanao

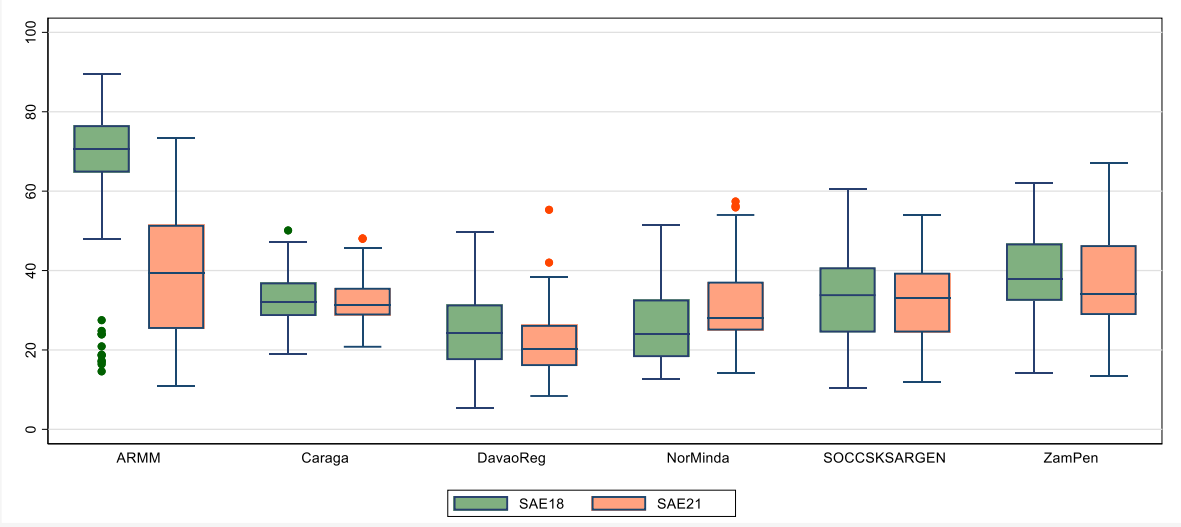

Figure 6: Boxplots of SAE of poverty incidence for 2018 and 2021 by AR

Table 2: Comparison of mean SAE of poverty incidence in 2018 and 2021 by AR

AR	Year	Total Municipalities and Cities	Mean (%)	SD (%)	Mean Difference (%)	p-value	Difference
ARMM	2018 2021	118	66.96 39.77	17.34 15.87	27.19	<0.001	Significant
Caraga Region	2018 2021	144	32.38 32.58	6.64 6.04	-0.19	0.866	Not significant
Davao Region	2018 2021	48	24.47 22.19	10.28 9.41	2.28	0.259	Not significant
Northern Mindanao	2018 2021	91	25.99 31.36	8.80 9.24	-5.36	<0.001	Significant
SOCCSKSARGEN	2018 2021	48	32.28 31.94	11.04 10.12	0.34	0.874	Not significant
Zamboanga Peninsula	2018	70	39.80	10.92	2.32	0.242	Not significant

In 2018, the mean poverty incidence in ARMM which is now known as BARMM through Republic Act 11054 approved on July 27, 2018, was 66.96%, with an SD of 17.34% [22].

Table 3: Results of the general *G* analysis

SAE	Z_G	p-value	Significance	Clustering
2018	20.70	<0.001	Significant	High
2021	9.18	<0.001	Significant	High

