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RESEARCH ARTICLE

Physical Geographical Factors Leading to the Disparity of Regional Development: The Case Study of Java Island

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Abstract.The complexity of regional disparity has encouraged viewing this issue from various perspectives, one of which is the role of physical geography in disparity. On Java Island, an observation on the role of geographical aspect is needed due to the spatial sturdiness of disparity. This study aims to provide quantitative proof that differences in the physical geography of Java's regions account for the persistent regional disparity. We applied two approaches namely correlation and typology, employing data of physical geographical attributes and development indicators. The methods used were correlation analysis, factor analysis, cluster analysis, and one-way ANOVA. Based on the correlation approach, we found the association of regional performance with terrain ruggedness, soil parent materials, sea depth, elevation, and precipitation. Then, based on endowment-based typology approach, Java's regions could be grouped into lowland, volcanic, old volcanic, and calcareous dry regions. The two latter performed poorly in all socio-economic indicators examined.

1. Introduction

Regional inequality is a fundamental and long-lasting issue for human society (Agusta, 2014). In academic literature, there have been many theories trying to explain this issue and to provide recommendations towards a more equal state. To comprehensively explain and alleviate regional inequality is admittedly challenging. The complexity of disparity has led scholars to a lengthy debate about theories, findings, and the policies that should follow (Wei, 2015). The convergence schools, which are dominant in the practice of examining regional performance variance, receive critical responses since they tend to remove structural and local variables and spatial heterogeneity. Fortunately, the advance of GIS and the flourishing spatial data and analysis during the last decades has helped to deal with the spatiality of regional disparity (Pravitasari et al., 2020; Wei, 2015).

McCord & Sachs (2015) state that the geographical patterns of income level are shaped by the spatial difference of institutions, technology, and geography. Between these three factors, geography is often underestimated in inequality studies (Hussey et al., 2020), especially biophysical and geophysical characteristics—also known as first nature. Gallup et al. (1999) believe that first-nature geography is one of the roots of regional disparity. In essence, regional bio-geophysical attributes have been a boon and a bane for inhabitants and economic activities (Ambarwulan et al., 2018). In the long term, such attributes specify agglomeration and core-periphery structure (Wei, 2015), leading to the varying socio-economic performances of regions. Some physical variables known to be responsible for inequality are coastal proximity, distance to navigable water (Gallup et al., 1999; Hao & Wei, 2010), malaria risk (McCord & Sachs, 2015), terrain ruggedness, storm risk, and high temperature range (Mitton, 2016).

In Indonesia, the in-depth itemization regarding the variance of regional physical conditions in relation to regional inequality has not received considerable attention. Most available studies focus on convergence, the effect of fiscal balance transfer, and infrastructures (e.g., Artaningtyas & Sriwinarti, 2020; Fadli, 2016; Irawan, 2014). Meanwhile, there is an urgent need to scrutiny the regional disparity from other perspectives due to the currently stagnant pattern of disparity. Hill et al. (2009) show that initially the disparity level in Indonesia declined between 1975 and 1997, then the pattern tended to be stagnant at a certain level for the following period. When oil and gas as components of GRDP are excluded from the analysis, neither convergence nor divergence has happened since 1975.

Between Indonesia's corridors—this country is often divided into five–six corridors in development studies—, Java conspicuously experiences stagnation. Disparity coefficients within Java (at the regency-municipality-level analysis) have remained constant since the late 1990s (Irawan, 2014, p. 87). Java is indeed the economic and population center of Indonesia (Statistics Agency, 2016, 2020). Its economic structure is more mature than that of other Indonesian corridors (Statistics Agency, 2020). Despite the central role of Java for Indonesia, this stagnancy is surprising because the government has issued a variety of policies, consistently implemented every year, aimed directly at striving for regional balance.

Agusta (2014) claims that if an effort has been made by the government but disparity has not decreased, there should be market or natural mechanisms that have a greater influence on it than the government's capability to intervene. In this case, observing other exogenous variables causing persistent disparity becomes necessary. The stagnancy of Java's inequality draws our attention to another dimension that has not been quantitatively addressed in the literature on Java, i.e., physical geographical aspects.

Our present work aims to give quantitative proof of the role of first-nature geography in Java's regional disparity. Two approaches were applied. The first one was a correlation approach to grab the rough individual relationship between physical attributes and development indicators. This work initially focused on the case of Java, but we also found a space to tuck our results into the broader literature. Previous studies of such observations have mostly centered on the level of cross-country, provinces/states across countries, and provinces/states within a country. The analysis at the regency-municipality level in a country, which is of concern to us, is barely discussed. The varying results among the studies on this topic are inevitable. We borrowed the perspective that "… regional inequality differs across scale… Sources of regional inequality are also sensitive to scale…" (Wei, 2015, p. 6) to discuss the differences of our results with that of other studies in a more structured way.