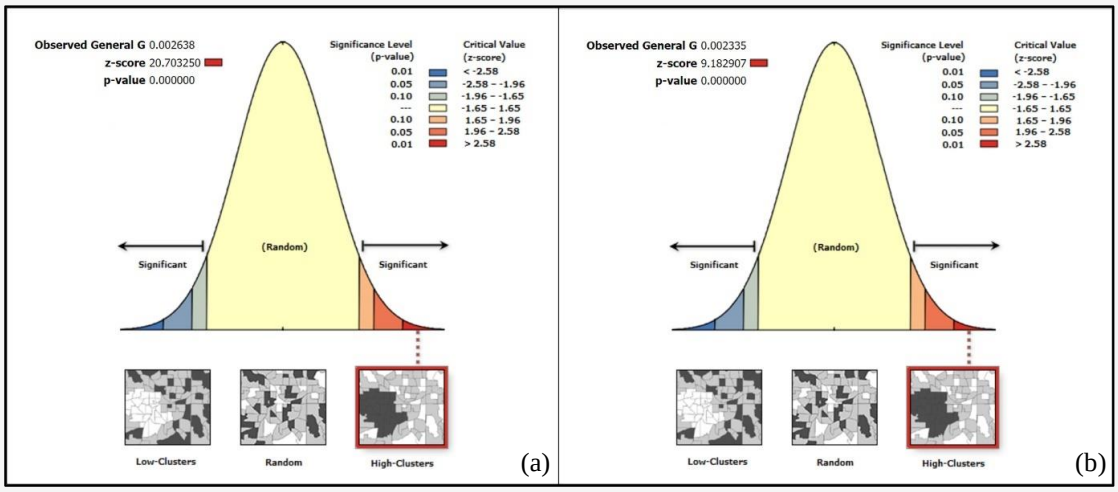

Figure 7: General *G* outputs of the SAE of poverty incidence in Mindanao (a) 2018 (b) 2021

3.2 Comparison of Hot Spots

Table 3 provides the General *G* statistic and the corresponding statistical inferences. The generated results used the data across all areas. As shown, the SAE of poverty incidence for 2018 has a value of Z_G = 20.70 with a p-value of less than 0.001. Hence, significant proof is found to support the presence of *high* clustering. The table also reveals that the SAE of poverty incidence for 2021 has a value of Z_G = 9.18, with a corresponding p-value of less than 0.001. Thus, *high* clustering is also statistically substantiated on a *global scale*. Figure 7 visualizes these results, with the left panel denoting 2018 and the right panel representing 2021. Moreover, the highly significant clustering results through the p-values for both periods ensure the cartographic observation of clustered hot or cold spots exists. Therefore, Figure 8 is provided for the maps at *local scales*. This study also focused mostly on the empirically identified hot spots of poverty. Figure 8 shows the result of the Optimized Hot Spot Analysis for the poverty incidence in 2018 using all the areas in Mindanao. With varying levels of confidence, some areas from the BARMM were significantly determined as hot spots. There were also cold spots from the Northern Mindanao and Davao regions. Some areas being statistically identified as hot spots that are clustered in the BARMM are quite expected relative to Figure 3. This also includes the island municipalities. The presence of armed conflict and violent extremist activity exacerbated the poverty situation in the provinces of BARMM [23]. In the previous years, Sulu and Basilan have consistently served as strongholds for the terrorist activities of the Abu Sayaff Group and its other terrorist organizations. Lanao del Sur has seen the full force of La Niña in 2016 and 2017. Additionally, the city of Marawi was destroyed during the Marawi Siege, causing immense suffering, misery, and poverty for its residents [23]. Figure 9 shows the map of Lanao del Sur and Marawi City. Both natural and human-caused disasters and calamities exacerbate poverty as well. Some of these disasters are El Niño, La Niña, and the changing climate, which may have had profound impacts in Mindanao albeit in a disproportionate scale [7]. In the case of BARMM, aside from these vulnerabilities, the region continues to face significant development obstacles due to the insufficient and substandard state of infrastructure support facilities, including roads, aside from bridges, ports, and seaports. The region's expansion and development of socioeconomic potential are hindered by the absence of potable water systems and the lack of infrastructure to support agri-fishery output as well [23]. If the cycle of poverty and war in the communities of the region is not effectively handled, the inhabitants of BARMM will remain trapped in these conditions [23]. Figure 10 shows that the hot spots and cold spots of poverty especially in the mainland of Mindanao have significantly changed for 2021.

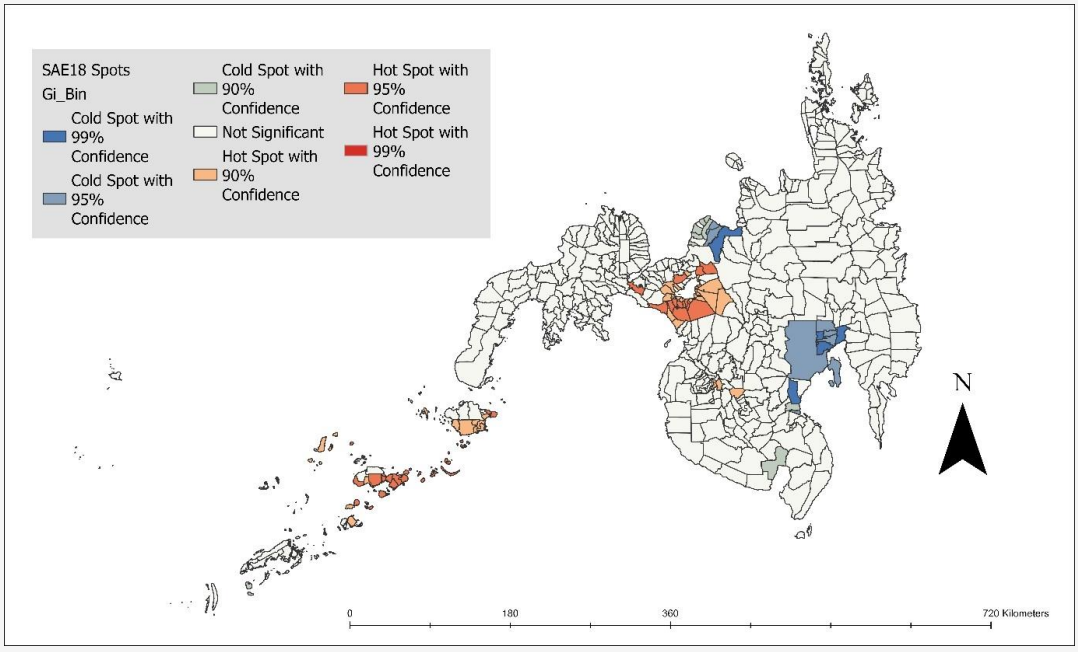

Figure 8: Hot Spots and Cold Spots of the SAE of poverty incidence for 2018

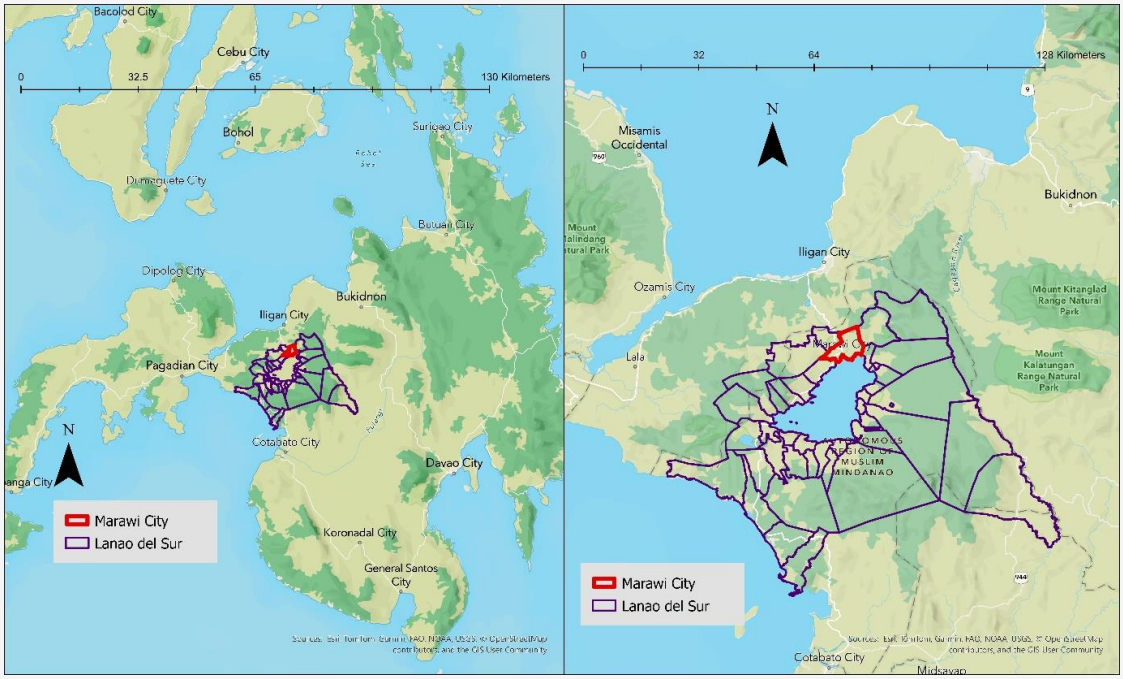

Figure 9: Locations of Lanao Del Sur with its provincial capital Marawi City

It appears that BARMM has made significant strides in decreasing its poverty incidence. In 2020, the pandemic brought the tourism sub-sector to a halt, resulting in a significant decline in tourist arrivals, reaching a minimum of 7,332 in BARMM. However, in 2021, there was a significant increase in confidence and interest, as evidenced by a thousand-fold growth in visitor arrivals, reaching a total of 195,822.