Thereupon, to consider first nature as a fundamental determinant of regional disparity has been underestimated by those studying institutions (e.g., Hussey et al., 2020). Physical condition is considered stable and difficult to change. The skeptical notion emerged that even "if geography was the key determinant, less could be done to alleviate income disparity…" (Hussey et al., 2020, p. 2). This notion probably appeared because most analyses on this discourse were based on regression models in which each geographic attribute was treated as an independent variable, whose variation does not depend on that of another. Handling geographic variables in that way may lead to an ambiguous exegesis. For example, even if light (flat) terrain is positively significant to socio-economic performance, it is impossible to flatten the landscape of rough-terrain (hilly or mountainous) regions.

This study is not aimed at debating the above statements because debates within this discourse are indeed complementary rather than competing (Lorenz et al., 2005). Nevertheless, the skeptical notion has led this research to use the second approach to differently discuss physical geography, i.e., the endowment-based typology approach by grouping the regions based on similar characteristics. Factually, the presence of geographic attributes is intercorrelated, as will be shown in the "Results and Discussion" section. It allows generalizing the regions into several common environments, e.g., lowland and mountainous regions. The physical condition's effect was observed by comparing the socio-economic performance of the resulting typologies. It was assumed that regions with the same physical typology would have relatively equal limitations with respect to the carrying capacity to support various human activities. Subsequently, we hypothesize that a typology with the least physical obstacles would achieve better socio-economic performance than one with more hurdles. In this article we would focus our discussion on the properties of physical attributes and its possible mechanisms towards interregional disparity.

2. The Methods

Study Area

This research took Java Island as a case study and involved all regions at the third administration level, i.e., 85 regencies and 34 municipalities, including those in Madura Island. Its total area, around 129,297 km2 (Statistics Agency, 2017), is almost equal to England's—130,279 km2 (World Bank, 2021). This study was conducted from March to November 2020.

We chose Java for at least three reasons. Firstly, necessary data has been well recorded and 119 regions as cases are enough to perform mathematical and statistical operations. Secondly, a casual look at the map indicates that there are links between the spread of the physical condition and regional performance. For instance, the south side of western Java is characterized by hilly and mountainous terrains, while flatlands conversely stretch along its northern part. This pattern has been followed by a typical distribution of socio-economic performance, presenting the widespread sentiment of the so-called "north-south regional disparity" in western Java's development (Rustiadi et al., 2010). Lastly, the regional inequality issue still persists (Artaningtyas & Sriwinarti, 2020). When most of Indonesia's corridors experienced a declining trend in income inequality after the stipulation of decentralization, the Javanese corridor's coefficient of disparity remained stable (Irawan, 2014).

Data Collection and Preparation

The data employed were all secondary data at the regency/municipality (RM) level and can be categorized into two groups namely physical attributes and development indicators. Spatial analyses for data preparation were done in ArcGIS 10.6 (ESRI, Redlands, CA, USA) using Batavia NEIEZ coordinate system (WKID: 3001). The regional boundary followed the 2020 version of Badan Informasi Geospasial (Geospatial Information Agency).

The physical attributes cover soil parent material, terrain, elevation, precipitation, coastal proximity, and sea depth. The first four data were drawn from the land capability concept in which they set the people's inclination to conduct various activities (Widiati et al., 2017; Widiatmaka et al., 2015; Wiyono & Sunarto, 2016). Terrain ruggedness affecting regional disparity has also been documented by Mitton (2016).

Coastal proximity provides a regional opportunity for being engaged in broader trade (Gallup et al., 1999), while sea depth prescribes the possibility of local people being fishermen. In the case of Java, sea depth could represent the waves and ocean currents (Rachmayani et al., 2018), which in turn affects the water transportation and seasonal work of fishing (Nariswati, 2016). During the preliminary trial, we found a medium, but significant, relation between sea depth and fisheries production (r(28) = -.446, sig. (2-tailed) < 0.05) in 2019 based on Pearson correlation analysis, involving 28 coastal regions of Central Java and East Java Province. As for coastal proximity, the nearest distance of the regional centroid to the coastline stipulated the distance to the sea. Meanwhile, sea depth is the mean score on four miles from coast, developed using GEBCO 2020 (GEBCO Bathymetric Compilation Group, 2020).

Since physical conditions within regions vary, we generated simpler quantitative measures for each region without substantially omitting the interregional variance. For example, an RM generally could contain varying terrain—from flat to mountainous. To build terrain value, we initially made slope data using SRTM 2019 from USGS with the following interval: below 3, 3–8, 8–15, 15–25, and above 25% rise. Each interval was given a weight of 1, 2, 3, 4, and 5 respectively. Then, the area percentage of slope intervals of each RM was calculated. Given that the sequences of slope intervals can be considered as ordinal sub variables, the quantitative value of each RM's terrain or x' is . i is the slope interval, xi is the percentage of i in a region, and wi- is the weight of i. This calculation was also implemented to obtain the "weighted score" of each region's precipitation and elevation. The annual precipitation has been developed using CHPClim v.1.0 2012 from Climate Hazard Center, UCSB, with the intervals of below 2000, 2000–3000, 3000–4000, and above 4000 milimeters per year. Elevation has been built from SRTM 2019 as well; the intervals were below 25, 25–100, 100–500, 500–1000, and above 1000 MAMSL (Hardjowigeno & Widiatmaka, 2007).

Soil parent materials were divided into alluvial, calcareous tectonic, felsic tectonic, volcanic, and old volcanic (Kartawisastra et al., 2017). They were developed from 1989 RePPProt data and a 1992 geologic map, respectively obtained from ICALRRD and Pusat Penelitian dan Pengembangan Geologi (Center of Geologic Research and Development). Marine and fluvial marine were excluded due to their small portions in Java. Subvariables of soil parent materials, delivered as a percentage, stood independently in the analysis (not weighted like slope, precipitation, and elevation), as they cannot be treated as ordinals.

The second data group is the contemporary variables used to determine and compare the regional performance. Rustiadi et al. (2011, p. 161) have listed the operational indicators for defining the regional performance based on development purposes, which in general consist of growth, equity, and sustainability. Among the derived indicators, we selected those stable in the long term for interregional comparison purposes. This selection corresponds to physical conditions which remain unchanged for an extended period, even for centuries.

Firstly, we chose the poverty rate and human development index (HDI). Since both are relatively steady, only their score in 2018 was presented. GRDP-related measures were also incorporated, as they are the mainstream indicator to address regional disparity. However, we performed modifications to tackle the short-term variation issue, altering it into average growth rate, average per capita value, and average sector ratio by involving the 2010–2016 sectoral GRDP data series. The former two were using non-oil and -gas (non-mining) GRDP at the constant price. The latter, sector ratio, was the ratio of agricultural sector to the sum of secondary and tertiary sectors, calculated using non-mining GRDP at the current price. Oil- and gas-generated GRDP was excluded because such extractive activities considerably affect measured local economic activity but have less impact on local economic and social welfare (Hill et al., 2009). All data of regional performance were obtained from Statistics Indonesia.

Analysis Procedure and Technique

The methods applied in this research engaged several mathematical and statistical operations, performed in SPSS 22 (IBM, Armonk, NY, USA). In the Introduction section, we have mentioned that, besides a correlation approach, we would develop typological groups to explain the common physical characteristics of Java's regions. Based on this, comparison of group means on socio-economic indicators would be conducted. At the first phase, Pearson correlation analysis (IBM, 2013, p. 123) helped in estimating the rough relation between geographical and socio-economic variables. Afterwards, we executed factor analysis and k-means cluster analysis to build typological groups and one-way ANOVA for means comparison.

The intercorrelations among geographic variables had been previously predicted. Thus, factor analysis with correlation matrix was run to construct the simplified data (factor score) of natural resource variables and, concurrently, to keep the variables' information. It consisted of three main steps: 1) the principal component extraction of initial factors, 2) varimax-normalized factor rotation, and 3) producing factor score coefficient using regression (IBM, 2013, pp. 330, 336–338, 343). Eigenvalues more than 1 and containing at least 75% of total variance established the number of extracted factors. The produced factors were utilized in k-means cluster analysis (IBM, 2013, pp. 785–786) to produce typology groups of which the Silhouette method underlaid the stipulation of the optimal number (Saputra et al., 2020).

Finally, means comparison would specify whether the endowment-based groups of regions (independent variable) experienced significant differences in socio-economic performance (dependent variables). Once one-way ANOVA (IBM, 2013, pp. 690–692) has determined that differences exist among the means (significance level below 0.05), post hoc pairwise multiple comparisons could scrutinize which means differ among the groups. If the groups' variance was homogeneous, a Bonferroni test was used (IBM, 2013, p. 999); otherwise, Games-Howell was employed (IBM, 2013, p. 1001). The homogeneity was estimated using Levene's test (IBM, 2013, p. 694).

3. Result and Discussion

Correlation Results & the Scale-dependent Significance of Physical Geography

Correlation analysis results (Table 1) show that several physical variables had significant connections to development indicators, albeit their correlations to which development indicators were not similar. The list of physical attributes from the most influential on regional performance was terrain ruggedness, alluvial material, calcareous tectonic material, sea depth, old volcanic material, elevation, felsic tectonic material, and precipitation. HDI was most linked to many physical variables, followed by the sector ratio, per capita GRDP, poverty rate, and GRDP growth. Some associations in our results differed from those of other studies. For example, coastal proximity has been documented to affect disparity, but we found no influence from it. Observations on terrain have also been made, where it is viewed as not directly affecting regional performance (Ketterer & Rodríguez-Pose, 2018). We argue that variation in the research scope, notably the scale, have led to these differences. Wei (2015) has warned the sensitivity of regional disparity to the geographic scale of analysis. Neglecting scales may cause misinterpretation. If the scale is considered in this difference of the results, a unique pattern appears: some physical variables became stronger in explaining the disparity in the narrower scale of study, while some others were getting weaker.