Despite the significant surge in 2021, the figure remains considerably lower than the levels observed before the pandemic in 2018 and 2019 [24]. The pandemic-induced restrictions led to a significant decline in investments in BARMM, dropping from PhP4.153 billion in 2019 (around US $ 58.11 million in 2019 base conversion) to a mere PhP14.0 million (almost US $ 196,000 in 2019 base conversion) in 2020.

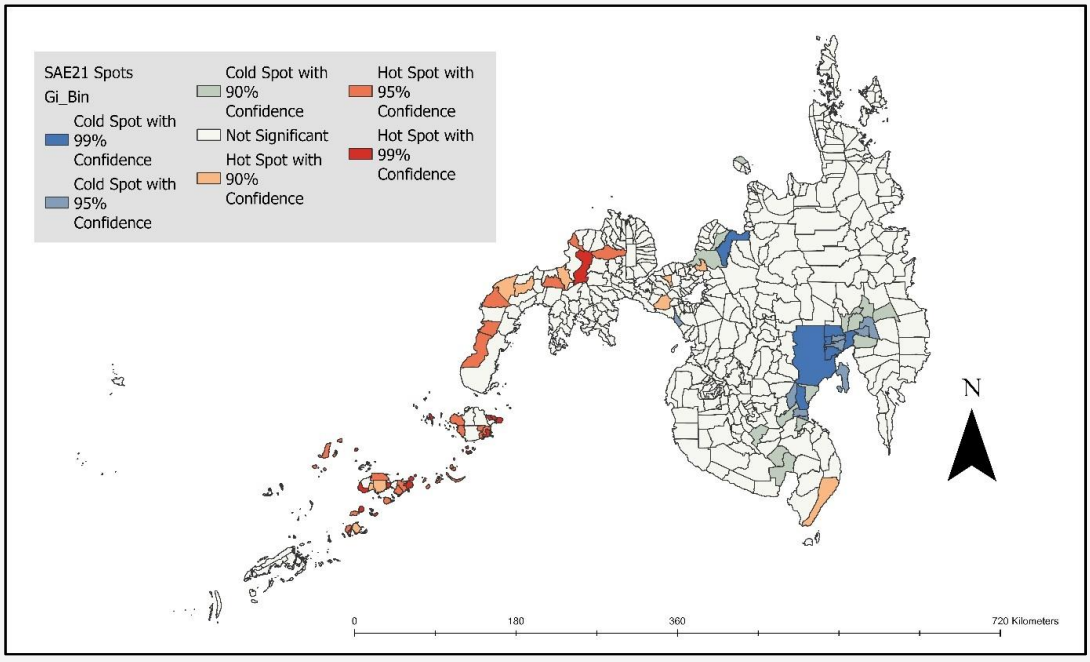

Figure 10: Optimized hot spots and cold spots analysis of the SAE of poverty incidence for 2021