Coastal Proximity and Sea Depth

Concerning the global scale analysis, Gallup et al. (1999) asserted the importance of sea access for trade and regional performance. It is a factor affecting the engagement with international trade. However, based on regency-municipality level of analysis, our result shows no relationship between distance to sea and any socio-economic indicators (Table 1). The advantage of coastal proximity may be relevant for regions that become or are close to port cities (Wei, 2015). To differ coastal and inland regions is also tricky in the case of Java given the size and the elongated shape of this island—even the farthest region from the sea, recorded as Ngawi Regency (81 km), may reach coastal area only within hours.

Sea depth was related negatively to HDI and positively to sector ratio. We expect that the shallow sea of coastal area brings more opportunities for local people to conduct more varied activities in the sea, e.g., mangrove tourism and stable fishing activities due to calmer waves and lower tidal height range than that of deep sea (Rachmayani et al., 2018). Still, to explain this finding is enigmatic unless addressing the fact that shallow sea depth is associated with other geographic attributes, especially light terrain, high alluvial land, and lower presence of old volcanic material.

Terrain Ruggedness

The causality of terrain ruggedness to regional performance was examined by Ketterer & Rodríguez-Pose (2018) on cross-country level analysis. They found that terrain was not significant in explaining regional performance. Mitton (2016) recorded a significant contribution of terrain ruggedness at the provincial unit of analysis. In our result, among other first-nature attributes, all socio-economic indicators were correlated to terrain ruggedness, which became the strongest predictor. Light terrain is preferred to human habitation and industrial agglomeration. Large areas with light terrain require lower costs for mobility, infrastructure development, and settlement than areas with rough terrain (Hardjowigeno & Widiatmaka, 2007; Priatama et al., 2020)—except the peatland and tidal area. Terrain may also contribute to the creation of the core-periphery pattern in which rolling, hilly, and mountainous regions normally take a role as hinterlands.

Elevation and Precipitation

Elevation and precipitation correlated negatively to per capita GRDP. Low elevation, associated with less intensive rainfall and shallow groundwater, is indeed considered a favorable location for human concentration and economic activity. The government uses these criteria to determine and concentrate the spatial allocation of settlement and industrial estates (Ambarwulan et al., 2018; Hardjowigeno & Widiatmaka, 2007). At a provincial-level analysis, Mitton (2016) considers elevation as less robust and not as economically significant. However, at province, the elevation of terra firma may stretch from low to high altitude. At RM level, the heterogeneity of elevation may be captured well. This research recorded its relationship with per capita GRDP.

Soil Parent Materials

All parameters of soil parent materials, except volcanic one, correlated to at least one regional performance indicator. Soil parent materials may affect regional performance via three channels. Firstly, it determines agricultural productivity through soil fertility (da Silva et al., 2017). Even though parent materials are not the only determinant of soil formation and fertility, it is regarded as the fundamental state of soil system (Suwardi & Rachim, 2008)—the other determinants are climate, organisms, topography, and time. The parent materials set which minerals would predominate in the derived soils. The minerals contained by parent materials play a major role in soil properties such as cation exchange capacity and plasticity (van Straaten, 2007). As parent material weathers, nutrients are released into soil solution. The released nutrients may be absorbed by plants and other organisms or leached.

The second channel is that some soil minerals are the basic material of industrial activities (Suwardi & Rachim, 2008). A concentration of these minerals such as potassium and phosphate in a certain area may induce mining activities. Thirdly, soils derived from soil parent materials differ in the quality for civil construction. Such a quality is examined using the following criteria: specific gravity, density index, consistency limits, particle size, compaction, consolidation, permeability, and shear strength (Roy & Bhalla, 2017). Before constructing any structures, geotechnical engineers conduct environmental site assessments in the proposed areas and make suggestions based on soil properties. They learn about the soil condition and predict the long-term effects of that soil on foundations, walls, septic system, and other structures that are integral to daily lives. For example, soil with too many sand particles is not appropriate for septic system (Hardjowigeno & Widiatmaka, 2007). Hence, it is not recommended for settlement.

However, the relation between soil parent material and regional performance tends to be mixed and affected by other physical factors. Table 5 shows that it was only alluvial material providing a beneficial association with regional performance. Alluvial was related negatively to poverty rate and sector ratio, and positively to HDI and per-capita GRDP. Both fluviatile and colluvial processes contribute to the accumulation of alluvial deposits. The soil fertility and quality for construction depend on the deposited materials and their geological age (Wiyono & Sunarto, 2016). One site may be dominated by sand deposit, while the clay is dominant in another site. Thus, it is challenging to claim that alluvial materials affect regional performance positively due to its agricultural fertility and quality for construction purposes—as it varies spatially. However, alluvial lands are characterized by plain terrain (alluvial material correlated negatively with terrain ruggedness in Table 1). Plain terrain is the favorable one for the concentration of various human activities.

Old volcanic and felsic tectonic material are less fertile for agricultural activities, but their properties required for construction, especially building, is suitable enough (Hardjowigeno & Widiatmaka, 2007). However, both appeared in nature mostly with rugged terrain (old volcanic and felsic tectonic material negatively correlated with terrain ruggedness in Table 1). The rugged-terrain condition may prevent their potential according to the soil properties. The more slopy the terrain is, the less slope stability and shear strength of soil would be. Old volcanic and felsic tectonic material were related to low HDI. In addition, old volcanic was also linked to regional dependency on the agricultural sector (positive correlation with sector ratio; Table 1).

Calcareous soils contain considerable calcium content which is useful for maintaining the ideal pH level of soil for plants (Virmani et al., 1982). The farmers cultivating such soils may need small effort to calcium fertilization. Moreover, the cation exchange capacity of calcareous soils is suitable for agricultural activities (Hindersah et al., 2021). For short, calcareous soils are potentially fertile for food agriculture. However, calcareous parent material was linked negatively to HDI, and positively to poverty rate and dependency on the agricultural sector (Table 1). This association is quite surprising. Calcareous material was not correlated to terrain, precipitation, and elevation. The limiting factors for calcareous soils, leading to unsatisfactory regional performance, might vary spatially. The actual potentials of calcareous soils are strongly affected by water content. Most calcareous soils can shrink and swell—it shrinks when water content is low and vice versa (Virmani et al., 1982). This ability is the first prominent limiting factor for both agricultural and construction activities. The second one is that some calcareous soil might be characterized by rough terrain, which is often found along the south part of Java (Hindersah et al., 2021; Kurnianto et al., 2019).

Endowment-based Regional Typologies and Regional Disparity

Intercorrelation among first-nature variables (Table 1) indicates that a certain physical attribute appears together with some other attributes in specific places. It implies that regions generally can be simplified into several typologies of common environments. Most studies cited in the previous subsection. were based on regression models in which geographical variables were treated as standing alone. The typological-group approach, discussed in this subsection, could differently address the first-nature geography concerning disparity.

Physical attributes appeared in nature by following certain associations. The factor loading of factor analysis (Table 2) displays this general association—coastal proximity was excluded due to its lack of correspondence with regional performance at regency-municipality level, although it would possibly become the strong component of Factor 1 considering the correlation analysis result (Table 1).

Factor 1 implied that abundant volcanic material coalesced with rough terrain and high elevation. Conversely, the presence of alluvial material cohered with light terrain and low elevation. Factor 2 represented the relation of old volcanic material, deep sea, felsic tectonic matter, and rugged terrain, which were often found

Table 1. Correlations between physical attributes and development-level indicatorsa

	Calc. tectonic	Fels. Tecto-nic	Volcanic	Old vol-canic	Terr-rain rug.	Ele-vation	Preci-pitation	Sea depth	Coas-tal prox.	GRDP growth	Poverty rate	HDI	Sector ratio	Per cap GRDP
Alluvial	-.327	-.302	-.646	-.296	-.739	-.815	-.441	-.251	-.355		-.363	.461	-.424	.418
Calc. tectonic			-.347								.621	-.415	.501	
Fels. tectonic				.402	.549	.249	.440					-.304		
Volcanic					.334	.718	.329		.439					
Old volcanic					.619	.256	.362	.579				-.357	.263	
Terrain rug.						.714	.543	.394		-.277	.322	-.549	.453	-.342
Elevation							.467		.590					-.321
Precipitaion									.265					-.303
Sea depth												-.351	.400	
Coastal prox.														

[a] Displaying only the significant results at the 0.01 level (2-tailed)

together to characterize the landscape. Calcareous tectonic was the only main contributor to Factor 3, while precipitation was not tied strongly to any factor. The status of calcareous material and precipitation denoted their relatively random spread in Java and probably in nature.

K-means cluster analysis and silhouette method resulted in four typology groups. Based on the characteristics of each group (Table 3 and Appendix 1), we labeled them from 1 to 4 into lowland, volcanic, old volcanic, and calcareous dry regions, respectively. The result of one-way ANOVA shows that significant differences in socio-economic performance existed between the groups, especially poverty rate, HDI, sector ratio, and per capita GRDP (Table 4). GRDP growth was not represented well by the endowment-based groups. This is probably due to its instability with respect to the time, as explained by Hill et al. (2009), that each region, either developed or less developed, in turn experiences ups and downs in economic growth in both the short and long term. The short duration of our time-series data may also deliver this result. What we can show so far is that GRDP growth was only positively correlated to terrain ruggedness (Table 1). The regional groups produced performed best in comparing HDI since five of six intergroup comparisons (asterisk in Table 5) were statistically significant. Per capita GRDP and sector ratio followed next: four out of six intergroup comparisons were significant. Regarding the poverty rate, there were only three of six clear between-group differentiations.