Despite being in the midst of the pandemic, investments surged to PhP2.8 billion (around US $ 39.18 million in 2019 base conversion) in 2021, representing a more than a thousand-fold increase compared to 2020. The cumulative investments generated from 2019 to 2021 amounted to PhP6.970 billion (around US $ 97.53 million in 2019 base conversion), resulting in the creation of 5,020 jobs [24]. As of 2021, there has been a significant gain of 161.46% in the registration of micro, small, and medium enterprises (MSMEs), with a total of 8,427 entities being registered compared to the previous year. It is the peak in five years. The rise in numbers demonstrated the tenacity of Bangsamoro entrepreneurs in the face of the enduring impact of the pandemic. From 2020 to 2021, the BARMM has successfully recorded the establishment of 11,650 firms through its five provincial offices, which include Cotabato City. Additionally, this initiative has resulted in the creation of 31,000 job opportunities and has attracted an investment of approximately PhP2.5 billion. Although there was a notable surge in business name registrations (BNRs) in 2021, the BARMM region had the lowest number of BNRs in the country, representing a mere 0.92 percent [24].

During the transition from being known as ARMM to BARMM, there was a significant decrease in crime-related occurrences, deaths, and relocation, reaching a record low. The persistence of violent extremism poses a constant threat in specific areas, and addressing the harmful underground economies, such as the illegal trafficking of firearms and drugs, is crucial. Immediate legislative measures and local support are necessary to tackle these difficulties effectively [24]. In fact, an article released in September 2024 stated that the markedly enhanced peace and order conditions in the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) have led to investments totaling PhP4 billion (almost US$6 million in 2019 base conversion) since January of the year [25]. It is also observable in Figure 10 that hot spots of poverty incidence have become apparent in the Zamboanga Peninsula. In 2020, when the COVID-19 pandemic hit, it reached a historically low level, along with all other regions in the country. The economy of the Zamboanga Peninsula was susceptible to both internal and external shocks, including fluctuations in gasoline prices and peso-dollar exchange rates, as well as the adverse effects of climate change [26].

The performance of Zamboanga Peninsula's Gross Regional Domestic Product was associated with the underutilized production in the agriculture, fishing, and forestry sectors, as well as the limited industrial growth. There was a decrease in the number of processing operations that had the potential to generate long-term employment and income for the working population. However, there was a notable increase in 2021 due to the concerted effort to maintain the food supply for the residents of the Zamboanga Peninsula [26]. The Zamboanga Peninsula has been classified as the third region in the country with the highest poverty incidence.

The prevalence of poverty was closely linked to the scarcity of sustainable and high-quality employment opportunities, as well as the instability of income sources for individuals impacted. In 2021, over 200,000 individuals were classified as underemployed, meaning they were engaged in jobs that were neither financially viable nor sustainable. These individuals continued to seek alternative sources of revenue. Most individuals belonged to the informal sector, specifically occupations such as fisherfolk and farmers, which did not provide them with social security benefits [26].

The lack of adequate infrastructure development impeded the achievement of the goals and aspirations of Zamboanga Peninsula. The national road density in the region was measured at 9.7 km/sq.km in 2021, which was lower than that of the Philippines. The region's national road density of 10.68 km/sq. km positioned it as the 10th lowest ranked among all the ARs in the country [26]. Furthermore, the forest resources were mostly endangered due to unregulated utilization and conversion for alternative purposes, driven by the growing demand for forest products and services resulting from the growing population. The problem was exacerbated by climate change, which negatively impacted the forests' capacity to deliver essential ecosystems, resources, and services to populations [26]. Efficient local administration in the forestry domain is essential for advancing the sustainable utilization of resources and guaranteeing the ability of ecosystems and communities to withstand the impacts of climate change [26].

Figure 11 shows a visualization of the hot spots and cold spots analyses which used the combined the results of the Optimized Hot Spot Analysis of both 2018 and 2021. There is a noticeable increase in the cold spots for 2021. While there are areas that became cold spots in 2021, the holistic poverty incidence levels have generally dropped in the Zamboanga Peninsula. Some island areas of BARMM are also observed to still be hot spots of poverty incidence. On the other hand, the consistency of areas from Davao Region may be attributed to its effective regional planning and implementation of their Programs, Activities, and Projects (PAPs). The Davao Regional Development and Investment Plan facilitates the realization of the vision of the region, which aims to establish a foundation for inclusive growth, a high-trust society, and a globally competitive knowledge economy. Their priority PAPs implement the region's strategies under three objectives: (1) strengthening the moral and social fabric, (2) diminishing inequality, and (3) augmenting the economy's potential growth [27]. The economic development of the Davao Region is enhanced by tourism, agriculture, abundant natural resources, a robust industrial base, an expanding business sector, government support, and a peaceful and stable environment, among other factors [27].

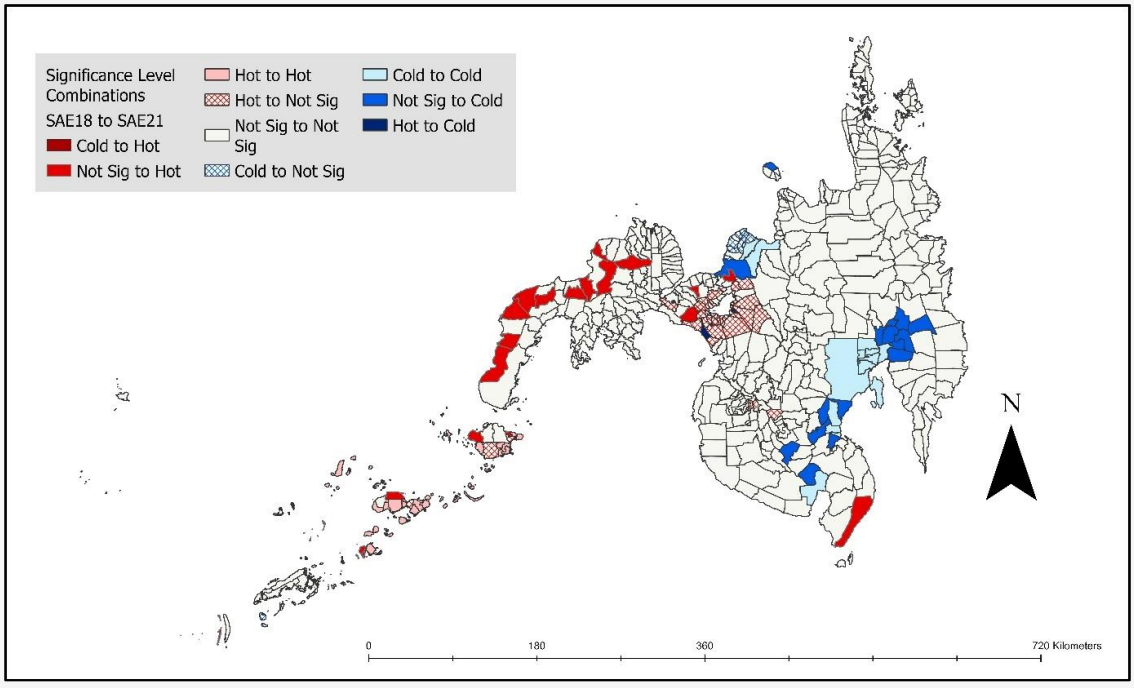

Figure 11: Visualization of the comparison of hot spots and cold spots analysis

3.3 Estimating the Effects of Road Density on the SAE of Poverty Incidence

Figure 12 shows the maps of the GWR Model. The left panel shows the constants (intercepts) while the right panel shows the coefficients for each location. Remark that the available data of road density are on provincial and HUC levels. Hence, the data of cities and municipalities making up a province were averaged to generate the mean poverty incidence. The maps show that the southern portion of Mindanao where the Davao Region and SOCCSKSARGEN are located have constants that on average have constants range from 19.88% to 20.46% or 20.45% to 23.95% while having coefficients varying from -0.24 to -0.07, or -0.43 to -0.25 *ceteris paribus*. This could be interpreted that at least for the available data for 2021, the impacts of road density in reducing the estimates of poverty, though