Lowland regions tended to have a satisfactory level in all socio-economic indicators (Figure 1 and Table 5). People living in these regions possessed high per capita GRDP, high HDI, and a low poverty rate. They also enjoyed various

Table 2. Factor matrix (rotateda)

	Factor loading[b]			Cumulative % of
	1	2	3	total var. explained*
Alluvial	-.892	-.264	-.295	77.320
Calcareous tectonic	.026	.026	.914	
Felsic tectonic	.125	.721	-.222	
Volcanic	.877	-.240	-.296	
Old volcanic	.046	.874	.092	
Terrain ruggedness	.630	.681	.094	
Elevation	.910	.216	-.006	
Precipitation	.475	.493	-.392	
Sea depth	.017	.625	.379	

[a] Varimax rotation with Kaiser normalization from the extraction of eigenvalues > 1
[b] Converged in 4 iterations

Table 3. Characteristics of physical attributes of group members

	Group			
	1	2	3	4
Alluvial	large	small-medium	small	small-medium
Calc. tectonic	negligible	small	medium	sizeable-large
Fels. tectonic	negligible	small	medium	negligible
Volcanic	small	large	small-medium	small
Old volcanic	negligible	negligible	high	negligible
Terrain	light	light-rugged	rugged	light-moderate
Elevation	low	moderate-high	moderate-high	low-moderate
Precipitation	low-moderate	moderate-high	moderate-high	low
Sea depth	shallow	shallow	deep-very deep	shallow-deep
Members	46	52	8	13
Seaboards	27	16	8	10
Municipality	23	11	0	0
Regency	23	41	8	13
Group name	Lowland	Volcanic	Old volcanic	Calcareous dry

Graphical plots are shown in Appendix 1.

economic activities (low sector ratio) supported by light terrain (Mitton, 2016). Rustiadi et al. (2021) and Pribadi & Pauleit (2015) have shown that the urban growth of Metropolitan Jakarta spread more intensively to the surrounding light-terrain regions. Industrialization and suburbanization tend to locate to Bekasi, Tangerang, and Karawang Regency—lowland region members, see Figure 2—rather than to Bogor Regency, a volcanic region member. Some may argue that the development of transportation routes, which was more intensive along the east-west direction of Jakarta (Pribadi & Pauleit, 2015), is more responsible than terrain. However, the cheaper cost of road development in interconnected light-terrain regions had been taken into consideration as well during its planning. In essence, lowland regions provide the amenities for the accumulation of people, greater market size, lower cost of infrastructure development, and industrialization in some cases (Rustiadi et al., 2015; Wei, 2015). Thus, most municipalities of Java, 23, were formed in lowland regions.

The volcanic group was in the second rank for its regional socio-economic performance after the lowland group. Eleven of its 52 members were municipalities. We predict that these municipalities were in the basin areas of the mountainous environment, which became the hub of the surrounding hinterlands. Indeed, both volcanic and old volcanic regions were in mountainous environments, but they differed physically in terms of the composition of soil parent material and terrain amenity. The first contained notable portions of light terrain and volcanic material, which provided lower economic costs and higher human mobility, while the latter had rugged terrain and a high portion of old volcanic material (Table 3). Therefore, volcanic regions reached a relatively better performance than old volcanic regions.

Meanwhile, old volcanic and calcareous dry regions performed poorly in all socio-economic indicators. These two groups had a strong dependency on agricultural activities since most of their annual GRDP was generated from this sector, as indicated by the high sector ratio (Figure 1). Consequently, none of these two-group members became a municipality. This indicates the low regional carrying capacity of these regions to support both regional socio-economic performance and city formation.

The main obstacle to the carrying capacity of old volcanic regions is the severe terrain condition. The topography is mostly rolling, hummocky, hilly, and mountainous (Kartawisastra et al., 2017). Light terrain landscapes exist but are scattered far apart and are relatively narrow in size. Hence, industrial activities are challenging in such conditions. Even human accumulation, expected to present sizeable market demand, is not easy to achieve (Munibah et al., 2018). In addition, old volcanic lands are also less fertile for food production than volcanic and alluvial material (Suwardi & Rachim, 2008).

As for calcareous dry regions, the explanation for their poor achievement is puzzling due to the absence of discussion on this issue in the literature. These regions had almost the same characteristics as lowland regions but with a high portion of calcareous tectonic material. We predict that calcareous dry regions have barriers in terms of water availability and agricultural productivity. During the dry season, vertisols, the dominant soil order in calcareous areas (Suwardi & Rachim, 2008), will solidify till only a few food crops can grow. Food agriculture is therefore strongly dependent on the rainy season, while these regions receive low annual precipitation (Table 3).