still significant, is lesser. While the expansion of roads in the locations can reduce the estimated poverty incidence, the diversity of the sources of economic improvements in those localities may be less dependent on road density. In contrast, the eastern portion of Mindanao including the Zamboanga Peninsula and the archipelagic parts of BARMM have higher mean constants with values from 35.86% to 45.87% or 30.21% to 35.86%. The estimated coefficients in these locations vary from -2.82 to -2.25 or -2.25 to -1.31, on average holding other conditions fixed. Hence, connectivity for these locations is more impactful relative to the available data. The findings corroborate the existing knowledge on how road systems might mitigate enduring poverty circumstances [4]. Furthermore, given that the territorial measurement of a geographical area seldom undergoes modifications and necessitates specific prerequisites, the construction of road networks is fundamentally crucial for augmenting road density especially to those locations that appears to have more benefits with road expansions.

The enhanced image of the scatterplot between the road density and SAE of poverty incidence and road density is shown in Figure 13. Vertical lines at the 20.00% and 40.00% of SAE of poverty incidence are shown for easier interpretability. A weakly negative trend can be observed. Moreover, the R-squared value from the GWR is 0.1116. Therefore, the explainability of the disproportionate distribution of poverty incidence in Mindanao can be attributed to the road density standing only at around 11.16%. There appears to be several major factors that could help in minimizing and equitizing the poverty incidence in Mindanao. This is in parallel with the research that asserts that, despite the presence of well-developed national road networks and connectivity, other factors and the combinations thereof have a crucial role in addressing poverty [4] and [28]. Conducting studies about the potential impacts of the construction of rural roads may be done in hopes to facilitate further growth as well [29] [30] and [31].

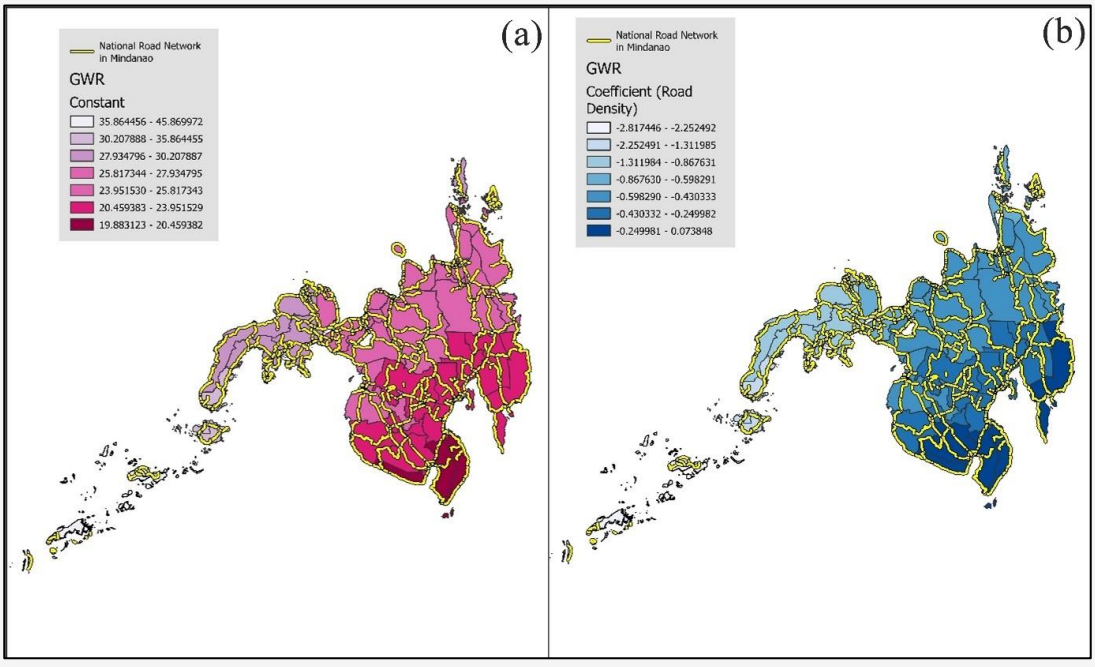

Figure 12: GWR map of the impact of road density to the poverty incidence in 2021 where (a) are the constants and (b) are the coefficients in each geographical level