Groundwater in calcareous regions contains undissolved minerals of the so-called limescale (Lestari et al., 2018). Then, the areas with cracking clayey soils, a typical trait of

Table 4. The result of one-way ANOVA and Levene's test

	Sum of squares		df		Mean square		One-way		Levene	
	BE	WI	BE	WI	BE	WI	F	Sig.	Stat.	Sig
GRDP growth	1.37	38.77	3	115	.465	.337	1.38	.252	2.50	.063
Poverty rate	611.53	1480.48	3	115	203.85	12.87	15.83	.000	.23	.878
HDI	805.14	2711.72	3	115	268.38	23.58	11.38	.000	2.65	.050
Sector ratio	1.88	4.70	3	115	0.63	.04	15.36	.000	1.94	.127
Per capita GRDP	34468.84	206353.46	3	115	11489.61	1794.38	6.40	.000	9.78	.000

BE is between groups, and WI is within groups.

Table 5. Multiple comparison: Post hoc tests

	GRDP growth[a]			Poverty rate[a]			HDI[b]			Sector ratio[a]			Per capita GRDP[b]		
	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1				*		*	*	*	*	*	*	*	*	*	*
2						*		*	*			*		*	
3															

[a] Compared through Bonferroni test; [b] Compared through Games-Howell test; * Significant at the 0.05 level
Figure 1 displays graphical means comparison.

vertisols in Java, also tend to experience water contamination due to soil ability to quickly drain off the surface water into the aquifer (Febriarta et al., 2020; Kurtzman et al., 2016). Before the common use of bottled mineral water in the market, local people had to treat groundwater so that it became fresh water for drinking. Overall, the conditions of calcareous dry regions that we have mentioned were probably (some of) the impediments to the creation of human accumulation in the past, which instead formed in other areas with better support in the form of food and clean water.

Although in this study we can prove that the level of regional development is influenced by regional physical factors, this pattern becomes seemingly apparent only after Javanese began to gradually apply efficiency-oriented economy, specifically, since the New Order government (1966-1988). Before 16th century, the Hindu-Buddhist kingdoms in Java tended to be inland-oriented, i.e., placing their settlement centers around valleys and foothills because 1) inland and rice production were considered sacred, and 2) the irrigation system was still simple (Setiadi, 2021). The latter issue caused the population in Java to

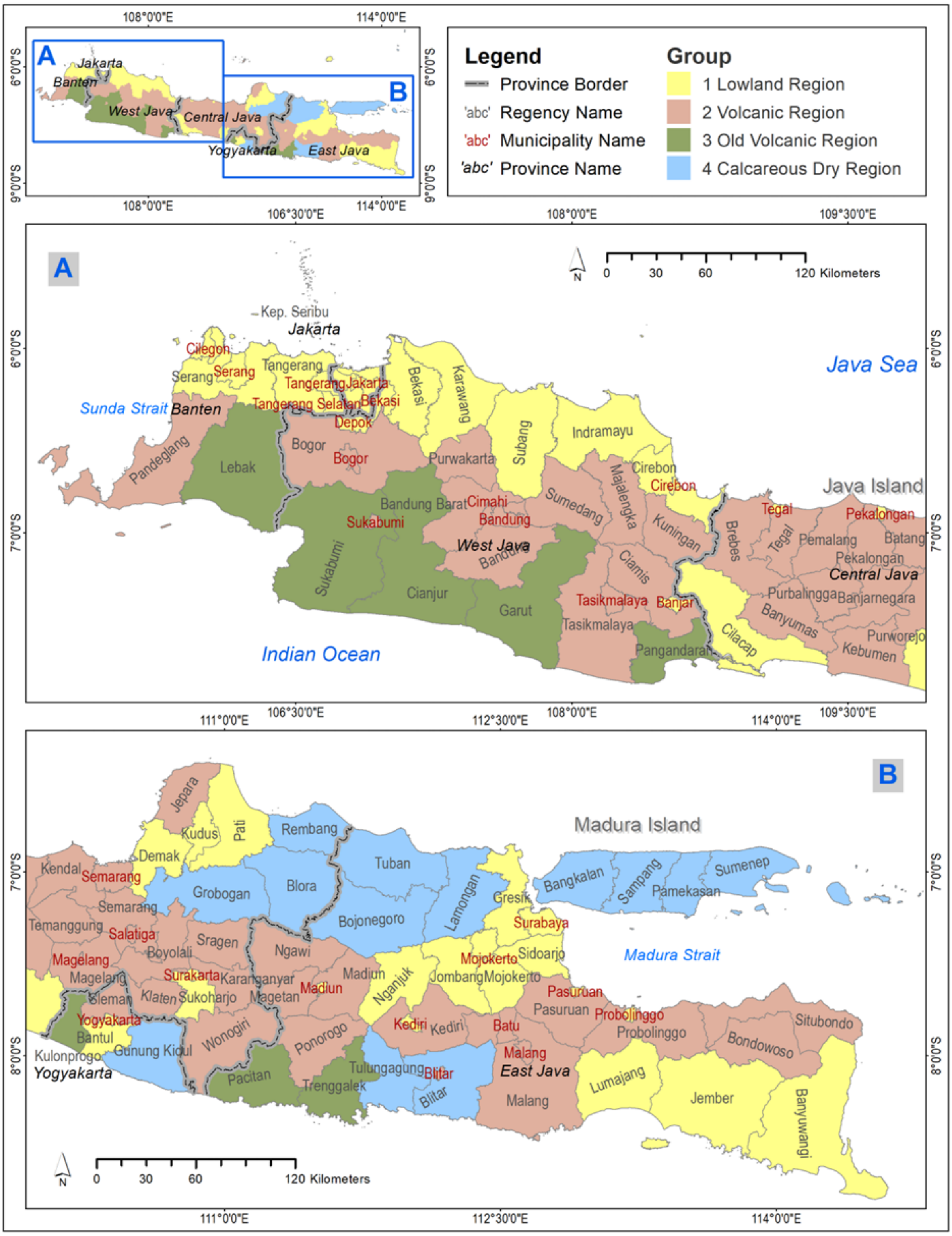

Figure 2. Groups of Java's regions based on first-nature typologies

depend on areas with sufficient rainfall. Economic growth in the coastal lowland area at least started to occur firmly in the second half of 19th century during Dutch East Indies era (Octifanny, 2020).

During the New Order era, a more advanced irrigation system was built on a massive scale and agricultural centers, especially rice, flourished in lowland areas. Around these areas, urbanization was more considerable (Octifanny, 2020), particularly in areas that had previously become human concentration during Java Islamization in 15th-17th century (Setiadi, 2021). Some of which had the advantage from first-nature conditions for cross-island trade, transforming them into big port cities such as Jakarta, Semarang, and Surabaya. Since the days of the Dutch East Indies until 2000's, the construction of cross-regency and -provincial roads tended to be carried out in lowland and nearly flat volcanic areas along the north coast of Java Island due to cheaper infrastructure construction costs. As a result, these regions were more inter-connected than others. In the practice of globalization, lowland areas were more ready to receive foreign investment in manufacturing activities, mainly those relatively close to port cities (Firman, 2016). Economic activities in the coastal lowland area have become more varied—competitive advantage has shifted from agriculture to the secondary and tertiary subsectors.

4. Conclusion

Physical attributes contribute to the persistent disparity. They, to some extent, present advantages and disadvantages to communities and regional performance, leading to differences in socio-economic performance among regions. Some variables associated with regional socio-economic performance in Java are terrain ruggedness, soil parent materials, sea depth, elevation, and precipitation. By applying endowment-based grouping, Java's regions can be categorized into lowland, volcanic, old volcanic, and calcareous dry regions. Regions with the least physical obstacles, lowland regions, experience the most satisfactory regional performance. Meanwhile, regions with a notable physical challenge, namely old volcanic and calcareous dry regions, performed poorly in terms of development.

All in all, it is important to highlight the major limitations of this study. Firstly, the individual link between physical attributes and regional performance was only interpreted from correlation analysis. Correlation is not causation. As stated previously, we merely focused on showing the rough relationship between the variables included in this research. Then, the result of cluster analysis was limited to testing our assumption. It is still weak to be used as a guide for regional policymaking. Better grouping using additional data, such as RM status and spatial agglomeration, is needed to build more comprehensive spatial clustering. Lastly, the interpretation of regional performance merely used data from some years within the last decade. The power of physical geography may differ across time due to the shifting nature of cultures and economies, as discussed in the "Result and Discussion" section. However, it cannot be denied that physical attributes are also responsible for regional disparity.

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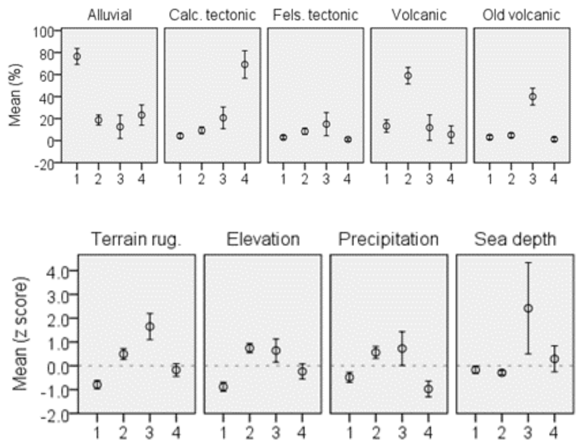
Appendices

Appendix 1. Graphical plot of the physical characteristics of the resulting groups (error bars: 95% CI)



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