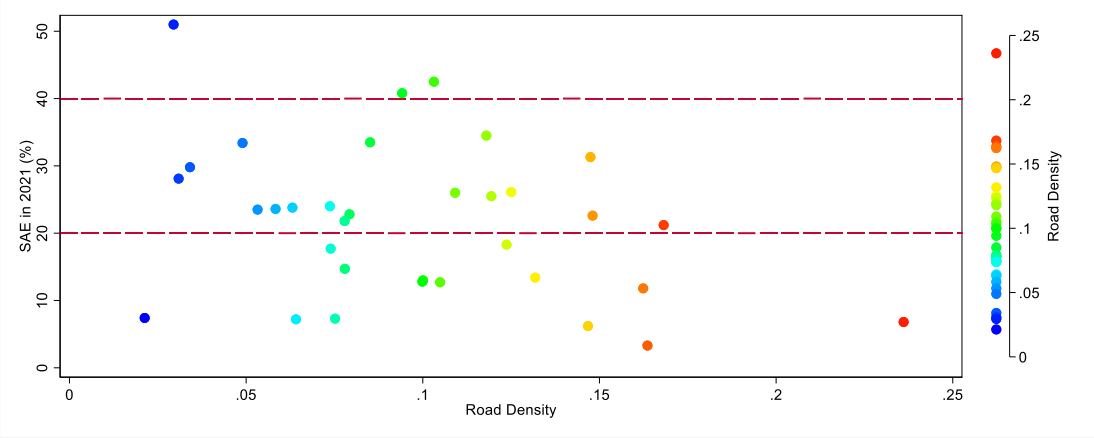

Figure 13: Mean SAE of poverty incidence in 2021 and road density in some locations in Mindanao

4. Conclusion and Recommendation

This paper compared the poverty situation in Mindanao using SAE of poverty incidence data for 2018 and 2021. The potential clustering of hot and cold spots of poverty incidence in the Mindanao areas was studied. It used Getis-Ord General *G* analysis to determine if poverty incidence hot spots and cold spots for 2018 and 2021 exist on a global scale. After confirming that hot spots and cold spots exist statistically, the comparisons of poverty incidence were done, the Getis-Ord Getis-Ord G_i^* was applied in both periods, which also revealed some notable variations in the significant hot spots and cold spots. A map that compares these results is presented which shows that (a) there is a significant decrease in the hot spots of poverty incidence in BARMM, (b) there is a significant increase in areas that are statistically identified as hot spots of poverty incidence in selected areas in Zamboanga Peninsula, and (c) Davao Region generally has areas that are statistically determined as cold spots of poverty incidence. The road density of provinces and HUCs was used to generate a GWR Model for the 2021 SAE of poverty estimates. The results revealed that a higher road density could promote poverty incidence reduction in most locations in the Zamboanga Peninsula and the island provinces of BARMM. However, fully relying on road expansions should be done cautiously, as the findings indicate that building more roads is merely a potential solution to the issue of poverty incidence and may be more profound to specific areas only. There appear to be more concerns to be addressed altogether, as well as concerted efforts of stakeholders to push the populations above the poverty threshold.

In addition to expanding national roads, directing smart spending towards the development of rural roads can also yield benefits, particularly in the long term. Rural roads can be a huge boost to economic activity and access to government healthcare services for poorer populations. Some major challenges remain for the population of Mindanao in its pursuit of economic progress. This includes the ongoing peace and order situation, as well as natural and human-induced disasters. The post-pandemic and conflict recovery seems promising through the emergence of MSMEs, tourism, and other industries that provide jobs.

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